

# The effect of tree and bundle size on the productivity and costs of Cut-To-Length and multi-stem harvesting systems in *Eucalyptus* pulpwood

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# DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

A.M. McEwan

Date

Note: Annexure D contains the official University of Pretoria declaration of originality.



# DEDICATION

To my wife Ronalda. Thank you for your encouragement, patience, support and most importantly love. Also to my girls, Chanté and Annabelle, you mean the world to me.



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#### ABSTRACT

There is currently a global increase in *Eucalyptus* pulpwood plantations. Harvesting systems traditionally utilised in the northern hemisphere are being used in *Eucalyptus* pulpwood plantations worldwide. However, the small tree size and complexity of debarking *Eucalyptus* have provided harvesting with productivity and cost challenges not previously experienced in northern-hemisphere conditions. Much research has been invested in these two harvesting methods in northern-hemisphere species and conditions. There is little research available on mechanised processing-machine productivity and costs in *Eucalyptus*.

This investigation aimed to quantify the effect that tree and bundle size has on the productivity of different processing machines in *Eucalyptus* plantation pulpwood. This was done through regression analysis, whereby productivity models that included tree size and bundle size were constructed. The research also aimed to determine whether or not the multi-stem systems were more cost-effective in smaller tree sizes.

The research investigated five mechanised harvesting options that forestry managers could use in *Eucalyptus* pulpwood plantations. These systems consisted of one CTL system, one full-tree system with single-stem processing and three full-tree systems with multi-stem processing. The CTL system used a harvester to process the trees into logs and to extract them. The full-tree system with single-stem processing used a dangle-head processor (DHP) to process trees into logs. The first full-tree system with multi-stem processing used a chain-flail debrancher debarker (CFDD) to produce debarked and debranched tree lengths, which were slashed into logs. The remaining full-tree, multi-stem systems both produced chips. The first used a chain-flail debrancher debarker chipper (CFDDC) and the second, a CFDD feeding into a stand-alone disc chipper (CFDD&C).

The productivity data, measured as m<sup>3</sup> per productive machine hour (PMH), was then statistically analysed using regression techniques. Productivity equations were formulated, considering tree size and bundle size, as well as the quadratic functions of these two variables and the interaction between them. Bundle size was only applicable to the multi-stem processing machines. The productivity equations successfully predicted processing-machine productivity, using tree size and bundle size as input variables. Apart from the 0.075 m<sup>3</sup> tree size class, the CFDD had the highest overall productivity.

The costs of the five systems were then calculated for different tree sizes. No single system was more cost-effective than the others across all tree sizes. In 0.075 m<sup>3</sup> trees, the CFDDC system proved the most cost-effective. All systems evidenced high costs in the 0.075 m<sup>3</sup> trees, ranging between \$19.43 per m<sup>3</sup> for the CFDDC system to \$28.84 for the harvester



system. In 0.40 m<sup>3</sup> trees, the cost differences between systems were lower, ranging from \$6.91 per m<sup>3</sup> for the DHP system to \$11.84 per m<sup>3</sup> for the CFDD&C.

This study confirms that the CTL system was very expensive to operate in the small tree sizes (0.075 m<sup>3</sup>). There is a cross-over point at 0.25 m<sup>3</sup> per tree, where the CTL system costs become lower than those of the full-tree system. At the 0.40 m<sup>3</sup> tree size, the full-tree system is slightly more expensive than the CTL system.

**Key words:** Processing, Debarking, Bark-wood bond strength, Debranching, Chipping, Chain-Flail Debrancher Debarker, Chain-Flail Debrancher Debarker Chipper, Productivity, Costs, Harvester, Dangle-Head Processor



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- Annexure C: Harvesting systems costing summaries
- Annexure D: University of Pretoria declaration of originality



# LIST OF ABBREVIATIONS

cmin	centiminutes
CFDD	Chain-flail debrancher debarker
CFDDC	Chain-flail debrancher debarker chipper
CFDD&C	Chain-flail debrancher debarker and chipper
CTL	Cut-to-length
DBH	Diameter at breast height
DHP	Dangle-head processor
FEL	Front-end loader
MAI	Mean annual increment
ODT	Oven-dry tonne
PMH	Productive machine hours
SMH	Scheduled machine hours
BWBS	Bark-wood bond strength



# 1 Introduction

This introduction presents the motivation for the research, followed by an outline of the research problem. Thereafter, a short description of the research design and methodology is offered and, finally, the structure of the document has been summarised.

#### 1.1 Motivation for the research

Historically, indigenous forests have supplied the world's timber needs. However, there is increasing pressure to reduce the amount of timber flowing from these forests. Reasons for this include preserving the biodiversity values that indigenous forests offer; maintaining forest ecosystems, particularly as these provide carbon storage areas to help prevent further climate change and protecting local communities who depend on these forests. Plantation forests have been established to meet increasing global demand for timber products (Food and Agricultural Organisation [FAO], 2009).

Many different species are grown in the plantations mentioned above, depending on site characteristics and market requirements. The predominant plantation genera include *Pinus, Eucalyptus* and *Acacia* (FAO, 2009). Specific species are selected, based on aspects such as their growth potential, resistance to pests and diseases, fibre properties and potential for yield improvements. *Eucalyptus* plantations have become increasingly important in the global supply of round timber for pulp and paper (FAO, 2009) and are expected to continue to expand (Spinelli, Ward and Owende, 2009). This is due to various factors, including the large number of species from which plantation owners can choose, depending on their local conditions; the generally good fibre properties of *Eucalyptus*; and, most importantly, rapid growth characteristics. Most of these *Eucalyptus* plantations are concentrated in the southern hemisphere counties of Brazil, Chile, Uruguay, Argentina, South Africa and Australia. However, new *Eucalyptus* plantations are currently being established in other African countries, and the Far East, especially China, which is increasing the global supply even further (FAO, 2009).

Bakker and Nel (2000) commented that, unlike trees planted for sawn-timber products, which need to grow until they have reached a certain physical dimension, trees for pulpwood or biomass should only be harvested at the culmination of the Mean Annual Increment (MAI) or when sufficient mature wood has been produced as per the specification of the pulp- and paper-making process. The physical size of the tree is only a consideration for maintaining



low harvesting and transport costs. Therefore, *Eucalyptus* trees grown for the pulp and paper/biomass industries are usually much smaller in size than trees grown for sawn-timber products. Conventional harvesting methods used in the past do not adapt well to high density, small-sized trees, resulting in poor tree and log handling, high harvesting costs and low levels of fibre recovery per hectare (Lambert and Howard, 1990). These high costs, especially for debranching and debarking, have been the main barrier to using smaller trees for products of lower value, such as pulpwood (Selby and Iff, 1986).

Many different harvesting methods and systems are available to fell, transport to a suitable location and convert a standing tree into a product (Brink and Kellogg, 2000). The reasons for choosing one system over another depend on factors such as client requirements, stand conditions and terrain. Forest engineering can make up 60 to 80 per cent of the annual forestry budget (Brink and Conradie, 2000). Forest engineering operations are also more capital intensive than silviculture operations. This is because of the machines and equipment that are used in the production process. Ultimately, the method and system selected should be low cost per cubic metre of delivered timber, but, at the same time, uphold silvicultural, environmental, social and customer values.

While much work has been done on tree species such as pine, scant harvesting productivity information is available on *Eucalyptus* (Spinelli, Owende and Ward, 2002a). Also, most *Eucalyptus* pulpwood has to be debarked in the plantation (Spinelli et al., 2009). Removal of the bark takes place either in the compartment or on the roadside, utilising various technologies and techniques, and is expensive. The bark-wood bond strength (BWBS), a measure of the strength of the wood-to-bark bond, varies between species, sites, seasons, soil moisture and the amount of time elapsed between felling and debarking. Therefore, the process of removing bark increases the costs of harvesting small trees even further.

An unwillingness across the world of the labour force to carry out difficult and menial manual tasks, as well as the inherent safety risks associated with manual- harvesting, is pushing companies to become increasingly mechanised (Spinelli et al., 2009). The felling and processing of *Eucalyptus* pulpwood in South Africa has traditionally been carried out using manual systems. This was due to relatively low labour costs, coupled with the high capital outlay and running costs of mechanised equipment (Mack, 2010). The low labour-cost scenario has now changed and harvesting operations are finding it increasingly challenging to find labour prepared to carry out these difficult tasks, even at a wage premium (FAO, 2009). This has also forced the South African forestry industry to investigate alternative methods of *Eucalyptus* pulpwood harvesting.



This research was conducted on sites across the southern hemisphere (South Africa, Chile and Australia) where the different harvesting systems were operating in order to compare these systems and measure the key factors that influence the investment decision and produce timber at the lowest cost. The sites had similar *Eucalyptus* species, site conditions and terrain characteristics, which made direct comparisons possible.

The harvesting systems having the most potential to cost-effectively process *Eucalyptus* pulpwood selected. Four full-tree harvesting systems and one cut-to-length (CTL) system were researched. Harvesting technologies included chain-flail debrancher debarkers (CFDDs), chain-flail debrancher debarker chippers (CFDDCs), a combination of CFDDs and chippers (CFDD&C), dangle-head processors (DHPs) and harvesters. The other equipment that was used and needed to be considered in the cost calculations included feller bunchers, grapple skidders, three-wheeled loaders, forwarders, slasher loaders, log truck loaders, log trucks and chip trucks.

#### 1.2 The research problem

Forestry companies across the world are struggling to identify systems that can be used to harvest *Eucalyptus* pulpwood cost effectively (Spinelli, et al., 2009). This is because many of the harvesting technologies are new to *Eucalyptus* pulpwood harvesting. Most mechanised harvesting technologies were originally developed and used in northern hemisphere forestry conditions, specifically North America and Europe, owing to increasing challenges with regard to labour costs, an escalating demand for timber and changes in forestry management (Akay and Sessions, 2004). Even where labour is still available and cost competitive, there is a trend towards mechanisation. This is due to the streamlining of the timber supply chain and predicted labour shortages (Spinelli, et al., 2009). Although mechanised systems are now being applied in plantation forestry in the southern hemisphere, much information needs to be digested before systems decisions of this nature can be made.

As indicated by Spinelli et al. (2009), high labour costs are contributing to the increased use of mechanised harvesting systems. Globally, the mechanised harvesting methods with potential for productive, large scale *Eucalyptus* pulpwood harvesting operations include cut-to-length (CTL), where harvesters and forwarders are used, and full-tree or tree-length methods, where a skidder conveys the tree length to the landing for processing (Spinelli, et al., 2009). Various derivatives of these methods are being used in *Eucalyptus* pulpwood plantations around the globe. They are not widely or consistently used because of uncertainty with regard to their application, productivity and cost under different

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circumstances. Very little research has been carried out on the individual mechanised harvesting systems operating in *Eucalyptus* and no scientific study has compared the various systems.

Tactical harvesting plans, which allow the balancing of terrain conditions with harvesting equipment and annual timber volumes, should be professionally scheduled over a three-to-five year period. Sound information is required to compile these tactical plans. This will allow decisions to be made on alternative harvesting systems (Akay and Sessions, 2004). However, *Eucalyptus* pulpwood forestry companies are generally unsure as to what the ideal system for their plantation situation would be, as key information regarding productivity is not readily available. The most important of this type of information that is missing deals with the various processing machines for different tree sizes (Spinelli, et al., 2009). There is also no information available that indicates the optimal number of trees to process for a given tree size when utilising equipment that processes multiple trees simultaneously. If this information were readily accessible, it would be easier to make informed decisions about systems, allowing for correct productivity determination.

Whatever the system is that has been selected, it must be able to overcome the high costs associated with harvesting and debarking the small trees usually encountered in *Eucalyptus* pulpwood. Incorrect system decisions are expensive and may lead to timber rejections at the mill because of quality constraints. It is also possible that the system could cause unacceptable environmental damage to the site. Forestry managers strive to select the most cost-effective harvesting systems for their plantations. Lack of information about tree and bundle size hampers their decisions.

To summarise, the research needs to answer the following questions regarding mechanised *Eucalyptus* pulpwood harvesting:

- 1. What productivity factors, cost and operating variables need to be considered for the CTL and multi-stem systems?
- 2. Which system should be used to accommodate different tree sizes?
- 3. For multi-stem processing machines, what are the optimal bundle sizes for different tree sizes?

#### 1.3 Research design and methodology

Various sites (South Africa, Chile and Australia) were identified where the applicable harvesting systems and processing technologies were operating and these sites were visited. Individual standing trees were measured to determine the tree size and work studies



were carried out on the processing machines. The work study data, which included information on tree and bundle sizes, were collected from each site, initially analysed using descriptive statistics and then subjected to regression analysis.

Productivity models were developed for the processing technologies within the different systems that considered tree size (volume) and bundle size. This information, along with existing information on the productivity of the other machines in the various systems studied, was included in costing models to determine which system had the lowest cost for specific tree size.

#### 1.4 Outline of dissertation

Chapter one provides the introduction, and outlines the motivation for the research, the research problem and the research design and methodology.

Chapter two serves as a literature review. It defines key concepts relevant to the research. It also identifies systems and machines that could have an application in mechanised *Eucalyptus* pulpwood harvesting. The systems and machines are described according to their costs, the factors that influenced their productivity, their advantages and disadvantages, and other general factors influencing the application. Future trends in mechanised harvesting of *Eucalyptus* are investigated and available literature on this subject is then described.

Chapter three explains the research design and methodology. It commences with the two research hypothesis. The different research sites are described, followed by analysis of productivity data, which includes the sample design, sampling method, methods of data collection, the initial data analysis and regression analysis. An analysis of cost data follows the productivity data analysis.

Chapter four contains the results and discussion. The different results with regard to processing technology productivity are provided, followed by results outlining system costs. The system-cost results are discussed per tree size to determine the optimal system for a specific tree-size class.

Chapter five provides the conclusions of the research and recommendations for future scientific investigation.

All photographs in this document were taken by the author, unless indicated. The Anglia Rusken Harvard Method of referencing was used.



# 2 Literature review

The literature review defines key concepts, provides a literature discussion and a summary of the main conclusions.

#### 2.1 Demarcation of literature covered

Much of the information on the CTL systems was obtained from European journals. The material on full-tree systems was principally drawn from North American research publications. Two particularly useful sources of the latter were the Forest Engineering Research Institute of Canada (FERIC – now FPInnovations) and the United States Department of Agriculture (USDA – Forest Service). Much of the information on full-tree systems with CFDDs and infield chipping are from the early 1990s, an indication of when most of the research into these systems in North American conditions took place. Now, there is renewed interest in these systems from companies harvesting *Eucalyptus* pulpwood because of their potential to reduce costs in harvesting small trees: most other systems exhibit debarking constraints. A great deal of the research on CTLs is from the early 21<sup>st</sup> century, when these systems ventured into *Eucalyptus* harvesting. Indeed, much development has taken place to accommodate harvesting smaller trees.

The following aspects were extensively investigated in the literature:

- the general operation and management of CTL and full-tree systems;
- the advantages, disadvantages, productivity and costs of these harvesting methods;
- detailed accounts of the specific processing technologies pertaining to CTL and full-tree systems.

# 2.2 Definition of key concepts

The key concepts that follow need to be understood clearly to obtain maximum benefit from the research process and results.

#### 2.2.1 Harvesting methods

A harvesting method is defined by the form in which timber is delivered to the roadside landing. It depends on the amount of processing which has taken place inside the



compartment (Pulkki, 2011). The following harvesting methods, as described by Pulkki (2011), are commonly used for harvesting *Eucalyptus* pulpwood:

# Cut-to-length (CTL)

After felling takes place, the trees are debranched, debarked, cross-cut and topped in the immediate vicinity of where the tree was felled. All harvesting residue is left spread across the site. A CTL mechanised system usually consists of harvesters that fell and process trees and forwarders that load the logs onto a bunk and transport them to a roadside landing (Pulkki, 2011). Figure 1 shows an example of a CTL system consisting of a harvester and forwarder.

Locality Activity	Stand	Extraction route	Roadside Ianding	Forest road	Millyard
Harvester					
Forwarder					

Figure 1: Example of a CTL system showing a harvester and forwarder

#### Tree length (TL)

After felling has taken place, the branches and tops are removed from the tree, either in the immediate vicinity of where the tree was felled or at a point before the roadside. It is also possible that the tree will be debarked. Harvesting residue is left spread across the site. The remaining stem is then transported to a roadside landing. The tree is usually skidded to the roadside, using a cable, grapple or clambunk skidder. Processing into logs could take place on the landing or the entire stem could be transported to a remote processing facility or mill (Pulkki, 2011). Figure 2 shows an example of a tree-length system. The debranched and topped tree lengths are extracted using a grapple skidder.





Figure 2: Example of a tree length system with cable skidder extraction

#### Full-tree (FT)

Full-tree harvesting is termed whole-tree harvesting in the United States of America (USA). After felling, the entire tree is extracted to a roadside landing with its branches, bark and top still intact. Extraction is usually with a skidder: cable, grapple or clambunk. The full tree is processed at the roadside or is loaded and transported to a centralised processing area or a mill. Depending on mill requirements, different levels of processing can take place at the roadside, such as debranching and debarking or full-tree chipping. If roadside processing takes place, then harvesting residue needs to be handled, either by stockpiling and burning it, returning it to the compartment or transporting it away for another use, such as for biofuel (Pulkki, 2011). Figure 3 shows an example of a full-tree system. The trees are extracted with a grapple skidder, with branches and tops still attached.





Figure 3: Example of a full-tree system with grapple skidder extraction

# 2.2.2 Harvesting equipment

A combination of harvesting equipment constitutes a harvesting system. A harvesting system is not the same as a harvesting method. A harvesting system refers to all the machines, equipment, people and tools required to harvest a certain site or group of sites (Pulkki, 2011). Therefore, there may be many combinations of systems that can make up one harvesting method. Mechanised harvesting may be defined as any operation during which at least one single or multi-function machine is used for felling, debranching, cross-cutting or chipping where the trees or logs are found in bunches prior to extraction (Kellogg, Bettinger and Studier, 1993). A brief description of harvesting equipment relevant to this research follows.

#### Harvester

A harvester, as shown in Figure 4, is a tracked or wheeled machine with an attachment that is capable of felling the tree, removing the branches and possibly the bark, and then cross-



cutting the stem into the log lengths desired by the customer (De Wet, 2000). All these activities take place within the compartment where the tree was felled. When harvesting *Eucalyptus*, the feed rollers of the harvester heads exert high pressure on the bark to break the bark-wood bond and thus remove the bark (McEwan, 2010). The harvester head is attached to the boom through a free swinging linkage and hydraulic rotator, and is commonly referred to as a dangle head. After the felling cut, the harvester head has limited control over the tree and drops it to the ground. Figure 4 shows a harvester operating.





Figure 4: Harvester operating, and Figure 5: Dangle-head processor

#### Dangle-head processor (DHP)

This is a processing head mounted at the end of a boom. Depending on the system in which it operates, the DHP can carry out two or many functions. It does not fell the tree, but operates within the compartment where the tree was felled or on a landing. Its processing functions can include debranching, debarking and cross-cutting (MacDonald, 1999). Figure 5 above shows a DHP operating.

#### Feller buncher

A feller buncher fells and and simultaneously bunches trees together for a skidder (Lambert and Howard, 1990), which extracts the trees to a landing for processing (Adebayo, Han-Sup and Johnson, 2007). They can be tracked or wheeled machines and reach the tree either by swinging a boom to it or by driving to each individual tree. The felling attachment normally used for smaller pulpwood trees is the accumulating or side-pocket type. The felling part of the head usually consists of continuous disk saws or shears (De Wet, 2000). Figure 6 shows a feller buncher operating.





Figure 6: Feller buncher, and Figure 7: Grapple skidder

#### Grapple skidder

A grapple skidder is a rubber-tyred, articulated machine designed for transporting trees by lifting the butt ends off the ground in a hydraulic grapple (Kellogg, Bettinger, Robe and Steffert, 1992). A bunching grapple, as opposed to a sorting grapple, is usually used to carry large loads of small trees. Figure 7 above shows a grapple skidder operating.

#### Forwarder

Kellogg, et al. (1992) described a forwarder as a rubber-tyred, articulated machine designed to carry logs in a bunk from compartment to roadside. It has a crane with a grab attachment to lift the logs from the ground in the compartment and load them, then to offload them at the roadside. Forwarders can have four, six or eight wheels, some now even having ten wheels. Different tyre configurations are available, including wide, flotation tyres. The tyres can also be fitted with chains or band tracks for increased traction or flotation (Kellogg, et al., 1992). Figure 8 shows a forwarder operating.





Figure 8: Forwarder, and Figure 9: Chain-flail debrancher debarker



#### Chain-flail debrancher debarker (CFDD)

Figure 9 above shows a CFDD operating. This portable machine operates in stationary positions (Wingate-Hill and MacArthur, 1991; MacDonald, 1999). It removes bark and branches from full-tree lengths by using hardened chain links, mounted on rotating drums (rotors) that make contact with bark and branches, knocking them off. This action results in debarked and debranched tree lengths (Sessions and Kellogg, 1994). The bark, branches and leaves fall to the bottom of the debarker and are expelled by a hydraulic bark discharger. There are integral knuckle-boom cranes that feed the trees into the machine (MacDonald, 1999). In the context of this research, the CFDD is a machine that is fed with multiple trees, not the small, mobile CFDDs mounted on front-end loaders. These small, mobile CFDDs do not meet the quality requirements of the mills as they cannot debark effectively (Mooney, Boston and Greene, 2000).

#### Chain-flail debrancher debarker chipper (CFDDC)

With a CFDDC, the operation of debarking and debranching is similar to that of the CFDDs above. However, the tree lengths are chipped by the same machine, using a disk chipper (a combination or integrated machine), immediately after the debranching/debarking. It is also possible to have stand-alone CFDDs feeding into stand-alone chippers (CFDD&C). The resultant chips are fed into chip trucks (MacDonald, 1999; Pulkki, 2011). Figure 10 shows a CFDDC operating.



Figure 10: Chain-flail debrancher debarker chipper, and Figure 11: Disc chipper



#### Disc chipper

The debarked and debranched tree is chipped, using sharp knives mounted onto a rotating disk (Lambert and Howard, 1990). In the context of the research, the debarked and debranched trees are fed straight from the CFDD into the chipper, although the chipper does have a crane to help feed if necessary. Chips are fed directly into chip trucks (MacDonald, 1999). Figure 11 above shows a disc chipper.

#### Loader

A loader is a machine that can lift logs or trees in a grapple and place them on a log truck or an area for temporary storage (Lambert and Howard, 1990). Figure 12 shows a knuckleboom loader.



Figure 12: Knuckle-boom loader, and Figure 13: Three-wheeled loader

#### Three-wheeled loader

A three-wheeled loader is a small, rigid machine, with hydrostatic power driving and steering the two large, front tyres (see Figure 13 above). There is a single, high flotation dolly wheel at the rear. It has a boom and log grab for taking hold of logs or tree lengths (Langenhoven, 2000).

#### Slasher loader

This consists of a tracked excavator operating with a hydraulically powered slasher (MacDonald, 1999). The tracked knuckle-boom excavator has a hydraulically operated joint at the midpoint of the boom, with a log grab at the end (Donovan, 1988). The slasher incorporates a cradle and a hydraulic power take-off from the excavator supplies the slasher with power. The slasher cuts tree lengths into logs, using a hydraulically operated chainsaw to cross-cut. The excavator can pick up the slasher and move it to the next slashing location.



The logs are then stacked on the roadside for transport. In some systems, the same excavator also loads log transport trucks. The ability to cross-cut many stems at once makes slasher loaders cost effective when harvesting small trees (McEwan, 2008). Figure 14 below shows a slasher loader in operation.



Figure 14: Slasher loader

#### 2.2.3 Activity concepts

The following activities need to be clearly understood in the context of the research

- Accumulation this applies to feller bunchers and some harvester heads when more than one cut is made per machine cycle by holding the previously felled tree vertically in the head (Johansson and Gullberg, 2002).
- Debarking the process of removing the bark from the tree or log length (Stokes, Ashmore, Rawlins and Sirois, 1989).
- Debarking quality achieving the levels of bark on the tree or in the chips that satisfies the customer. Debarking quality is measured by determining the residual bark left on a tree/log or in the chips after debarking has taken place and is measured as a percentage. Debarking quality also considers the amount of useful wood fibre lost while debarking. This is also measured as a percentage of the stem wood or chips (Raymond, 1989).
- Debranching the removal of branches flush with the stem so that there are no protruding stubs, also called delimbing. There should be no damage to the bole of the tree where the branch was attached (Mooney, et al., 2000).



- Multiple stem/tree (multi-stem) handling the ability of a machine to fell, process, handle or extract more than one tree or stem at a time. Many smaller stems and tree lengths are handled together in an attempt to overcome the costs of handling these individually. A multi-stem system is one where all the machines within the system are capable of handling more than one tree at a time (Dahlin, 1991). Examples of this type of machine would be feller bunchers, grapple skidders and CFDDs.
- Tree-length bundles trees that have been placed parallel to and on top of each other in a condensed pile format. This facilitates multiple handling or gives the following machine easier access to these trees (McEwan, 2010).
- Bark-wood bond strength (BWBS) the ease or difficulty with which bark can be removed from the tree. It reflects the strength of the adhesion between the bark and the wood (Baroth, 2005).
- Hot-deck an area where tree lengths or logs are processed or loaded immediately after being placed there (Stokes, et al., 1989).
- Cold-deck an area where logs or tree lengths are stored for later processing or loading (Stokes, et al., 1989).

# 2.2.4 Location concepts

Some important definitions:

- Compartment a territorial unit of land which is permanently demarcated and defined for record keeping and description. Different management, silvicultural and harvesting prescriptions are formulated per compartment, based on site characteristics. The trees within a compartment should be uniform with regard to species, age, stems per hectare and site quality. Separate income, expenditure, yield and treatments are recorded per compartment (Louw, 2000).
- Landing a processing area adjacent to the harvesting area and an accessible road (Lambert and Howard, 1990). It should be accessible to both the extraction machines and log or chip trucks.

#### 2.2.5 Time and productivity concepts

The following concepts regarding machine management are important to the understanding of this report:



- Scheduled machine hours (SMH) the time in which machines are scheduled to carry out their productive work (Hogg, et al., 2009).
- Productive machine hours (PMH) the time that the machine is available and is actually working, determined as a percentage of SMH (Hogg, et al., 2009).
- Machine utilisation (MU) the ratio between PMH and SMH is known as machine utilisation. Machine utilisation indicates how well the SMH are being used (Hogg, et al., 2009).

### 2.3 Literature discussion

Development and use of mechanised harvesting systems in global forestry have increased rapidly over the last two decades (Jiroušek, Klvač and Skoupý, 2007). This has been due to labour shortages and the need for cost-effective harvesting operations (Schäffer, Hartmann and Wilpert, 2001). There has also been renewed interest in CTL ground-based mechanised harvesting systems in North America and Europe. There are several reasons for this renewed interest, among them: the ability of these systems to leave tops and branches in the compartment, better partial cutting (or thinning) abilities, the need for smaller landing areas and improved labour productivity (Akay and Sessions, 2004).

Mechanised ground-based machines have traditionally operated on slopes of less than 35 per cent and in trees with diameters of less than 50 cm (Bettinger, et al., 1993). However, new technologies and modifications to machines are allowing ground-based mechanised systems to operate on increasingly steeper slopes and handle and process larger trees (Amishev and Evanson, 2010). Mechanised systems can be difficult to manage owing to equipment breakdowns, seasonal access restrictions, the inability of the equipment to work on very steep terrain and possible environmental impacts. The expectation that more processing would be carried out at centralised locations with machines that are less complex has proved incorrect. Indeed, increasingly sophisticated machines are processing timber in the compartment or on the roadside (Gellerstedt and Dahlin, 1999).

Traditionally, CTL methods were popular in Europe and full-tree systems were used in North America. The full-tree method is based on the concept of handling as many stems as possible to compensate for small tree sizes in an attempt to maintain competitive harvesting costs (Spinelli, Hartsough, Owende and Ward, 2002b). The trees are normally bunched during felling to optimise multiple-stem or downstream handling.



# 2.3.1 General costs of mechanised harvesting systems

The total cost of producing a unit of timber is determined by machine costs and system efficiency (Stokes and Hartsough, 1993). When calculating machine rates, which are the hourly costs of running a machine, the most important input factors in the costing are the purchase price of the machine and the fuel cost – the fuel price and fuel consumption rate (Akay and Sessions, 2004).

#### 2.3.1.1 Machine purchase price

The purchase price is particularly important because it plays a role in determining the annual investment cost, depreciation, the repair cost factor and insurance. Machine life is also important as it can help dilute the ownership costs (Akay and Sessions, 2004).

#### 2.3.1.2 Fuel costs

The fuel component will always be important in forestry because large, heavy machines are required to pull or carry heavy loads. Harvesting costs of mechanised systems are usually sensitive to the diesel price per litre. Spinelli, et al. (2009) simulated the impact of the change of the diesel price on the cost of a full-tree system (with CFDDC) and a CTL system. Even though both systems were impacted, the full-tree system with infield chipping was more sensitive to an increase in the diesel price owing to the high fuel consumption of the CFDDC. However, when chipping infield, there are no energy costs for chipping at the mill, and this needs to be considered in fuel-use calculations.

# 2.3.2 General factors influencing the productivity and cost of mechanised harvesting systems

The machine rate on its own is not sufficient to determine whether a machine or system is suitable. The productivity of the machine in relation to the machine rate is the most important consideration (Akay and Sessions, 2004). Adebayo, et al. (2007) found that full-tree systems had a higher overall productivity than CTL systems. They attributed this to the full-tree system having dedicated machines for specific tasks in the forest engineering value chain, whereas the CTL machines carry out multiple functions. As indicated below, the general productivity of mechanised harvesting systems is dependent on three key factors, namely tree size, operator skill and extraction distance.


# 2.3.2.1 Tree size

Average tree volume is very important when determining the productivity of mechanised harvesting machines and systems (Kellogg and Spong, 2005; Jiroušek, et al., 2007). As tree DBH increases, harvesting productivity increases. Harvesting small trees one tree at a time has always been comparatively unproductive (Johansson and Gullberg, 2002). Harvesting small trees requires efficient felling and bunching, as the bunching process facilitates log or tree removal (Stokes and Hartsough, 1993). Adebayo, et al. (2007) found that as tree size increased, the productivity of feller bunchers increased non-linearly more than that of a harvester. This is consistent with the findings of Li, Wang, Miller and McNeel (2006), who observed that the productivity of a feller buncher could be four times higher than that of a harvester. Andersson (1994) commented that even though tree size affected both feller bunchers and processors, size influenced processors more. The explanation offered was that a feller buncher could accumulate trees, whereas a processor was only able to process one tree at a time. Although felling with a chainsaw might cost very little, the inability to bunch may actually increase total system costs (Stokes and Hartsough, 1993).

Thus, as explained in the literature mentioned above, all forestry machines are affected by tree size in one way or another. While machine productivity slows as the tree size being harvested increases, the unit cost per tree drops substantially (Spinelli, et al., 2002b).

Only a few research articles indicate CTL costs as being similar to full-tree system costs. Gingras (1994) did find that CTL costs were lower in tree sizes averaging between 0.15 and 0.25 m<sup>3</sup>. However, in Gingras's 1994 research, the ground was very wet, which resulted in the grapple skidder travelling with reduced payloads and often getting stuck. A considerable travel distance between felling areas, which favoured the CTL systems, also contributed to the results recorded.

Three investigative publications indicated CTL systems were between 15 and 30 per cent more expensive than full-tree systems. The researchers were Gingras (1994; 1996) and Li, et al. (2006), analysing a sample of trees between 13 and 21 cm DBH. Richardson and Makkonen (1994) calculated that the costs of CTL systems were 10 to 75 per cent higher than full-tree mechanised systems in tree sizes ranging between 0.30 and 0.05 m<sup>3</sup>. Hartsough, et al. (1997), found CTL stump-to-mill costs to be 25 per cent higher than full-tree costs.



# 2.3.2.2 Operator skill

The more complex a machine is to operate, the more important operator skill becomes. Complex machines occur mostly in CTL systems, where single machines can carry out multiple functions. Differences in operator performance can result in machine productivity variations of between 20 and 50 percent (Bergstrand, 1987). Bergstrand found that it would be necessary to include nearly 400 operators in a machine-productivity research exercise to achieve a 95 percent confidence level. This is not economically justifiable. It may be possible to overcome skill differences between operators while carrying out work research by using operator ratings. However, it has been discovered that ratings can only be used when the work is simple - for example, manual tasks. Ratings would not be an effective tool with the complexity of tasks carried out by most forestry machines (Samset, 1990). A second option considered by Bergstrand (1987) was to replicate the research, but, as Glöde (1990) observed, this is also not economically feasible in most situations. Bergstrand (1987) did conclude, however, that even though the operators' skills played a key role in all comparative research, the results could still be used as productivity indicators, offering guidance for the evaluation and development of new systems and methods. Operators must be experienced and trained to obtain acceptable machine productivity. Purfurst (2010) found that harvester operators begin their careers at between 50 and 60 percent of mean operator performance.

#### 2.3.2.3 Extraction distance

The largest component in the primary transport of both harvesting methods is extraction distance (Adebayo, et al., 2007). Kellogg, et al. (1992) indicated that there was much information on how harvesting productivity and stand variables affected the productivity of mechanised harvesting systems. However, there are still many discrepancies surrounding cost differences of CTL and full-tree systems (Adebayo, et al., 2007).

In research conducted by Adebayo, et al., (2007), the extraction costs of both full-tree and CTL systems accounted for between 36 and 54 percent of the total system costs, the greatest proportion of any of the components of the harvesting systems. Adebayo et al found that full-tree harvesting was more cost effective than CTL systems, but the differences between the systems were sensitive to machine productivity and stand variables.



# 2.3.3 CTL systems

Mechanised CTL systems usually consist of harvesters and forwarders. However, they can also consist of a feller buncher operating with an infield processor and a forwarder. Karjalainen, et al. (2001) affirmed the wide use of these systems in many countries, among them, Sweden, Ireland and Finland. Percentages reflecting the extent to which the systems are preferred in these three countries are 98, 95 and 91 respectively.

# 2.3.3.1 Advantages of CTL systems

CTL systems have been favoured in many countries owing to their requiring less labour, less road construction and fewer and smaller landing areas than other ground-based harvesting systems (Bettinger and Kellogg, 1993; Meek, 1993; Gellerstedt and Dahlin, 1999).

There is less traffic in the compartment because there are fewer machines in the system and forwarders can carry larger payloads (Gellerstedt and Dahlin, 1999). The lower road construction requirements arise because forwarders are able to carry timber over a longer distance economically.

Because the logs are carried off the ground, they normally have much less soil contamination and fewer stem breakages (Gellerstedt and Dahlin, 1999; Pulkki, 2011). The logs can be offloaded directly onto log trucks, or trailers if necessary. CTL systems also usually have lower annual volume requirements to sustain good utilisation levels than full-tree systems. If there are many different log assortment classes, CTL systems are often preferred, as less space is needed to process the tree (De Wet, 2000). The different log assortment classes can also be more easily stacked along the roadside by the forwarders (Pulkki, 2011). CTL systems are normally versatile, as they can be used in clearfelling and thinning operations (Gellerstedt and Dahlin, 1999). They tend to cause less damage to residual trees in thinning operations (Richardson and Makkonen, 1994; De Wet, 2000).

Harvesting residue is left scattered in the compartment, which can result in fewer soil nutrient problems (Spinelli, et al., 2002a) because of the high levels of nutrients found in bark and foliage. Poor soil can cause severe complications on intensively managed sites. Higher residue levels also retain soil moisture effectively, especially during drier periods (Hartsough and Cooper, 1999).

The forwarder can travel over residue mats created by the harvester, reducing soil compaction (Meek, 1993; Gellerstedt and Dahlin, 1999; Hartsough and Cooper, 1999). Owing to its lower ground pressures, a forwarder has the ability to extend the harvesting

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season where this is a limitation, and sometimes even achieve year-round logging (Gellerstedt and Dahlin, 1999). This also results in less soil damage.

Another benefit is that CTL systems can usually operate on steeper terrain than full-tree systems (Gellerstedt and Dahlin, 1999) and perhaps one of the most important advantages is that the forwarder is less sensitive to tree size (De Wet, 2000).

# 2.3.3.2 Disadvantages of CTL systems

One of the greatest disadvantages of CTL systems versus tree-length and full-tree systems is the high capital cost of individual machines (Gellerstedt and Dahlin, 1999; De Wet, 2000; LeDoux and Huyler, 2001). In a similar vein, the cost of repairs and maintenance of the onboard computer system in CTLs is usually high

Gellerstedt and Dahlin (1999) observed that a great deal of training was required before high operator proficiency could be achieved and commented that the operators' natural ability still played a large role in their ability to control these machines.

CTL machines are often not mechanically available because of machine breakdowns. CTL machines utilise highly intricate technologically: hence, the skills required to maintain them have to be equally sophisticated (Gellerstedt and Dahlin, 1999; McEwan, 2010).

Because of the nature of the felling and processing equipment, there is a specific diameter range in which CTL systems are forced to work (De Wet, 2000). This diameter range varies between different processing heads and carrier machines (Richardson and Makkonen, 1994) and is being increased at both the lower and upper limits in new machines (McEwan, 2010).

Fowarders are limited by the strength and hydraulic power of the crane, as well as by the stability of the machine while loading. The log length that a forwarder can carry is limited by the length of the log bunk (Hartsough and Coooper, 1999). Hartsough and Coooper (1999) found that forwarders are very sensitive to crooked logs, with up to half the nominal payload of the forwarder being lost in severe cases. Variable log lengths within a load can also reduce the payload of a forwarder by increasing the air-space factor within the load. Fowarders are relatively unstable when travelling on side slopes and over rough terain (De Wet, 2000), owing to their higher centre of gravity compared with grapple skidders.

Site preparation costs can be higher for CTL systems as there is more residue left scattered within the compartment. These higher residue levels can also create a fire hazard (Hartsough and Cooper, 1999).



# 2.3.3.3 Productivity of CTL systems

Focusing specifically on CTL systems, the main factors affecting productivity include the forest stand, site, ground conditions, slope, operator motivation, operator skill, branch size, operational layout, tree size, tree form, log assortments produced, number of merchantable and unmerchantable trees, hauling distance, undergrowth density and machine design (Andersson, 1994; Jiroušek, et al., 2007). Richardson and Makkonen (1994) found that harvester productivity depended primarily on average tree size, operator skill and the ratio of merchantable to unmerchantable stems. Tree volume was found to be the most important of these three factors. CTL systems are very senstive to changes in tree size (Richardson and Makkonen, 1994). Richardson and Makkonen (1994) also found that branchiness, stem form, multiple-stem handling, length accuracy requirements and the technical characteristics of specific harvesters all affected productivity, but not significantly. Operator skill and difficult terrain conditions do have an influence as well (Richardson and Makkonen, 1994). Some of these factors affecting harvesters are discussed in more detail under **Harvesters** in Section 2.3.3.4.

With the extraction component of CTL systems, fowarder productivity is mostly influenced by extraction distance and forwarder size. Richardson and Makkonen (1994) agreed with Jiroušek, et al. (2007) that forwarder productivity primarily depended on extraction distance. Forwarder productivity is also affected by the piece size of the logs, the size of the log stack, the amount of slash in the stack and the neatness of the stack (Andersson, 1994). Table 1 contrasts the approximate annual production capabilities of the harvester, DHP and fowarder CTL machines for different tree sizes, as researched by Richardson and Makkonen (1994).

Production per year (m <sup>3</sup> )	Average tree volume (m <sup>3</sup> )			
	0.10	0.15	0.20	0.25
Harvester	26,000	35,000	42,000	49,000
DHP (cutting felled trees into logs at the stump)	39,000	49,000	56,000	62,000
Forwarder @ 100 m average extraction distance	51,000	60,000	75,000	84,000
Fowarder @ 400 m average extraction distance	38,000	45,000	51,000	59,000

Table 1: Annual production capabilities of CTL machines(adapted from Richardson and Makkonen, 1994, pg 7)

Note the DHP in this research was cross-cutting the trees and that debarking was not included. What is clear is the rapid increase in the productivity of the harvester and DHP with increasing tree size. Forwarder productivity does not increase as rapidly as it is less sensitive to piece size. When considering only ownership and operating costs, the harvester-



based CTL system only started to become competitive when tree volume approximated 0.15 m<sup>3</sup> or more (Richardson and Makkonen, 1994).

Jiroušek, et al. (2007) divided harvesters and forwarders into three different classes when comparing their productivity:

- Class I (small) harvesters with an engine output of up to 80 kW and forwarders with a payload of up to 10 tonnes.
- Class II (medium) harvesters with an engine output ranging between 80 and 120 kW, and forwarders with a payload of between 10 and 12 tonnes.
- Class III (large) harvesters with an engine output of more than 120 kW and forwarders with a payload greater than 12 tonnes.

Jiroušek, et al. (2007) found that even though larger forwarders cost more to own and operate per machine hour, their higher productivity made the cost per m<sup>3</sup> lower when compared with that of smaller forwarders in clearfell operations. Therefore, larger forwarders should be selected for such operations. However, the size of harvester utilised was determined by the average tree size and the technical capabilities of the machine. The smallest harvester technically capable of harvesting the required tree size should be selected.

# 2.3.3.4 Harvester

The single-grip harvester head originated from the need to make thinning profitable (Gellerstedt and Dahlin, 1999). Gellerstedt and Dahlin (1999) identified the design reasons for the different parts of a harvester and these are summarised in Table 2.



Machine part or quality	Reasons behind the construction or quality		
Ten-metre boom	20 m between strip-roads in thinning		
Weight of harvester head under 1,200 kg	Ten-metre boom – machine stability and weight		
Small size of the harvester head	Felling diameter of most trees is less than 65 cm		
Confined debranching capacity	Trees with small and uniform limbs		
Good terrain accessibility	Rocky terrain; most slopes less than 40%; great variation in ground strength		
Multi-functional machine	Thinning and smaller clear cut areas; must be easy to plan, supervise, control and transport; shortage of labour; less ground damage		
The flexibility of the harvester concept	The variation in tree size and terrain factors		
The high safety and ergonomic standard	The few operators are key persons; a multi-functional machine requires an easy-to-use and comfortable work area as part of the machine		

# Table 2: Design reasons behind the Nordic harvester(Gellerstedt and Dahlin, 1999, pg 18)

Various factors to be considered with regard to harvesters include:

#### Tree size

The reason tree volume plays such an important role in harvester productivity is that these machines can only process one tree at a time. The cycle time to harvest one small tree is similar to that required to harvest a large tree. Therefore, the additional volume of a large tree enables proportionately higher productivity (Richardson and Makkonen, 1994). The debranching/debarking and cross-cutting time elements are significantly affected by the length of the tree (Richardson and Makkonen, 1994).

Harvester producivity is negatively affected when operating in compartments with highly variable tree sizes and poorly managed coppice compartments (M. Brink, Ass. Prof. University of Pretoria, South Africa, personal communication [Conversation], 17 September 2010).

A harvester is unable to fell and process trees over a certain butt diameter. Unmerchantable trees in the compartment reduce productivity by forcing the harvester to move around them, reducing visibility. Further productivity reduction occurs if the operator attempts to process such trees. If unmerchantable, stems can be manually felled before harvesting. In Richardson's research (1992), harvester productivity was shown to increase by between 22 and 37 percent. Harvester operators can take up to two years to reach their full potential, although the most productivity gain takes place in the first six months (Richardson and Makkonen, 1994).



# Fibre utilisation

Leaning trees can cause high stump heights and therefore lower fibre utilisation, as the operator lifts the head due to the risk of the chain cutting into the ground (Hartsough and Cooper, 1999).

# • Multi-tree harvester heads

One way of trying to reduce the costs of harvesting small trees with a harvester is to fell and process many trees simultaneously. Gringas (2004) explained how multi-tree harvester heads are capable of processing more than one tree at a time, as well as being able to handle trees of different sizes and length simultaneously.

The key technologies allowing more than one stem to be processed at a time utilise:

- accumulating arms, which keep trees vertical in the head while additional trees are being felled;
- extra feed rollers (normally four in total), which help prevent slippage during processing; and
- a wider-than-usual measuring wheel, which allows contact with the trees to be maintained.

In research conducted by FERIC in 0.10 m<sup>3</sup> trees, a comparison between the multi-tree and conventional harvester heads showed the former was able to improve productivity by between 21 and 33 per cent (Gingras, 2004). Cycle times increased by between 30 and 40 percent, but the mean processing time per stem was lower and the heads were not able to calculate production output with any level of accuracy.

The benefits of multi-tree harvesting heads are most pronounced in very small trees in dense stands (Johansson and Gullberg, 2002; Gingras, 2004) As average tree size increases, the benefits gained from multi-stem handling decrease. Bergkvist (2003) reported an 18 per cent productivity gain in slightly larger trees. In Gringas's research (2004), the debranching quality and accuracy of log length was good. However, there was no debarking element.

Bergkvist's research (2003) indicated that six per cent of the logs produced were rejected because of poor debranching quality or because the log diameter was below the mill specification. Gingras (2004) did specify that if there were large differences in the diameter of the trees being processed (greater than 4 cm), the top ends of the trees might not be



topped at the correct diameter. He concluded by stating that quality problems posed a real risk and had to be carefully managed (Gingras, 2004).

None of the above research included a debarking element. Indeed, this technology is not yet able to debark adequately owing to the reduced contact between the feed rollers and the trees. The mutli-tree machine is unable to spin the trees, an action that is required during the debarking element.

#### Terrain

To obtain the lowest cost operation when using a harvester, the terrain needs to be flat (Spinelli, et al., 2002a). On steeper terrain, the cost will increase, owing to productivity reductions and more expensive machine requirements.

# Log lengths

Richardson and Makkonen (1994) found there was up to 20 per cent difference in harvester productivity when using longer log lengths.

#### Construction excavators versus purpose-built carriers

Construction excavators, rather than purpose-built forestry excavators, have become more popular as carrier machines in forestry, especially for smaller tree sizes, roadside processing and easier terrain. However, matching the harvester or DHP head to the carrier can be difficult, specifically with regard to the hydraulic systems. Richardson and Makkonen (1994) identified problems with hydraulic flow capacity, inadequate filters, small reservoirs and inadequate cooling systems. They also observed that the stick boom normally had to be extended to allow processing close to the excavator. Safety can also cause concern, particularly with roll-over protection structures (ROPS), operator protection structures (OPS) and fall-over protection structures (FOPS).

Many of these problems have been overcome, but not all. The hydraulic power of construction excavators was found to be less than that of purpose-built wheeled forestry harvesters (Nakagawa, Hamatsu, Saitou and Ishida, 2007). This is important for machines operating in *Eucalyptus* as a great deal of hydraulic power is required for the debranching and debarking elements.

Johansson (1995) studied productivity in and other variables of four construction-based excavator harvesters and found no difference between their productivity and that of Nordic-



type wheeled harvesters. The excavators had increased boom reach and had higher lift, which enabled more trees to be harvested from one position. This resulted in a higher concentration of logs being prepared for the forwarder. However, the ergonomics of the wheeled harvesters was better.

Spinelli and Visser (2008) observed that mechanical problems in purpose-built wheeled harvesters were often assumed to cause fewer delays than those in tracked excavators. However, they found the opposite to be true: excavator-based harvesters were less susceptible to mechanical breakdowns than their wheeled counterparts.

# 2.3.4 Full-tree systems

This section examines the advantages, disadvantages and productivity of full-tree systems. Different processing technologies that occur in full-tree systems are also included.

#### 2.3.4.1 Advantages of full-tree systems

# Tree size

When harvesting small trees, such as is often the case with *Eucalyptus* pulpwood, it is often better to handle multiple stems throughout the system to reduce costs. Full-tree systems lend themselves more towards multi-stem handling, which improves the handling efficiencies of each stem (Boprey, 1988; Stephenson, 1989). Multi-stem handling is most feasable when harvesting small trees of a uniform size, where the trees do not have excessively large branches (Richardson and Makkonen, 1994). Even though length-measuring accuracy is not that good, they found between 5 and 25 per cent increases in productivity by handling multiple stems. If the tree needs to be accurately optimised, the entire stem is now available in a more controlled location (Gellerstedt and Dahlin, 1999).

Fibre utilisation

As timber resources become increasingly scarce, the harvesting system selected must be able to optimise as much useful fibre from a tree as possible. Fibre recovery was deemed so important to FPInnovations of Canada (then FERIC), that the cost models developed to investigate systems and system alternatives included fibre-recovery efficiency (Favreau, 1992). When a full tree is debarked and debranched with chain flails, large branches are left



intact and the flails do not completely remove the top. When these stems are then fed directly into a chipper, there is the opportunity for increased fibre utilisation.

CFDDCs can even use trees that would be considered unmerchantable for roundwood systems (Favreau, 1993). Rodden (1994) indicated that low grade trees, tops, twisted trunks and other deformed pieces that might have been left in the compartment previously can now be processed into clean chips. Furthermore, there is no wastage from cross-cutting operations (Favreau, 1992). Full-tree systems using CFDDCs could therefore substantially increase the fibre yield from a given site by 10 per cent or more. Favreau (1992) indicated that the greatest opportunities for increased fibre yields and, therefore, lower costs, came from low volume stands.

Favreau (1992), Flanders (1994), Hartsough, Spinelli, Pottle and Klepac (2000) and Mooney, et al. (2000) conducted research which showed or inferred increased fibre yields. Their findings indicated that over 95 per cent of the potentially available wood culminated in the chip truck. This figure decreased slightly when processing trees of less than 0.05 m<sup>3</sup>, as there was a proportionately large percentage of smaller breakable material.

Markham (1995) and Rodden's (1991) research also indicated greater fibre yields. Markham (1995) found that the yield per tree and per hectare increased because previously unmerchantable trees could be processed. The increase was by 1.5 per cent in spruce, by between 10 and 12 per cent in jack pine, over 25 per cent in poplar and over 5 per cent per hectare. Rodden (1991) reported yield increases ranging from 1.6 to 16 per cent in poplar. Even short lengths of 1.22 m tops of trees were flailed in Rodden's research.

Buggie (1991) conducted research on two sites with black spruce of very small tree size (0.05 m<sup>3</sup>). By including stems that other systems were not able to harvest, fibre yields were increased by between 20 and 56 per cent. Much of the additional fibre came from the tops of merchantable stems and trees as small as 2.5 cm in diameter. When considering the improvement in fibre yield from only the merchantable stems on the same research sites, the gains on the two sites were 7.2 and 8.4 per cent. The main reasons for this improvement are:

- $\circ$   $\;$  the use of tops down to much smaller diameters,
- the chipping of large branches,
- there were no cross-cutting losses as is usual with most systems that produce logs.



It must be noted that these trials only achieved bark percentages of 3.3 and 2.3, which would be unacceptable to many mills. However, the technology used in the trial was that of the first Peterson Pacific 5000 built and much development has taken place since then.

In 1991, Stokes and Watson conducted a trial on 21-year-old *Pinus elliottii* and found that infield CFDDCs produced 4.3 tonnes of acceptable chips per hectare more than a method sending full trees to the mill for processing. Interestingly, the CFDDCs generated a tonnage of 9.6 more than a tree-length method that attempted to remove branches with a gate debrancher in the compartment and then transport the tree lengths to the mill. The increased breakages of this latter method were mainly responsible for the lower chip production. The mill also had to deal with increased residues when the full-tree and tree-length methods were used.

Stephenson (1989) showed 25 per cent increases in fibre utilisation when harvesting small pine with CFDDs compared with log production. This was due to the ability to process tops and previously unmerchantable stems. Simultaneously, bark contents, silica levels and debris contents were reduced.

Feller bunchers are normally able to cut stumps to a lower level than harvesters, which improves fibre utilisation (Favreau, 1997). Hartsough and Cooper (1999) showed that the stumps left by a harvester averaged 26 cm in height, whereas those remaining after a feller buncher with a shear-felling attachment had been through the compartment were only 12 cm high. In 1992, Shaffer's summary of literature focusing on stump height revealed that the quantum of the height difference was not normally so large. Most research showed an eight centimetre height difference (Shaffer, 1992), which is still substantial.

#### Harvesting residue for energy production

Full-tree systems enable the more economical use of harvesting residue as material to generate energy (Spinelli, et al., 2009). The material is concentrated on the landing and can either be processed and transported simultaneously with the timber product or stockpiled for later processing and transportation. Spinelli, et al. (2009) calculated that if harvesting residue were valued at between  $\in$ 10.00 and  $\in$ 15.00 per tonne on the roadside landing, the costs should be divided by three (the proportion of harvesting residue generated per tonne of pulpwood) to obtain the value of the additional income that could be added to the conventional harvesting product. Therefore, an additional income of approximately  $\in$ 4.00 per tonne of pulpwood can be achieved by utlising harvesting residue.



In addition to the economic benefits of using the plantation residue, reduced fuel loading in the compartment would lessen the fire risk. Re-establishment activities, such as site preparation and planting, would also be easier and more productive with lower harvesting residue loads (Spinelli, et al., 2009).

# Harvesting residue handling if returned to compartment

Even though full-tree systems result in harvesting residue at the landings, a grapple skidder is still more effective at returning this residue than other extraction equipment (Rodden, 1991). If properly supervised, most of the residue can be returned into the compartment to the place desired. The grapple skidder can leave the slash in windrows, large residue stacks, scattered piles across the compartment or accumulate it on a landing for bio-energy use. Grapple skidders can also be fitted with debris attachments on the front, which further assist with residue handling (Rodden, 1991). Front-end loaders (FELs) with timber grabs or forks have also been used for extracting small trees successfully. They lift bunches completely off the ground in their grabs and carry the trees out of the compartment. The tree lengths are carried perpendicular to the extraction route (Spinelli and Hartsough, 2001). Although FELs are slower per cycle than grapple skidders, their ability to take larger payloads of very small trees makes them competitive (Spinelli and Hartsough, 2001; Spinelli, et al., 2002b). The FEL is also more versatile than the grapple skidder and is better when working on landings, specifically when handling harvesting residue (Spinelli, et al., 2002b).

#### • Equipment robustness

The equipment used in full-tree systems is inclined to be more robust (Pulkki, 2011). Operator training is also likely to be easier and quicker, and spare parts for the equipment are usually more readily available.

#### Other advantages of full-tree systems

- Reduced inventory If carrying out infield chipping of tree lengths, the amount of inventory in the plantation can be reduced (Favreau, 1992).
- Uniform moisture content of chips Product with a more uniform moisture content is offered to the mill, as the time from felling to chipping is normally similar to that of infield chipping systems (Favreau, 1992).



- Public perception of chip trucks The chips are usually transported in an enclosed chip truck that looks very similar to other trucks on public roads. The negative public perception of log trucks is not attached to these vehicles (Boprey, 1988; Stephenson, 1989; Rodden, 1991).
- Larger chip-truck payloads with small trees By converting small trees into chips, it is also possible to achieve larger and more uniformly distributed truck payloads more easily and this reduces transport costs (Mooney, et al., 2000).
- Low capital option for new mills For new mills, having the trees chipped in the plantation could also offer a lower capital option.
- Multi-functional machines CFDDs also eliminate the need for a separate machine to execute debranching, one of the problem areas that needed addressing (Stokes and Watson, 1991). Flanders (1994) reported that CFDDCs could eliminate the need for debarking at the mill. By carrying out chipping in the plantation, there is the possibility of producing a chip product of higher value, as well as using a larger portion of the tree.

#### 2.3.4.2 Disadvantages of full-tree systems

A disadvantage of full-tree systems is that they normally require high annual volumes to utlise the system fully (Gingras, 1994). Full-tree systems can also cause more soil compaction and disturbance, as the tree length being extracted tends to sweep organic material off the extraction route, leaving the soil exposed (Hartsough, et al., 1997). This also creates more dust (Hartsough and Cooper, 1999). If full-tree systems are going to be used, the inadequate return of plantation residue to the compartment could result in site nutrition problems on sensitive sites (Spinelli, et al., 2009). This could be compounded if plantation residue is removed from the site for energy production.

Full-tree and tree-length systems also require much larger landing areas than CTLs for the storage and processing of trees (Raymond, 1990; Gellerstedt and Dahlin, 1999; Spinelli, et al., 2009; Pulkki, 2011). Because of the additional slash brought to the landing by the full-tree system, landing requirements can be even higher than for the tree-length system.

Full-tree systems usually have many different types of machines that work in close proximity to each other. In order for the system to work most effectively, there needs to be sufficient buffers between machines (Pulkki, 2011). The reason is that breakdowns in a full-tree system can result in the entire system stopping production relatively quickly. This will vary



with the species being harvested, the type of processing equipment used and mill requirements. The hot nature of most full-tree systems can result in system inefficiencies because of congested landings, longer extraction distances, interference between machines and problems with debris disposal (Raymond, 1990).

Skidding full-tree lengths can result in dirt contamination and more stem breakage during the extraction process (Gellerstedt and Dahlin, 1999; Spinelli and Hartsough, 2001; Wang, LeDoux, Vanderberg and McNeel, 2004). The amount of damage depends on ground roughness, felling direction, operator technique, operator visbility and extraction route layout (planning). In a *Eucalyptus* harvesting operation, dirt contamination is less problematic, as the tree is extracted with the bark on, which is then removed by the processing equipment on the landing.

If dry wood or trees with a low basic density are chipped infield, it could happen that it is not possible to achieve payload on the chip trucks. The payload can vary between 15 and 20 per cent less than that of log trucks (Favreau, 1992). Naturally, this will increase transport costs.

The safety risk is also considered to be higher, as there are many machines working in close proximity to each other (Gellerstedt and Dahlin, 1999).

# 2.3.4.3 Productivity of full-tree systems

Productivity levels of some of the equipment used in full-tree systems is discussed below.

#### • CFDDs and CFDDCs

Thompson and Sturos (1991) reported productivity figures of 30 to 60 tonnes per PMH in research conducted in North American indigenous hardwoods, using a two-flail Peterson Pacific 4800 CFDD. Even though the species were different to *Eucalyptus*, debarking still took place and, therefore, an indication of the productivity levels possible in *Eucalyptus* could be provided. In research conducted by Hartsough, Spinelli and Pottle (2002), it was discovered that the productivity of the CFDDC gradually reduced over the course of each day. In the small, hybrid poplar being studied, the drop amounted to half an oven-dried tonne (ODT) per hour. This was attributed to operator fatigue, but a dulling of the chipper knives could also have contributed to the diminished productivity.



#### Feller bunchers

Tree size is the major factor that affects the productivity of a feller buncher. The number of trees per accumulation has a smaller influence on productivity than tree size. Thereafter, factors such as bunch size, spacing between corridors and the average distance between trees come into play (Johansson and Gullberg, 2002). The proportion of fallen and leaning trees could also influence productivity. Drive-to-tree machines are more affected by poor terrain than other machines (Spinelli, et al., 2002a).

Three-wheeled feller bunchers can be used effectively for clearfelling under the correct terrain conditions. These machines work better on flat areas with few obstacles. The wheeled drive-to-tree machines are effective on flatter terrain, while the tracked levelling machines are needed for steeper slopes (Spinelli, et al., 2002a).

When handling trees with a diameter smaller than 56 cm, continuous disk-saw feller bunchers have been found to be more productive than bar-saw feller bunchers (Adebayo, et al., 2007). However, bar-saw feller bunchers have a much lower investment and maintenance cost and can handle a wider range of tree diameters, although this is not really important in pulpwood operations involving small tree sizes. The shear felling attachment is less productive than a continuous disk saw, but is able to cut at ground level, even cutting below this level at times. It has a narrower kerf, which increases fibre utilisation further (Adebayo, et al., 2007). Adebayo, et al. (2007) also indicated that shear heads were more reliable and had lower capital, fuel consumption and maintenance costs than continuous disk felling heads.

# Extraction equipment

As with CTL extraction equipment, extraction distance affects grapple skidder productivity most, but load size and average tree size are also important (Andersson, 1994). The skidder's load capacity is influenced by its grapple area and the drag force of the trees being extracted (Spinelli and Hartsough, 2001). It should be noted that a grapple skidder is not the only option for full-tree timber extraction for small trees.

In their research on *Eucalyptus* pulpwood and with tree sizes of less than 0.1 m<sup>3</sup>, Spinelli, et al. (2002a) established that a FEL could carry two-thirds more payload than a grapple skidder. The FEL, operating in tree sizes of 0.058 m<sup>3</sup> and with an extraction distance of 201 m, carried 61.2 trees per cycle, with an average payload of 3.54 ODTs. The grapple skidder, operating in tree sizes of 0.087 m<sup>3</sup> and with an extraction distance of 251 m, carried 17.1 trees per cycle, with an average payload of 1.49 ODTs. The FEL productivity was higher than the grapple



skidder over the entire range of extraction distances (up to 400 m) in the research. Even though the FEL is slower, it does not have drag on it the way the grapple skidder does.

Stability is a concern with large loads. As the extraction distance increases, the average travel speed increases as well because the operator becomes more comfortable with the load stability. In the research conducted by Spinelli, et al. (2002a), the FEL had much spare capacity and was able to carry out the work at the landing as well. However, the grapple skidder had very little spare capacity and a second machine was necessary for landing work (Spinelli and Hartsough, 2001). It is interesting that the number of trees per cycle being carried by the grapple skidder was very low and the reasons for this were not indicated.

Spinelli, et al. (2002) observed that the use of a larger capacity grapple should increase the skidder payload and make it more competitive in comparison with the FEL on longer extraction distances. They also observed that the FEL:

- o operated best in compartments with small, uniform-sized trees;
- o resulted in less dirt contamination of the trees during extraction;
- was more expensive than the grapple skidder;
- was less robust and had poorer terrain-handling capabilities than the grapple skidder.
   The latter is a purpose-built forestry machine and is able it to work on steeper and softer ground with more obstacles (ground clearance 450 versus 700 mm);
- when travelling loaded, was approximately 30 per cent heavier than the grapple skidder and would not be capable of extracting immediately after heavy rains on clay soils.

There is the possibility that there could be more soil compaction owing to higher axle loads, so the FEL would be restricted to areas with gentle slopes, low ground roughness (Spinelli and Hartsough, 2001) and good soil conditions in the wet – indeed, it would only be able to operate in areas that were not waterlogged. These authors also stated that the FEL operates best in compartments with small, uniform-sized trees.

#### Systems planning

With full-tree and tree-length systems, proper planning of the landing area before harvesting will ensure that imbalances caused by interaction between system machines are minimised (Adebayo, et al., 2007). When carrying out system balancing for a compartment, the spare capacity of all systems should be examined. The lowest overall cost for the system has to be



achieved. If it takes a long time to set up the landing, then spare capacity of the extraction equipment should be used to extract longer distances than usual (Favreau, 1992; Spinelli, et al., 2002). This could apply when using processing equipment such as CFDDs or CFDDCs.

Favreau (1992) indicated that due to longer extraction distances, extraction costs to feed these processing machines can be 15 percent higher than for other full-tree methods. Longer extraction could reduce the total road requirements for this full-tree system as well. However, as stated above, it should not compromise the overall system cost. When considering CFDDCs as part of full-tree harvesting for small *Eucalyptus* trees (<0.1 m<sup>3</sup>), Spinelli, et al. (2002b) recommended three-wheeled drive-to-tree feller bunchers for felling and a FEL for extraction on easy terrain. For difficult terrain, Spinelli, et al. (2002b) advocated tracked swing-to-tree feller bunchers for felling and grapple skidders for extracting.

Hot-deck operations, where the tree lengths are brought to the landing by the extraction equipment and immediately processed by the processing machine, incur more delays than cold-deck operations, where the trees are brought to the landing and then processed at a later stage (Spinelli and Visser, 2008). Most literature reports delays as a percentage of the total scheduled time (SMH). Spinelli and Visser (2008) found that delays can vary between machine types, stand conditions and terrain variables. Therefore, delay categories need to be identified for machines operating under specific stand and terrain conditions. It is not possible to use standardised factors to measure delay for different technologies.

#### Costs of full-tree systems

In Favreau's research on softwood (1992), two full-tree systems were compared with each other. One system included a CFDDC and the other a stroke-boom debrancher with subsequent slashing and loading of logs. The stroke-boom debrancher system could be most closely correlated to the DHP full-tree system researched as part of this dissertation (see Section 2.3.4.4 below). Favreau (1992) found that when the tree size was lower than 0.22 m<sup>3</sup>/tree, the CFDDC system was cheaper. Total system costs were discussed in Favreau's research (1992), including debarking of logs produced by the stroke debrancher system at the processing plant. These research results indicated a cost reduction of more than 10 Canadian dollars per cubic metre in small trees (0.1 m<sup>3</sup>/tree) if the roundwood system was converted to a CFDDC system. The main savings came from reductions in log handling, chipping and chip handling at the mill. Even in larger trees (0.3 m<sup>3</sup>/tree), the cost of the CFDDC system was still lower.



# 2.3.4.4 Dangle-head processors (DHP)

Richardson and Makkonen (1994) found processor productivity generally higher than harvester productivity, but this was greatly affected by average tree size. They found that tree size was the most important factor determining the DHP productivity. As with factors that influence harvesters, operator skills, branchiness and accuracy requirements also played a role in DHP productivity (Richardson and Makkonen, 1994).

In research conducted by Spinelli and Visser (2008), it was found that DPHs working on a hot deck evidenced delay factors of 62.6 percent. This indicates how difficult it is to balance systems in 'hot' tree-length or full-tree operations. This high percentage could also apply to other processing equipment working on a hot deck. However, the inherent reliability of the processing equipment should be considered as well. While it is hypothesised that CFDDs would give a lower delay percentage because they are more robust, they are also more sensitive to a shortage of trees being placed at the infeed because of their high production rates. Long extraction distances or breakdowns of the grapple skidders will very quickly result in the CFDD or CFDDC being delayed.

DHPs are also much easier to operate than harvesters as there are two fewer functions to perform (felling and cross-cutting/topping).

# 2.3.4.5 Chain-flail debrancher debarker (CFDD), Chain-flail debrancher debarker chipper (CFDDC) and Chain-flail debarker debrancher & chipper (CFDD&C)

CFDDs are commonly used in the western half of North America to process trees. They produce clean wood chips of high quality on short-rotation (fewer than 10 years) poplar plantations (Sessions and Kellogg, 1994; Hartsough, et al., 2000). Because the trees are so small, it is necessary to find systems that are economical (Stokes and Watson, 1991). A CFDD is most commonly used with infield chipping (Mooney, et al., 2000), offering a cost-effective method of producing chips in the plantation from full trees (Stokes and Watson, 1991). The eastern half of North America does not need this equipment as debarking generally takes place at the mills. This is discussed further below under *Chip quality* below.

The reasons for the implementation of CFDDCs are varied. Certainly, this machine's ability to process multiple small trees with possible poor form and BWBS into chips of the correct quality, ready for further mill processing, may be offered as the main reason. Secondary reasons for utilising a CFDDC include the following:



- the high productivity levels of the system in which it operates enable areas to be clearfelled quickly with minimal labour;
- o quicker re-establishment opportunities;
- the robustness of the processing equipment;
- the reduction of equipment requirements for the total system; and
- the system's ability to utilise plantation waste for biofuels in the future (McEwan, 2010).

CFDDCs can result in increased tree utilisation as the entire tree is chipped, including tops and branches that have not been debranched, without saw-kerf wastage. It should be borne in mind that the investment costs for these machines are very high (Spinelli, et al., 2009).

The cost of CFDDCs as a percentage of the total system cost can be as high as 50 per cent (Favreau, 1992). The system must therefore be set up to reduce the operational delays that might affect this machine. However, no additional loaders are needed to remove material, stack it and load trucks, thus reducing the complexity to some degree. Proper truck scheduling and system management are prerequisites for operating the CFDDC system successfully, but these do increase the complexity of the scheduling immensely. In order to plan and coordinate properly, the chip-truck fleet is often considered part of the harvesting system when operating CFDDCs (Favreau, 1992).

Tree size

CFDDs are processing machines able to process a much wider spread of trees sizes and species than most other processing methods (Creelman, 1989). CFDDs with chippers have the potential to cost effectively produce chips in the plantation, utilising small trees more effectively than other log production systems (Stokes and Watson, 1991). These CFDDCs can process smaller trees cost effectively as they handle many trees simultaneously.

Because trees are processed as bundles, it is difficult to quantify the effect of tree size and stem form on the productivity of these machines (Spinelli, et al., 2002b). Mooney, et al. (2000) tried to develop transformations to explain the effect of a number of trees per cycle, but their results did not explain the significant variance in cycle times. They also commented that this was not an unexpected result when the method of debarking/debranching was taken into account.



With CFDDs, it is preferable to process trees of similar sizes. If very big trees and very small trees are found in the same bundle, the big trees tend to shield the small trees from the flail action, resulting in poor quality of debarking and debranching. Also, trees of the same size within a given compartment tend to have the same physical characteristics. For example, all the very small trees might have poor BWBS or all the very big trees might have big branches. The bundle then has to be fed through the machine at a rate that will achieve the desired quality for the most limiting tree. This results in an overall lowering of productivity (Mooney, et al., 2000; Hechem, pers. com., 08 March 2010).

In addition, when large and small trees are fed through together, the infeed rollers have no grip or control over the small trees. These small trees tend to be swept through the CFDD by the flails, with little debarking taking place (Araki, 1994). The chipping quality is affected as the small stems are not fed into the chipper at a controlled speed, a requirement for uniform chip sizes. Uniform stands are therefore ideal for optimising the productivity of CFDDs. If this is not possible, then, in extreme cases, it might be worthwhile attempting to sort stems by DBH, so that a bundle consists of uniformly sized trees before they are processed (Mooney, et al., 2000).

#### Fibre utilisation

Even though fibre yields have been shown to be greatly improved, CFDDs still have the potential to waste fibre if not operated properly. Raymond (1989) showed that CFDDs can lose as much as five per cent of available fibre. However, with current knowledge and new CFDD technology, this amount is much lower and is more than offset by the additional fibre gains through tops, large branches and unmerchantable stems. Much other research has shown that CFDDs can achieve lower fibre losses than drum debarking and producing logs in the plantation (Raymond, 1989).

An additional area that could be focused upon to increase the fibre yields from CFDDCs and CFDD&Cs is the waste chute. Hartsough, et al. (2000) showed that most reject material from the chipper is wood and that 80 per cent of all the wood lost in the CFDDC process comes out of the waste chute. This percentage was influenced by tree size, with larger trees resulting in more waste wood. But, as explained in the paragraph above, if expressed as a ratio of waste from waste chute to tree size, smaller trees had more wood waste. As a comparison, only five per cent of the wood lost came out of the hydraulic bark discharge (0.8 dry kilograms per tree) and this was irrespective of tree size. This figure clearly indicates that wood material actually lost because of flail action was minimal.



It is not clear what causes the wood to be found at the waste chute. Researchers have suggested the following factors play a role in this: knife sharpness, knife design, number and size of branches, incorrect flail setup, incorrect feed speeds of the flails and chipper and damage from flails (Hartsough, et al., 2000). If technology advances to reduce the amount of wood from the waste chute, the overall percentage of fibre utilisation will naturally increase.

#### Harvesting residue

Because debranching and processing frequently takes place on the roadside, it is often difficult to handle the large amount of plantation residue (bark, leaves, branches) generated (Hartsough, et al., 2002). The machine removes material from the bole of the tree, the residue consumes space in the infeed and thus reduces the capacity for additional trees. Some systems have chainsaw operators who top the trees and remove very big branches in the compartment. This results in reduced residue at the landing and higher CFDD productivity.

If plantation residue is utilised (for example, transported to a power generation plant), then this system is ideal as the residue can be fed straight from the CFDD into a transport vehicle or moved to one side of the landing for later processing and transport (McEwan, 2010). The residue that a CFDD or CFDDC produces is more compact and easier to handle than residue from other processing methods (Favreau, 1992). It is also possible to use a conveyor to feed the bark and branches into a plantation residue truck, another chipper or a grinder, which will process the residue for transport. However, there can be broken chain links in the residue. This needs to be considered when deciding on which grinder to use to process the residue (Stephenson, 1989).

With CFDDCs, residue can also block the waste chute if the hydraulic bark discharger is not able to remove all of it and some is fed through to the chipper with the debarked bole. Hartsough, et al. (2002) explained that large amounts of residue increase the operating costs of CFDDs and CFDDCs by increasing fuel consumption and chain wear. These are two of the most important operating costs of these machines. To reduce these costs, an attempt was made to debranch hybrid poplar trees with a pull-through static debrancher before the trees were flailed. Even though the productivity of the CFDDC did increase by 10 per cent, this was not sufficient to justify the additional costs incurred by using an additional machine. However, Hartsough, et al. (2002) did state that some form of debranching before flailing might still be an option in certain site-specific situations.



# Debarking

The ability of CFDDs to remove the bark from trees is dependent on species, temperature, moisture content, tree size, number of trees fed at the same time, branchiness, feed speed, flail speed, number of chains used and flail condition (Thompson and Sturos, 1991). Thompson and Sturos (1991) reported that branches could actually improve debarking quality as they slowed the movement of the tree through the flails, resulting in greater chain contact. Sauder (1990) recommended reducing the bark content of the chips produced from flailed trees by not feeding too many trees through at one time, with three to five tree lengths being considered acceptable. Other methods of reducing bark on chips included:

- o adjusting flail infeed and rotation speeds;
- synchronising the CFDD outfeed and the chipper infeed so that the trees were not pulled in by the chipper faster than the flails could debark them;
- the operator's examining the specific dynamics of the trees being debarked and ensuring that the CFDD infeed rollers could grip small trees tightly so they were not propelled through the CFDD without being adequately debarked.

Stephenson (1989) also investigated feed speeds and arrived at the same conclusions as Sauder (1990). Creelman (1989) tested an infield CFDD and found that it was consistently able to produce chips with a bark content of less than one per cent if the feed speed was controlled.

The number of flail drums used to debark usually varies from two to four. More flail drums result in better debarking and debranching quality. Often the last flail drum is used as a sweep drum. This drum rotates in the opposite direction to the others, preventing bark from being expelled with the debarked timber. For stubborn bark, two chains per attachment on the drum and more attachment points can be used (McEwan, 2010). The number of chains per drum can vary, but most flails make provision for between seven and ten chains per row, and have eight rows of chains per drum. CFDDs are very good at handling crooked stems and forked trees, removing bark effectively where a harvester is not able to (Wingate-Hill and MacArthur, 1991; Hartsough and Cooper, 1999).

Even though CFDDs are able to handle many stems at a time, it is still possible to over-feed the machine. Too many stems being fed through at once will result in poor debarking and debranching quality because some stems shield others (Rodden, 1991). Stephenson (1989) found that overfeeding results in patches of bark being left on the stem. Rodden (1991)



stated that feeding the correct number of trees through resulted not only in better debarking quality, but it also enabled all the bark to drop to the floor of the machine for expulsion.

When too many stems are fed at once, the chipper has to slow down, which causes the feed speed of the trees moving through the CFDD to decrease. The excessive flailing of the stems subsequently causes white fibre to be lost. This results in an excess of fines and pins in the chips, as well as brooming of the chip ends (Araki, 1994). Thompson and Sturos (1991) affirmed that if the machines were fed with too many trees at once, then debarking quality was lower. They also mentioned that faster flail speeds improved debarking, but could result in an excess of poor quality chips (most notably, fines) and decrease chain life.

Tree size plays a role in the effectiveness of debarking. In their pine research, Watson, Twaddle and Stokes (1991) observed that smaller tree sizes had a naturally high level of bark in proportion to the entire stem and producing low levels of bark content could be more difficult. However, in research on a CFDD in North American hardwoods conducted by Thompson and Sturos (1991), the small trees achieved better debarking levels. This was attributed to the smaller trees having thinner bark.

#### • Chain life and performance

Flail chains are listed as one of the items incurring the highest expenditure in CFDDs. Thompson and Sturos (1991) found that chain costs can account for up to one third of the total CFDD operating costs. This expenditure concerns many potential operators and contractors. Chain condition is very important to achieve the correct debarking quality levels (Thompson and Sturos, 1991). Only a few missing links from a key area on the drum can reduce debarking quality.

Worn chain tends to fold up easily, which reduces the debarking effectiveness (Jackson, Thompson and Sturos, 1993). The aggressive nature of the flailing process puts stress on the chains, which causes them to wear rapidly (Sessions and Kellogg, 1994). Sessions and Kellogg (1994) reported that the major factors affecting the action of flail chains were:

- the amount of space within the link too much space allowed the chain to fold up and it became less efficient;
- link length as the length increased, the chain bounced off the stem more easily, causing faster wear;
- $\circ$   $\;$  link mass the comment about link length applies to mass as well; and



• link shape – round links folded up too easily.

The cost of chains for the CFDD varies with the species being processed, wood density, tree size, drum design, hardness and rotational speed, bunch size, the time of year (both in terms of BWBS and cold – the trees are sometimes frozen), the size and frequency of the branches, feed rate, number of chains per drum and specific chain characteristics (Jackson, et al., 1993; Sessions and Kellogg, 1994). Table 3 shows the factors that influence the performance of flail chains.

Workpiece	Machine	Chain	
Volume processed	Drum placement Wire diameter		
Tree species	Drum orientation	Link size	
Tree size	Cavity design	Number of links	
Branch size	Residue removal system	stem Link geometry	
Number of branches	Feed rate	Composition	
Bunch size	Drum speed	Heat treatment	
Number of trees per bunch	Drum design	Hardness	
Dirt and rocks on trees	Drum hardness	Toughness	
Previously delimbed	Number of chain rows	Impact strength	
Time of year	Number of chains per row	Working temperature	
Temperature	Chain position on drum	Weld quality	
	Link position in chain	Wear to present	

Table 3: Factors influencing the performance of flail chains(Jackson, et al., 1993, pg 30)

Harder wood and bark puts more stress on the chains. The number of chain rows and the number of chains per row influence chain wear. The more chains there are per drum, the lower the individual chain wear is, as the load is spread and the chains support each other. The chains at the centre of the drum (in horizontal drums) also wear more quickly as they make most contact with the stem (Raymond and Franklin, 1990). Chain costs for processing hardwoods are more than those for processing softwoods (Jackson, et al., 1993). Jackson, et al. (1993) observed that a high density of branches per tree and large branches made chains wear faster.

The main source of wear has been identified as the aggressive action between chains, with the chain hitting the drum playing a minor role. The chain motion most responsible for the wear is the whipping and snapping action of the last three links after the chain has struck an object (the stem) and is trying to catch up (Sessions and Kellogg, 1994). The wear from the chain striking wood is insignificant compared to the chain-on-chain wear, and, to a lesser



extent, from chain-on-drum contact. The third link from the end generally shows the highest wear, but link failure normally occurs with the two end links (Jackson, et al., 1993). It has happened that the anchoring device fails as well. Raymond (1990) discovered that certain operators would extend chain life by cutting off the last link once the third-last link showed wear. This would effectively create a new third-last link which doubled chain life. The link normally fails at the weld, as can be seen in Figure 15.



Figure 15: Chain link failure at the weld

Shorter link chains seem to exhibit the least wear. Jackson, et al. (1993) also reported that once an eight-link chain has lost two links, it becomes ineffective for debarking. However, if mounted next to another eight-link chain, it can provide stability and shock absorption which can actually reduce wear. Chains should be rotated as wear becomes evident. Chains should be rotated end-to-end and should be moved to areas on the drum or to another drum less likely to promote wear (Raymond, 1990; Carte, 1991).

New chains are normally placed on the first drum where the most wear takes place (Raymond, 1990). In extremely difficult conditions, such as difficult debarking with lots of branches, chains with welded studs can be used (Sessions and Kellogg, 1994). These should not be used continuously though, as they can cause high fibre loss and the chains are expensive. Quick-disconnect links have also been used successfully to reduce the time taken to change chains. Jackson, et al. (1993, pg 33), stated that "Good debarking chain starts with good quality wire." Obtaining chains at a lower price makes no sense if they wear quickly.



Mooney, et al. (2000) reported obtaining 400 truckloads of chips (eight weeks' worth of production) from a set of flails in a *P. taeda* thinning. Thompson and Sturos (1991) obtained 25 loads (each load was 26 tonnes) of timber from a set of chains before the chains were rotated for another 25 loads, giving an average of 50 truckloads of chips per set of flails or 1,300 tonnes from a set of chains. Gehoski (1989) managed to process 2,500 tonnes of trees on average before the chains were replaced. Thompson and Sturos (1991) predicted two future methods of improving the life of the chains: the first was through improved chain technology and the second was to separate the debarking/debranching function from the chipping function. Twenty years on, chain technology has indeed improved, However, no research has been conducted to quantify this improvement.

There is no rule as to how many chains should be mounted onto each drum. This is established by trial and error and fluctuates according to the variables mentioned above and in Table 3 (Jackson, et al., 1993). The minimum number of chains required for debarking and chip production of suitable quality should be used. If the stem is too close or too far from the flail, debarking and debranching are not as effective. Trees are also tapered, which makes maintaining the distance from the drum to the stem difficult. At least one drum, usually the upper one, should be floating in order to maintain this distance (Franklin and McPhee, 1993). It takes approximately 20 minutes to change chains (Selby and Iff, 1986).

#### CFDDs feeding chippers

CFDDs' feeding into stand-alone chippers (termed CFDD&Cs in this report) allows the flexibility of producing debarked and debranched tree lengths if desired, as opposed to chips only. The CFDD operator can concentrate fully on optimal tree intake, relieved of having to guide the chip chute and watch material exiting the waste chute. It can also result in cleaner chips as monitoring of debarking quality is easier. Further to this, bark that still escapes the CFDD outfeed can fall onto the ground instead of being chipped with the tree lengths (McEwan, 2008).

Stephenson (1989) stated that if debarking levels of less than two per cent are required, it is better to have the chipper and CFDD a little further apart to allow bark to drop to the ground. However, Stephenson's research was undertaken before integrated CFDDCs had become commonly used and further developed. Previous methods of debranching and debarking to feed infield chippers often had undesirable levels of bark and soil contamination. CFDDs have the ability to remove this debris successfully (Thompson and Sturos, 1991).



One of the problems with having separate machines is that the chipper often has a much higher potential for productivity than the chipper. One option is to use two CFDDs to feed the chipper (Thompson and Sturos, 1991). This would create a system of exceptionally high productivity and there would have to be sufficient yearly volume to utilise the machines fully. This has been experimented with in *E. globulus* in Western Australia (Cameron, personal observation, 30 September 2010), but has not been scientifically researched. Two or more separate machines increase the need for operators and feeding cranes, as well as requiring more engines, which, in total, consume more fuel. All of this has the potential to drive costs up instead of down (Thompson and Sturos, 1991).

#### Chip quality

CFDDCs are able to debranch, debark and chip full-tree lengths to meet the strict quality requirements of international pulp mills (Stokes and Watson, 1991). Infield chipping is a costeffective method of producing chips for the forests' customers (Thompson and Sturos, 1991). CFDDCs are capable of producing chips with a bark content of less than one per cent (Rodden, 1991; Markham, 1995; Hartsough, et al., 2000) and can remove bark to levels similar to those achieved by fixed millyard installations (Mooney, et al., 2000). In the research by Markham (1995), the CFDDCs achieved a lower debarking percentage than that obtained by debarking drums at a mill. Keeping the bark at levels below one per cent does, however, require specific focus (Rodden, 1991).

Research has also been carried out to investigate chip quality, both in terms of chip-size distribution and bark content (Saunder, 1990). Rodden (1991) investigated aspects such as the chip yields as a percentage of the total material, yield comparisons between a number of harvesting systems and the percentage of useful wood fibre lost in the flailing process. Rodden also examined chip yield as a function of tree size. It was discovered that the chip output per cubic metre of stem volume increased with tree diameter. With regard to considering the useful fibre lost in the flail process, Rodden's results varied between three and five percent. None of this research was conducted on short rotation species such as *Eucalyptus* or hybrid poplar.

Debarking before chipping improves chip quality, enables the knives to stay sharper for longer and makes it unnecessary to separate the bark from the clean fibre at a later stage (Stephenson, 1989). Sauder (1990), in research which included *Picae mariana* (black spruce), *Pinus contorta* (pine) and *Abies species* (fir), found that the chips produced from infield CFDDs were of the same quality as those produced by ring debarkers at a mill. Poor debranching quality reduces the quality of chips produced by increasing the amount of fines,



bark and undersize/oversize chips (Mooney, et al., 2000). Proper setup of the machine, including chip-knife maintenance, is important to ensure that both high productivity and good chip quality is obtained (Rodden, 1991). Feed rate differences between the CFDD and the chipper can also affect chip quality, as the incorrect average-size chip will be produced (Thompson and Struos, 1991). Stephenson (1989) warned that quality monitoring was very important when a bark content of less than one per cent was produced. There is an inverse relationship between debarking quality and chip fines. If, in trying to achieve very low bark levels in the chips, excess chip fines are produced, it could become problematic for the digester screens in a pulp mill. If pre-screening at the mill takes place, then this problem is eliminated (Stephenson, 1989).

Jirjis (1995) found that chip quality was mostly influenced by moisture content, tree species and size distribution. Higher moisture content results in the production of a higher proportion of 4 mm to 8 mm acceptable chips (Araki, 1994). Araki (1994) added ambient temperature as an influencing factor. Rodden (1991) indicated that chip quality from a studied infield chipping operation continuously produced chips of a better quality than the mills could. Spinelli, Hartsough and Magagnotti (2005) indicated that moisture content and tree species were not influenced by processing machine characteristics, whereas the chip-size distribution could be largely influenced by machine design and setting. Therefore, chip-size distribution is a very good indicator of the quality of chips that a particular type of chipper is capable of producing. Chip screening has been attempted infield (Araki, 1997), but adds an additional degree of complexity to the operation. This is best carried out at centralised processing yards or at the mill itself.

Araki (1994) observed that overall chip quality was negatively influenced as stem size decreased. This is due to small stems already having a high proportion of bark surface area to solid wood than larger stems (Araki, 1994). Flailed tops of trees can also result in lower chip quality and can even discharge these chips out of the waste chute. Very small stems are also negatively affected when debarked at the mill by means of drum or trough debarkers. As Stephenson (1989) explained, small stems tumble and break which results in broomed ends and under- and oversized chips. When chipping at the mill, it is also difficult to chip large and small trees separately because of the high productivity rates and the mix of timber being processed. If small trees are processed with infield chipping, the chips can be stockpiled and processed separately. This can reduce pulping losses by about the 10 per cent that would normally be attributed to the increased amount of juvenile wood (Stephenson, 1989).



Even though increased fibre utilisation has been demonstrated as an advantage of CFDDCs, bigger branches can result in many chip slivers and oversize material because the angle of contact with the chip knife is not usually correct (McEwan, 2010). If the trees have many branches, these can cushion the effect of the flails on the tree, resulting in poorer debarking quality (Araki, 1994). Keeping chipper knives sharp will reduce the proportion of chips outside specification parameters and ensure that the overall fibre yield from the tree is kept high (Hartsough, et al., 2000).

Sauder (1990) stated that the counter knives should also be in good condition and the anvil properly adjusted. In research conducted in pine, Watson, et al. (1991) found that infield chippers working with CFDDs produced fewer pins and fines, but more oversize chips, than the mill installation chippers. These oversize chips were partly attributed to inexperienced operators and the situation was expected to improve. Measuring chip quality accurately infield would make the team aware of potential problems in this regard. However, these infield tests have been shown to be very unreliable. If infield tests are carried out, it is best to place a bucket under the chip spout very briefly, repeating occasionally until the bucket is full (Stephenson, 1989).

As the team operating the CFDDs, CFDDCs and CFDD&Cs becomes more experienced, so the productivity, debarking quality and chip quality improves (Rodden, 1991).

# 2.3.5 Future trends with mechanised harvesting systems

Even though the harvesting costs of one harvesting system over another may indicate significant differences, it does not necessarily mean that a system change will take place. If a certain type of harvesting method has been established in a country or group of countries for some time, it becomes difficult to introduce radically different harvesting methods, even if the cost advantages are large. Spinelli, et al. (2009) listed factors such as the market for machinery, the mechanical support network and operator training as being important issues that cause people to ignore the cost advantages of a new method.

When the possibility of changing from a full-tree system to a CTL system arises, sometimes impediments prevent this from occuring. Such obstacles include not finding trained and experienced operators, poor organisation of the work crew, lack of mechanical backup for the machines and insufficient funds because much capital is already tied up in existing systems (Gellerstedt and Dahlin, 1999).

Gellerstedt and Dahlin (1999) averred that future mechanised systems would have to handle trees of both large and small sizes. While this is true, the situation is different in southern



hemisphere plantations and the variations in tree size are unlikely to be as large as in the natural forests in the northern hemisphere. Gellerstedt and Dahlin (1999) indicated that the environmental aspects surrounding the consumptions of fuels, lubricants, oils and metal would have to decrease, but, at the same time, not compromise the power efficiency of machines. Another important aspect which Gellerstedt and Dahlin (1999) raised was reduced storage of wood in the forest, rather increasing buffers of logging capacity and not logs. Increasingly, harvesting systems would have to handle and process plantation residues at the same time as processing the conventional product. It is even possible that harvesting systems might have to switch between harvesting conventional products and energy wood throughout the year (Gellerstedt and Dahlin, 1999).

Machine operators will increasingly be required to carry out basic repair and maintenance of their machines or a dedicated person within a contractor's or company operation will have to be appointed to deal with these tasks (Gellerstedt and Dahlin, 1999). With the depreciation life of machines moving from the 15,000-hour mark towards 20,000 hours, management of maintenance is becoming increasingly important. Sourcing a person who can repair a machine as well as operate it is becoming more difficult in many countries. The prime reason for this appears to be that working alone in an isolated plantation forest is not very attractive to young people, many of whom are already migrating to the cities. Increased operator training through simulators and training schools will assist with the skills base and shorten learning curves (Gellerstedt and Dahlin, 1999).

Even though new technology in some harvesting machines, such as computer and control systems, leads to cost increases, some of the costs have been reduced. This is due to increases in parts coordination across products and more efficient assembly lines in the factories (Gellerstedt and Dahlin, 1999).

When questioning operators about new technology that they see as potentially helping them become more productive and comfortable in their work, Courteau (1996) identified several factors, including diagnostic and monitoring systems, navigation aids, improved seat suspension and automatic levelling of the cab.

Globally, an overall trend embracing CTL systems is expected because of their silvicultural and environmental advantages (Gellerstedt and Dahlin, 1999).

# 2.3.6 Mechanised harvesting of Eucalyptus

Owing to the wide range of provenances, clones and species available, it is possible to plant *Eucalyptus* on most sites, including soft underfoot conditions and steep terrain. Different



mechanised harvesting systems therefore need to be available to handle most of these conditions (Spinelli, et al., 2009). *Eucalyptus* is a very dense wood which can reduce productivity by causing higher levels of mechanical breakdown in harvesting machines. These machines should be designed or modified for a *Eucalyptus* application.

Different solutions need to be found for debarking infield, at the landing and at the mill. The debarking technology has to handle the variety of small and large trees that are produced from the same compartment or felling programme (Wingate-Hill and MacArthur, 1991). Wingate-Hill and MacArthur (1991) predicted that a number of different technologies would emerge to harvest small-sized *Eucalyptus*. However, Spinelli, et al. (2009) found that knowledge of *Eucalyptus* harvesting is fragmented and spread over many different research projects.

Spinelli, et al. (2002a) found very few productivity models for *Eucalyptus*: most are based on other tree species. BWBS could also play a role, but it was assumed it would prove of less importance than average tree volume. Debarking trees, however, will lower the productivity level across the entire range of tree sizes.

Spinelli, et al. (2009) were able to develop a cost model for mechanised harvesting of *Eucalyptus* with both full-tree (using CFDDCs) and CTL systems (using harvesters). The model was able to predict costs within the systems utilising these two processing technologies for various machines under different working conditions. This model would assist forest engineers to make system decisions that are specific to the conditions they face. It should be noted that these cost models only include two different processing options, a CFDDC and a harvester.

#### 2.3.6.1 Tree size

Spinelli, et al. (2009) found full-tree harvesting systems that used CFDDCs in *Eucalyptus* to be much less sensitive to tree size when compared with CTL systems utilising harvesters. They attributed this to the multi-stem handling ability of these full-tree systems, which were able to overcome the problem of harvesting small trees individually. They found the cut-off tree size, where costs for the CTL became unacceptably high, to be less than or equal to 0.10 m<sup>3</sup> per tree. The full-tree system used in their research (using CFDDCs) would be the preferred system. However, this research did not include other full-tree systems, such as DHPs operating on the roadside, CFDDs producing logs or a combination of CFDD and chipper (CFDD&C) that could produce chips. Spinelli, et al. (2009) also found that the full-tree system (using CFDDCs) was also the preferred system for trees between 0.10 and 0.20



m<sup>3</sup> per tree. Figure 16 shows the research results of Spinelli, et al. (2009). Note that WT refers to Whole-Tree System. In the United States, the whole-tree system is the equivalent of the South African full-tree system.



Figure 16: System cost comparison between full-tree (with CFDDC) and CTL (with harvester) systems for different tree sizes (Spinelli, et al., 2009, pg 5)

Figure 16 shows the steep CTL curve for small trees. It also shows that the system costs of the full-tree system are lower than those of the CTL system across the entire range of tree sizes. For the conditions encountered in the Spinelli, et al. (2009) research (*E. Globulus*, tree size: 0.15 m<sup>3</sup>, two-metre logs for CTL, extraction distance: 400 m, transportation distance: 35 km, easy terrain), the full-tree system cost  $\in$ 20 per tonne of mill-delivered chips, whereas the CTL system resulted in a cost of between  $\in$ 25 and  $\in$ 30 per tonne for mill-delivered logs. These authors did caution that all of their data had been collected in Europe and North America. Application to southern hemisphere countries should be done with care. No indication is given in any of this research about how to rank different classes of BWBS.

Hartsough and Cooper (1999) compared a CTL harvester, forwarder and chipper system with a full-tree feller buncher, grapple skidder and CFDDC in *Eucalyptus*. They found that the CTL system was only cost competitive for larger trees with good form.

Spinelli, et al. (2009) suggested that the only way to make CTL systems cost-effective in small tree sizes would be to manage the plantations in a manner that allowed the trees to grow larger. This included using genetic improvement, fertilisation and having longer rotation lengths. Steeper areas with slopes in the region of 30 percent caused an increase in harvesting costs because productivity levels were lower. Added to this, different (more



expensive) machine configurations were required to enable the system to operate effectively on the steeper slopes.

# 2.3.6.2 Debarking

Debarking *Eucalyptus* pulpwood trees is a complex problem and many different aspects influence the debarking method and technology used (Wingate-Hill and MacArthur, 1991). These include debarking location, tree-length or log-length processing, method of transporting, bark disposal, physical properties of the bark, BWBS, tree characteristics and labour availability.

Debarking a *Eucalyptus* tree is only one of many interconnected operations that transfer a standing tree into a product suitable for use by the customer (Wingate-Hill and MacArthur, 1991). *Eucalyptus* trees also have certain characteristics which can complicate the harvesting process. If the plantation is being coppiced after the initial planting rotation, specific technologies, systems and skills may be required for successful harvesting. The different species of *Eucalyptus* have different types of bark and bark-removal properties (Wingate-Hill and MacArthur, 1991).

Wingate-Hill and MacArthur (1991), stated that the BWBS is one of the most important properties affecting debarking ability. Hartsough and Cooper (1999) indicated that the BWBS varies with season, although they did not conduct research to quantify the claim. They expected *Eucalyptus* that grows all year round to have less variation in BWBS than deciduous species have. Wingate-Hill and MacArthur (1991) found a two-to-one variation in BWBS between winter and summer in natural stands of *Eucalyptus*. They also indicated that the sapwood moisture content was a good predictor of this bond strength, although testing sapwood moisture content is a difficult task in the forest. Wingate-Hill, Cunningham and MacArthur (1989) found that the BWBS increased significantly as days after felling increased. However, little detail is provided.

The BWBS also behaves differently as the time after felling increases. Wingate-Hill, et al. (1989) found that with species such as *E. grandis* and *E. globulus*, the BWBS tended to increase until approximately four weeks after felling, regardless of the processing machine used. From approximately four weeks to four months after felling, these trees became almost impossible to debark. After four months, the BWBS tended to become weaker once again.

Many *Eucalyptus* species have long, strongly tensioned fibres that run the length of the stem. Because it is difficult to cut these fibres transversely during debarking, the bark often



comes off in long strips. These strands may wrap around the moving parts of machinery and cause blockages (Wingate-Hill and MacArthur, 1991). Kerruish (1984) categorised *Eucalyptus* species according to their debarking characteristics, as can be seen in Table 4. The table shows that different *Eucalyptus* species have different bark properties, which will affect the ability of certain machines to carry out debarking. The bark structure determines the type of debarking method to be used.

 
 Table 4: Eucalyptus species categorised according to debarking characteristics (adapted from Wingate-Hill and MacArthur, 1984, pg 112)

Category	Bark structure	Species	Readily barked by ring-type debarker	Debarked by ring with difficulty	Hand stripping – no established mechanical process for small trees
Туре 1	Smooth surface, short fibre strands in outer and thicker bark. Bark tends to come off in platelets	E. diversicolor E. maculata	X X		
In-between 1 & 2		E. viminalis E. globulus		x x	
Туре 2	Smooth surface, short fibre strands in outer bark, long in inner bark. Bark tends to come off in strips	E. regnans E. grandis E. nitens		? X	
Туре 3	Rough surface, short fibre strands in outer and inner bark. Bark tends to come off in platelets	E. calophylla E. fastigata E. delegatensis	X		X X
In-between 3 & 4		E. cloeziana			
Туре 4	Rough stringy surface, long fibre strands in outer and inner bark. Bark tends to come off in strips	E. oblique E. pilularis E. sierberi E. agglomerate E. laevopinea E. muellerana			X X X



Wingate-Hill and MacArthur (1991) concluded that the available literature did not reveal much regarding the debarking potential of *Eucalyptus* species in relation to the harvesting method, and more research would be required. Even though this literature is now dated, very little further research providing clarity on the above BWBS problem has been conducted.

Wingate-Hill and MacArthur (1991) added additional BWBS factors that compounded the general debarking problems in *Eucalyptus*:

- o seasonal variation;
- between-species variation;
- o within-species variation;
- o compartment variation,

Spinelli, et al. (2002a) attempted to determine the effect that bark adherence had on the productivity of a harvester. They separated the trees processed in spring from those processed in winter. It was discovered that although the trees harvested in spring debarked within the first two passes, there was no productivity difference. This was due to the operators carrying out additional actions to indent the stems, making them less slippery and easier to handle. This negated any productivity benefits.

#### 2.3.6.3 Harvester

A purpose-built *Eucalyptus* harvester head is usually heavier than harvester heads operating in similar tree sizes, but not debarking. This situation is complicated further, as the head is often too heavy to be placed on the smaller, wheeled harvesters (Spinelli, et al., 2000a). This can increase capital expenditure considerably (McEwan, 2010).

Spinelli, et al. (2002a) considered the duration of the time elements for a harvester operating in *Eucalyptus* and found that these were influenced by the terrain conditions, operational layout, tree volume, tree form, lengths of trees and the characteristics of the log assortments produced. The productivity and quality factors affecting harvesters in *Eucalyptus* are discussed below.

Tree size

The affect of tree size on a harvester has been covered in the sections above.


## BWBS and debarking

Compression forces applied to the outside of a *Eucalyptus* log or tree are able to break the wood-bark bonds. In order for this to be effective, especially where the BWBS is high, the forces must be applied to as much of the surface area of the log or tree as is possible (Wingate-Hill and MacArthur, 1991). It is much easier when the tree is straight.

*Eucalyptus* processing rollers are made of hardened steel and have ridges that are angled to cut through, bruise and detach the bark and to assist the tree rotation in the head (Wingate-Hill and MacArthur, 1991). The spiralled roller ridges exert a tangential shear force between the bark and the wood. Careful matching of the feed roller ridge profile is necessary for different species and BWBSs (Hartsough and Cooper, 1999). This ensures that maximum contact is made with the tree to loosen the bark. The axis of the feed rollers is slightly angled to impart a spiral motion to the tree as it passes through the head (Hartsough and Cooper, 1999). It also allows the head to process slightly crooked trees.

In species which are difficult to debark or crooked, it might be necessary to use more than two feed rollers to increase the contact area on the tree for debarking. Then the grip can allow the head to pass over crooked or forked sections and sever large branches (McEwan, 2010). The debranching knives are designed both to debranch and to cut under the loosened bark to remove it. If there are few or no branches, the tree is often processed with the debranching knives open. This allows the tree to pass more easily through the head, especially important when processing trees with poor stem form (McEwan, 2010).

With debarking, it is normally necessary to debark and debranch before cross-cutting takes place because often more than one pass up and down is needed to remove the bark successfully. The measuring wheels struggle to measure accurately while debarking is taking place and the angles on the feed rollers also cause the tree to rotate, which makes measuring even more difficult (McEwan, 2010).

Tree form

Forked and crooked trees can slow the feed speed of the tree through the head (Hartsough and Cooper, 1999). Such trees can also decrease the length of stem that can be debarked and debranched before a cross-cut has to be made. Hartsough and Cooper (1999) found the harvester was not capable of removing bark from areas close to severe crooks or forks because the feed rollers and debranching knives were not making contact at that point. Even with the harvester spending much time to remove all the bark from the tree, poor stem form can still result in debarking percentages on the tree which are unacceptable to chipping



mills. In the research by Hartsough and Cooper (1999), even after considerable effort to remove all the bark from crooked and forked trees, the chip-bark content was still at 1.5 per cent, which was above the mill's limit of 1 per cent.

### Multi-stemmed coppiced compartments

If a harvester is used to fell multi-stemmed coppiced compartments, its productivity can be reduced due to additional handling. In research on *E. globulus* pulpwood conducted by Spinelli, et al. (2002a), it was found that if multi-stemmed coppiced trees were pre-felled with a chainsaw, productivity of the harvester increased by 13 cmin per tree. The productivity increase, measured in m<sup>3</sup> per PMH was not provided.

### Debarking quality

Hartsough and Cooper (1999) conducted research in *Eucalyptus* which examined the productivity of a harvester permitted to leave different amounts of bark on the tree. There were three categories: removing all the bark, partial bark removal and single-pass debarking (whatever bark remained after a single pass was left on the log). It took between one and nine passes to remove all the bark from the tree. Partial debarking, which attempted to remove half of the bark from the tree, took between one and five passes.

The resultant logs were then extracted to a landing where they were chipped and screened in an attempt to remove more bark utilising the screened chips from partially debarked and single-pass logs. The screening of chips in this research did not reduce bark content significantly: indeed, it appeared that none of the remaining bark had been removed. If partial debarking is going to take place infield and the mills have low bark tolerance, additional processing machines will have to be placed somewhere in the supply chain.

Wingate-Hill and MacArthur (1991) also observed that debarking performance utilising a harvester evidenced high variation between compartments and between trees within a compartment. In the best case observed, the bark was all removed with one pass of the head, but five to seven passes were sometimes necessary, and even then only 70 per cent of the bark was removed successfully. In this research, it was found that bark was often left in strips where the feed rollers did not have contact with the tree. Even though the spiral rollers attempted to turn the tree in the head, they did not always succeed, resulting in lack of roller contact with the tree and ineffective debarking. Wingate-Hill and MacArthur (1991) also discovered that the butts of some trees did not debark well. Higher BWBS at the butt-end of the tree lengths, together with the harvester head struggling to debark very close to



the butt because of the distance between the felling saw and the feed rollers, resulted in the bottom 30 cm of the tree not being debarked. Attempting to debark this section often resulted in the tree falling out of the head, which reduced productivity.

### 2.3.6.4 Dangle-head processors (DHPs)

With *Eucalyptus,* DHPs remove the bark and branches using the same technology as a harvester does. Very little literature is available on the use of DHPs in *Eucalyptus.* 

Hogg, Pulkki and Ackerman, (2009) used discrete event simulation in an attempt to provide an estimate of the DHP system performance in *Eucalyptus* harvesting on the Zululand coast of South Africa. Research was conducted on the entire system and the resultant data were used to simulate changes to the system. This research used an average tree size for the productivity determination of the entire compartment and did not consider the effect of different tree sizes on system productivity and cost. In addition, the results, while being useful for the prediction of system changes, were only applicable to the site where the research took place.

# 2.3.6.5 Chain-flail debrancher debarker (CFDD), Chain-flail debrancher debarker chipper (CFDDC), and Chain-flail debrancher debarker and chipper (CFDD&C)

The use of CFDDs in *Eucalyptus* is relatively new. The little information that is available is neither scientific nor detailed. CFDDs are regarded as a processing method with the potential to overcome the problems associated with small tree sizes and poor BWBS (McEwan, 2008).

Tree size

The effect of tree size on a CFDD has been adequately explained in the sections above. No additional information is available at this point.

#### BWBS and debarking

Very little research has considered the effect of BWBS on productivity. Hartsough, et al. (2000) did indicate that as BWBS became stronger, productivity was expected to decrease. However, in certain species of *Eucalyptus*, if the bark is removed too easily, it can come off in long strips. These can wrap around moving parts and eventually jam them or clog the hydraulic bark discharge. To avoid this, the feller buncher may have to fell trees a few weeks



prior to processing (McEwan, 2008). Thompson and Sturos (1991) found that prolonged dry periods were noted for causing a drop in CFDD productivity because of lower BWBS. They did not, however, quantify this.

# 2.3.7 South African harvesting of *Eucalyptus*

Hogg, et al. (2009) found few benchmarks within South Africa regarding the productivity levels of mechanised harvesting systems in *Eucalyptus*. They also found that accepted, standardised operating practices for the existing mechanised systems were lacking, which meant that contractors and companies were determining best practice and productivity standards as their operations progressed. There is also no documentation referring to productivity levels in different tree sizes and stand conditions, which means that there is no productivity history with regard to the various operations. Hogg, et al. (2009) attributed this lack of background on productivity to the recent implementation of mechanised harvesting systems in *Eucalyptus* and the paucity of research on these systems.

# 2.3.8 Other debarking technologies

Although this section mixes debarkers with harvesting systems, other technologies can also be used to process *Eucalyptus* trees or logs. Only technologies with the ability to work within a compartment or on a roadside landing were considered for review.

## 2.3.8.1 Trough debarkers

Logs pass through a chamber with rotors that create a lateral, turbulent circular motion (Bren and Weidemann, 2006). Bark is removed by the logs coming into contact with each other and the rotors (Wingate-Hill and MacArthur, 1991). The logs rotate on their own axes as well as all the logs in the unit rotating together. Trough debarkers are good at debarking small, crooked logs. The logs are carried longitudinally along the debarker until they are discharged and the loose bark is collected in an outfeed chute for disposal or further processing. Trough debarkers are available in different lengths and some are even modular, with different units joined together to create a longer debarker. This would enable a continuous debarking process as opposed to having to batch process logs. More modules can be added to obtain the correct debarking quality (Wingate-Hill and MacArthur, 1991).

Bren and Weidemann (2006) tested the Savico trough debarker using various *Eucalyptus* species in Western Australia. This debarker was operated in batch fashion and showed much promise. Using 'fresh' wood – wood that was debarking easily – the debarker was able



to obtain production rates of over 100 tonnes per machine hour. However, as time increased after felling, the debarking efficiency and productivity dropped. With one-week-old timber, only 81 per cent of the bark was removed and with two-week-old timber, only 72 per cent of bark was removed.

The debarker is only in proof-of-concept phase and needs refinement before commercialisation. It is designed to operate as a fixed type of industrial debarker and moving it to and around the plantation requires further research and modifications. At present, this debarker also requires a high kW generator (200 kW) as a power source in the plantation. Material handling, both into the debarker and after the logs have been debarked, poses additional challenges.

### 2.3.8.2 Pull-though debrancher

The pull-through debrancher (also known as a static delimber) is able to debranch more than one tree at a time (Hartsough, et al., 2002) and debranching is the only function this machine performs. Hydraulically operated debranching knives close around the tree bundle and the trees are then pulled through the knives. It has to be fed by an additional machine (for example, an excavator), which increases the resource requirements of the system. It can be used to debranch trees before they enter a CFDD, CFDDC or even before processing by a DHP. If used to feed CFDDs and CFDDCs, more than one debrancher would be required to keep up with the productivity of the debarking machines. It is only capable of removing approximately 70 per cent of the branches, depending on the branchiness of the trees (Hartsough, et al., 2002). If this machine is able to improve the productivity of the debarking machine sufficiently, it could result in a lower system cost overall.



#### 2.3.8.3 Mobile chain-flail debrancher

The mobile chain-flail debrancher is mounted on a FEL and could possibly be used to remove the branches of species with excessively large, dense or strong branches, prior to further processing (Mooney, et al., 2000). It also has limited debarking capabilities. The machine operates on a similar principle to the CFDDs mentioned above, with chains mounted onto a hydraulically powered rotating drum. The FEL drives over the tree lengths with the flails removing the branches. Quality concerns demand that further debarking, and possibly debranching, takes place.

This machine would only be used as an attempt to increase the productivity of the primary processing machine, such as a DHP or CFDD. As with the pull-through debrancher, the entire processing cost would have to be examined to determine whether the use of an additional machine is justified. There are other semi-mechanised chain flails where short logs are hand-fed through a single set of chain flails. The unit is usually pulled and powered by an agricultural tractor. It is not suitable for higher production operations as it has intensive labour requirements and wide-ranging safety risks.

### 2.3.8.4 Double-grip harvesters

Double-grip harvesters have different attachments in order to fell and process trees. They are not suited to small *Eucalyptus* pulpwood applications where debarking is required. They are of greater value in stands where the average tree size is greater than 0.5 to 0.8 m<sup>3</sup> per tree (Glöde, 1999). There are very few double-grip harvesters operating today as the technology of single-grip harvesters is superior in terms of productivity and cost.

#### 2.3.8.5 Ring debarkers

These machines, which operate in the compartment, on the roadside or at the depot, have not been considered because of their semi-mechanised operation. They have knives and scrapers mounted on rotors that rotate around the tree or log, cut into the bark and then scrape the bark off in small pieces. They are generally an option for smaller volumes of timber on isolated landholdings (for example, small landowners who have limited volumes of trees to fell per year). They can also only be operated where sufficient labour is available.

Other debarking options – such as water-hydraulic debarkers, which utilise water under high pressure, Rosser-head debarkers and drum debarkers – have not been investigated



because of their non-use in the plantation. A mobile drum debarker was tested in Canada (Fortin, 1988), but was never commercialised.

## 2.4 Summary of main conclusions

A review of available literature has indicated that much research has been conducted on mechanised full-tree and CTL systems in the forests of northern hemisphere countries. The literature shows many advantages and disadvantages to utilisation of specific systems and describes factors affecting the operation and productivity of these systems. Most research indicates that the direct costs of CTL harvesting are greater than full-tree operations with roadside processing.

All the research pointed to tree size as the most important factor affecting system and machine productivity. It would appear that single-stem handling machines and systems are most sensitive to small tree sizes. Examples of such machines include harvesters and roadside DHPs. Costs increase rapidly for small trees. Multi-stem systems and machines were shown to be less sensitive to tree size. Examples of these machines include CFDDs and chippers. The literature shows that systems with single tree processing machines can be more expensive than multi-stem systems in tree sizes up to 0.30 m<sup>3</sup>.

When compared with traditional northern hemisphere harvesting, it seems that minimal research has been conducted on the effects of tree size in mechanised harvesting of *Eucalyptus*. The influence of tree size on productivity is still poorly understood. The little research that has been done focuses mainly on harvesters and CFDDCs. No published information was found on the productivity of DHPs operating on the roadside. Neither had much research been undertaken on CFDDs and CFDDs operating with stand-alone chippers and accommodating different tree sizes.

The literature indicated that the additional debarking element when harvesting *Eucalyptus* compounded the problem of tree size, especially with single-tree handling machines and systems. Inevitably, costs increase, but using multi-stem full-tree systems has been recognised as an option for reducing harvesting costs in small trees. Spinelli, et al. (2009) produced the most recent and comprehensive research on the effect of tree size on mechanised CTL and full-tree multi-stem harvesting. They indicated that the heaviest cost gains for utilisation of a full-tree multi-stem system in *Eucalyptus* rather than a CTL system are for trees less than 0.20 m<sup>3</sup> per tree.

Researchers have found the bundle-processing method has made it difficult to determine the effect of tree size on the productivity of multi-stem processing machines. No research has



been able to explain the effect of bundle size on the variation of cycle times. All current productivity determinations have been based on the average tree size occurring within a compartment or trial area and not on the actual tree sizes entering the machine. If a method were developed to determine individual tree sizes, more valuable data would be available to create a model that simulates a wider variety of tree sizes more accurately.



# 3 Research design and methodology

This chapter includes the aims of the research, key concepts and variables related to the research design, research sites, productivity data collection and analysis, cost data analysis and shortcomings and sources of error.

# 3.1 The aims of the research and the research hypotheses

To conduct successful research requires explicit aims and clearly defined hypothesis statements.

### 3.1.1 Aims of the research

This research encompassed the following aims:

- to investigate the productivity relationship between tree size and bundle size for various processing machines;
- to build a productivity prediction model that could relate the productivity of the processing machines to tree size and bundle size;
- to determine the costs per m<sup>3</sup> for different tree and bundle sizes per system in which the processing machines operated;
- to verify whether full-tree multi-stem systems have much lower costs than CTL and full-tree single-stem processing systems in very small tree sizes.

## 3.1.2 Hypotheses

The null and alternative hypotheses are outlined below.

#### 3.1.2.1 Null hypotheses

- Prediction models are not able to relate the productivity of chain-flail debrancher debarker, chain-flail debrancher debarker chipper, chain-flail debrancher debarker and chipper, dangle-head processor and harvester processing machines to tree size and bundle size.
- Full-tree multi-stem systems do not have lower costs than cut-to-length and full-tree single-stem processing systems in very small tree sizes.



### 3.1.2.2 Alternative hypotheses

- Prediction models are able to relate the productivity of chain-flail debrancher debarker, chain-flail debrancher debarker chipper, chain-flail debrancher debarker and chipper, dangle-head processor and harvester processing machines to tree size and bundle size.
- Full-tree multi-stem systems do have lower costs than cut-to-length and full-tree single-stem processing systems in very small tree sizes.

# 3.2 Key concepts and variables related to the harvesting systems researched

Five different mechanised harvesting systems were researched, with the focus on the processing equipment. Four of the systems were full-tree systems and one was CTL. Three of the full-tree systems had multi-stem processing machines and one had a single-stem processing machine (DHP).

The systems have been named according to the processing technologies as follows:

- CFDD (Chile): feller buncher grapple skidder CFDD three-wheeled loader slasher loader;
- 2. CFDDC (Western Australia): feller buncher grapple skidder CFDDC;
- 3. CFDD&C (Western Australia): feller buncher grapple skidder CFDD chipper;
- 4. DHP (Zululand, South Africa): feller buncher grapple skidder DHP slasher loader;
- 5. Harvester (Zululand, South Africa): harvester forwarder.

The above systems did not all generate the same products. The CFDD, DHP and harvester systems all produced debarked logs, while the CFDDC and CFDD&C produced bark-free chips. However, different prices would be paid for the two products at the mill gate, which still makes comparisons possible. Also, not all processing machines carried out the same processing activities. Examples are the harvester, which felled and processed the trees into logs, whereas the DHP only debarked, debranched and topped trees. Therefore, the productivity of each processing machine needed to be determined, and then placed into systems costings in order to make accurate comparisons.

From the literature examined in Section 2, it was predicted that tree size would play a large role in processing machine and system productivity. In the context of this research, tree size refers to the utilisable volume of the tree in cubic meters (m<sup>3</sup>). The volume is determined using the total tree height, diameter at breast height (DBH) over bark and the topping diameter of the tree. To make measurements, productivity and cost comparisons easier, tree



size was categorised into various size classes. This is expanded upon in the sections below. The productivity of the multi-stem processing machines was hypothesised to be dependent on bundle size (the number of tree lengths fed through the machine per work cycle), while bundle size could also be dependent on the average tree size in the bundle. Other variables that were predicted to play a role in machine productivity were BWBS and tree form (straightness of the tree and the number and size of branches). This has also been described in more detail in the sections below.

The species selected for the research consisted of *E. globulus*, *E. grandis* and *E. grandis x camaldulensis*. These are some of the most important species for global pulpwood production. Different species had to be researched because of the different geographic locations: *E. globulus* was researched as part of the CFDD, CFDDC and CFDD&C systems in Western Australia and Chile and the *E. grandis*-based species were researched as part of the DHP and harvester systems in South Africa. As mentioned in the literature review, these species had very similar debarking characteristics and could therefore be compared in research. Through the determination of BWBS before debarking, it was possible to ensure that different systems were compared objectively.

# 3.3 Background to the selection of research sites, data collection methods and other machine productivity influencing factors

All harvesting systems consisted of a number of machines that carried out various functions to enable logs or chips to be transported to a mill. Depending on the type of harvesting system, each machine could be more, or less, dependent on another and was affected by the performance of the machine that worked before or after it. To understand the operation of a harvesting system fully, the dynamics of each machine in the system needs to be understood. In full-tree systems, such as the CFDD, CFDDC, CFDD&C and DHP, the machines' form of dependency on the others is due to their higher productivity levels and the need to optimise storage and processing space. The harvester was less sensitive to the operation of the forwarder in a CTL system as it was the first machine in the system and was able to build up higher stock levels infield for the forwarder.

Time-and-motion research has been, and still is, used to describe, understand and improve forestry operations accurately (Spinelli and Visser, 2008). This research investigated the time taken for specific processing activities and the quantity produced during the same period for these activities (Steinlin, 1955).



In this research, only the processing machine within each harvesting system was investigated, even though the processing machines could theoretically be influenced by other machines within the system. This was possible as only the productivity per productive machine hour (PMH) of the processing machines was researched, and not the machine utilisation levels. All processing technologies always operated at full efficiency and did not slow production because of a machine of lower productivity working before or after them: they either functioned at full production or they did not operate. It was therefore possible to isolate the productivity of the processing machines. Further to this, as highlighted in the literature review, the lack of knowledge only existed for the processing technologies. The productivity and operation of other machines in the systems had been researched and information recorded. Therefore, the focus fell on the processing machines only.

The **input variables** for each type of processing machine researched consisted of **tree size** (in m<sup>3</sup>), **number of trees processed per bundle** (for the CFDD, CFDDC and CFDD&C), **BWBS and tree form**. These variables were chosen for their potential effects on processing machine productivity, as identified in the literature review. These variables are further described in Section 3.4.3.1.

The **output variables** consisted of **debarking quality**, **machine productivity per PMH and system costs per m<sup>3</sup> produced**. Debarking quality needed to be considered, as the machines could potentially operate at very high productivity levels, but the product might not meet the customer's bark-quality requirements. Processing machine productivity per PMH showed the production rate of the machine per unit of time. However, it was not possible to make direct comparisons between productivity per PMH or the processing machine costs per m<sup>3</sup>, as each of the machines carried out a different number of processing functions. It was therefore necessary to examine the entire costing of each system under review in order to select which was most cost-effective.

Machine costs within each system were determined by identifying all machines used in the system and then collecting all input costs and assumptions. The productivity figures determined from the research for each processing technology were then used in the system's costings to obtain a cost per m<sup>3</sup>. The description of debarking quality and machine productivity was included in Chapter 2 and system costs appear at the end of this chapter.

#### 3.4 Research sites

Owing to the very high operating costs of the machinery, it was not possible to get all the systems or processing machines working on one site and the researcher had to find sites



where the machines were operating. Research was ultimately conducted on ten different processing machines that harvested 11,632 trees on ten different sites in three countries on three different continents. An overview is first provided of the general areas where the research was conducted, followed by the detailed compartment information in the subsections below. The description of the productivity variables studies and the actual data collection is included in Section 3.5.

The only place in the world where the CFDD was operating in *Eucalyptus* to produce debarked tree lengths for logs was in Chile. There were other CFDDs in use in *Eucalyptus*, but these systems were set up to feed the debarked and debranched trees into mobile disc chippers. One week was spent in Chile investigating the CFDD system and related productivity.

Both the CFDDC and CFDD&C were researched across various sites in Western Australia. Western Australia was chosen for the research owing its large concentration of CFDDC and CFDD&C systems operating in *Eucalyptus*, on sites similar to those found in South Africa and Chile. One week was spent on the four CFDDC sites and one week on the three CFDD&C sites. Each technology was researched at various sites: even though it would have been possible to spend the entire week at one site, different sites added variation to the data, especially regarding tree size.

The DHP and harvester were researched in the Zululand area of South Africa. The DHP and harvester processing heads were mounted on 20-tonne construction excavators as carriers. This was the predominant carrier used in *Eucalyptus* pulpwood harvesting in South Africa, Australia and Chile, as well as in most other parts of South America. Within the full-tree systems, the working routines of like machines were similar. This included the feller bunchers, grapple skidders, CFDDs and CFDDCs. This is discussed further below.

The terrain conditions at each site were determined using the South African National Terrain Classification System (Erasmus, 1994), which considers the trafficability of a compartment for ground-based machines. Table 5 indicates how the terrain is evaluated. The exact conditions encountered in each compartment are included in the subsections below.



Ground conditions	Ground roughness	Slope
1. Very good	1. Smooth	1. Level (0-10%)
2. Good	2. Slightly uneven	2. Gentle (11-20%)
3. Moderate	3. Uneven	3. Moderate (21-30%)
4. Poor	4. Rough	4. Steep 1 (31-35%)
5. Very poor	5. Very rough	5. Steep 2 (36-40%)
		6. Steep 3 (41-50%)
		7. Very steep (>50%)

#### Table 5: Terrain classification classes (Erasmus, 1994, p3)

Slope was measured with a clinometer at various points across the research sites and averaged. Ground conditions were not monitored in the research as this had little influence on the processing machines researched. Ground conditions considered topsoil clay percentage and the diagnostic topsoil type (Erasmus, 1994). Vehicle trafficability was determined for ground conditions in dry, moist and wet states. Ground roughness was based on the presence of obstacles (stones and boulders) and depressions, their frequency and size (Erasmus, 1994). The terrain conditions for each of the research sites are included in the subsections below.

Bark had to be removed completely at all research sites. All mills that took possession of the debarked logs or chipped had bark tolerances of less than one per cent of the clean fibre delivered (N. Hechem, personal communication [conversation], 3 April 2008; D. Sawers, personal communication [conversation], 7 July 2008; A. van Rooyen, personal communication [conversation], 2 October 2008).

# 3.4.1 Chain-flail debrancher debarker (CFDD) (Chile) research site, operation and system information

The research site was located close to the town of Concepcion in Chile. The compartment was level, with few obstacles. The relevant compartment information is indicated in Table 6.



Dates (all 2008)	21 to 26 April 2008
Harvesting contractor/company	Mecharv
Grower company	CMPC – Forestal Mininco
Farm	Totoras
Compartment number	3
Species	E. globulus
Plant year	199805
Fell age (yrs)	9 yrs, 11 m
Average tree volume	0.190 m <sup>3</sup>
Ground conditions	Not determined
Ground roughness	1 - Smooth
Slope	1 - Level

### Table 6: CFDD compartment information in Chile

There was visual variability in tree size, which appeared to be related to soil quality, across the compartment. Parts of the compartment evidenced very good growth, while other parts had smaller trees. This particular area of Chile was under drought conditions, which resulted in the smaller (stressed) trees dying back. The ground roughness for all research sites was classified as smooth, as no obstacles were found. Tree form was relatively good for *E. globulus*. These variations were captured and analysed.

A topless, full-tree harvesting system was used. After felling, the trees were topped with chainsaws. Only the trees that were accessible to the chainsaw operators were topped. Table 7 shows the detailed activities that were measured during the operation of the CFDD.

#### Table 7: CFDD operation

Pre-processing	The CFDD operated within the compartment on a roadside landing. A feller buncher felled trees and grapple skidders extracted them to the CFDD. The grapple skidder presented the bundles to the CFDD in two lines, one slightly to the left of the infeed and one slightly to the right.
Feeding	The infeed rollers gripped the trees and pulled them into the machine. The CFDD operator picked up the large trees as far down the stem as he could, lifted the bunch and pushed it into the machine. The CFDD operator fed the machine from one bunch of timber while the skidder placed the next bunch beside it. In this way, the skidder did not disturb the feeding element. Trees were fed into one side of the feed chute and spread out for maximum contact with the flails. As the trees moved through, the next batch of trees was placed on the other side of the infeed and spread. The trees were often placed over the tops of previous trees. This allowed the flails to beat the tops against a solid surface to facilitate debarking.
Debarking/ debranching	The CFDD had an integral knuckle-boom loader for feeding trees and removing residue from the infeed area and the hydraulic bark pusher. The CFDD fed trees through a chamber that consisted of feed rollers and three sets of chain flails mounted on rotating drums. The flails



	on the rotating drum beat the bark and branches from the tree. This debris fell to the bottom of the chamber where it was expelled by a hydraulic pusher. The first two flails rotated in the direction of tree movement and were mostly run at maximum speed. The last flail was rotated in the opposite direction. It functioned as a sweep to prevent loose material from being swept out of the outfeed. Various rollers inside the chamber assisted with keeping the trees moving
Outfeed	A pair of outfeed rollers pulled the trees out of the chamber to the waiting three-wheeled loader. A working rack of debarked stems was placed at the outfeed of the debarker as a bearer. The trees were able to slide along this surface, which helped prevent soil contamination. These bearer stems were moved from landing to landing as the system progressed through the compartment. As the debarked trees exited the CFDD, the three-wheeled loader gripped the butt ends and pulled the trees. As the three-wheeled loader moved forward, the trees rested on a plate above its drive wheels. The trees were placed in a 'V' formation on a bearer log in front of the CFDD's outfeed. This enabled the slasher to process one pile while the other was being rebuilt. The three-wheeled loaders scattered slash across their work area to prevent soil contamination and to protect the soil surface. The debarked trees were then slashed to length and stacked along the roadside.
Other	Chain life depended upon the BWBS of the trees, which flail drum they were on and their position on the drum. Standard practice was to use the chains for 18 hours, then rotate them and use them for a further 9 hours. The operator could tell the condition of the flails from the appearance of the debarked stem. The CFDD sourced its power from one engine, with each flail drum having its own hydraulic motor (hydrostatic drive).

Figures 17 and 18 show trees being fed into and out of the CFDD. The Bell loader carried the logs to the slasher.



Figure 17: Trees being fed into the CFDD, and Figure 18: The Bell loader removing trees



The other elements of the system were as follows:

#### • Felling – feller buncher

Trees were felled, accumulated and placed in optimal bunches for the grapple skidder by means of a wheeled feller buncher,.

### • Topping – chainsaw

Two chainsaw operators topped the larger trees in the compartment while the trees lay bunched. Very big branches were also removed. The tops of trees that were hidden by other trees were not topped.

### Extraction – grapple skidder

Bunches were collected, extracted and deposited at the infeed of the CFDD by means of a grapple skidder. The skidder also removed slash from the hydraulic bark pusher and stockpiled it for a separate processing operation for energy production. When the research commenced, two skidders were being used. One skidder was removed during the research to test how well the system would function with only one skidder.

### Debarking and debranching – CFDD

A detailed description of the operation can be found in Table 7 above.

### Tree handling – three-wheeled loaders

Two three-wheeled loaders were used to pull the debarked trees from the outfeed of the CFDD to the slashing area. However, there was often only one loader working, as the other would be used to help with other functions of the operation.

#### Slashing and stacking

A tracked excavator loader, operating with a slasher, crosscut the debarked and debranched trees into logs of seven metres and stacked them. A separate loader (the same type of machine as the slashing excavator) loaded the rigid trucks with drawbar trailers, which were piggy-backed onto the rigid truck. The loader would remove the trailer from the truck for loading.

#### Log transport

A six-axle rigid truck with a two-axle drawbar trailer was used to transport the sevenmetre logs to the pulp mill. When travelling empty, the stanchions of the trailer and truck were lowered and the trailer was placed on the drawbar truck. The loading and transporting of seven-metre lengths enabled higher productivity. Compared with costs incurred when shorter log lengths were used in other similar operations, the operating costs of both the slashing and loading machines were lower because of the increased productivity with the seven-metre lengths



The equipment used in the CFDD system is shown in the matrix in Figure 19 on the following page. The matrix provides a visual indication of how the processing equipment interacts with the rest of the equipment in the system.

Locality Activity	Stand	Extraction route	Roadside landing	Forest road
Wheeled feller buncher				
Grapple skidder				
CFDD				
Three-wheeled loader				
Slasher loader				

Figure 19: CFDD system matrix

The details of the machines used in the CFDD system are indicated in Table 8 on the following page. This provides a more detailed indication of the machines used during the research.



Activity	Machine type and detail	Machine make and model
Felling	<ul><li>Feller buncher:</li><li>wheeled drive-to-tree</li><li>continuous disc saw</li><li>accumulator</li></ul>	One Tigercat 724E
Extraction	Grapple skidder: single arch bunching grapple	One or two Tigercat 620Cs
Debarking and debranching	CFDD: three flail drums	One Morbark 2455
Tree handling	Three-wheeled loader: telescopic boom	Two Bell 220 (Super) Teleloggers
Slashing and stacking	Slasher loader: • tracked • swing-to-tree • bar-and-chain slasher	One Tigercat 240B

#### Table 8: Machine information for CFDD system

# 3.4.2 Chain-flail debarker debrancher chipper (CFDDC) (Western Australia) research site, operation and system information

The operations in Western Australia were chosen because of the similarity of the site conditions, tree sizes and tree characteristics to those in South Africa and Chile. Numerous CFDDC systems were also working within close proximity to each other, which catered for a wider variety of tree sizes and characteristics, as well as making research logistics easier. All chips produced were transported from the compartments by means of chip trucks, with the chips eventually being exported by ship, mostly to Japan (Sawers, personal communication [conversation], 7 July 2008). Four different research sites were selected, as per Table 9.



Dates (all 2008)	26 & 27June	30 June & 01 July	30 June & 02 July	26 June & 03 July
Harvesting contractor/company	Softwood Logging	WAPRES 1	WAPRES 2	Dohnt LV & Co
Grower company	GSP	ITC	ITC	ITC
Farm	Oriole	Willow Springs	Willow Springs	Coopers
Compartment number	10	13	12	CH12
Species	E. glob	E. glob	E. glob	E. glob
Plant year	1997	1997	1997	1997
Fell age (yrs)	11	11	11	11
Average tree volume	0.105 m <sup>3</sup>	0.335 m <sup>3</sup>	0.272 m <sup>3</sup>	0.344 m <sup>3</sup>
Ground conditions	Not determined	Not determined	Not determined	Not determined
Ground roughness	1 - Smooth	1 - Smooth	1 - Smooth	1 - Smooth
Slope	1 - Level	1 - Level	1 - Level	1 - Level

#### Table 9: CFDDC research sites in Western Australia

The systems were operated by the organisations indicated below.

#### Softwood Logging

One research site with one operation close to the town of Albany and a separate contractor (Southern Haulage) transporting the chips.

### WAPRES

Two research sites close to the town of Bunbury, but the same operation being conducted on both sites. A separate contractor (Brooks) transported the chips. WAPRES are also plantation owners, but have their own harvesting operations that harvest procured timber.

#### Dohnt LV & Co.

One research site and one operation close to the town of Albany, with a separate contractor (Southern Haulage) transporting the chips.

The various compartments were all level, some with gentle slopes in certain areas. The compartments were obstacle-free, and therefore had a ground-roughness class of smooth. The soils were mostly sandy, which necessitated good road access. All compartments were planted with *E. globulus*. The average tree size across the research sites varied substantially. This was due to site-quality factors, as opposed to tree age. The compartments were all harvested in winter, which is the rainy season in Western Australia.

Full-tree harvesting systems were used throughout. Table 10 shows the detailed activities that were measured during the operation of the CFDDC. A large part of the basic operation of the CFDD operation is the same as documented in the section on the Chile CFDD.



# Table 10: CFDDC operation

Pre-processing	Trees were felled with a feller buncher and brought to the CFDDC by means of grapple skidders. The grapple skidder presented the bundles to the CFDDCs in two lines, one slightly to the left of the infeed and one slightly to the right. This operation used an integrated machine that had both flailing and chipping functions. The remainder of the grapple-skidder operation was the same as that at the CFDD.
Feeding	An integral knuckle-boom loader was used for feeding trees in and removing residue from the infeed area and the hydraulic bark pusher. Feeding the trees through the CFDDC was also the same as described for the CFDD, with the exception that the trees were also chipped.
Debarking/ debranching/ chipping	Trees were fed through a chamber that consisted of feed rollers and sets of chain flails mounted on rotating drums. The number of flails, the flailing action and operation were the same as the CFDD. This debris also fell to the bottom of the chamber, from where it was expelled by a hydraulic pusher. With the Peterson 5000, a pair of dual-feed rollers inside the CFDDC pulled the trees from the flail chamber and pushed them against the chipper disc.
Chip chute/ truck loading	The chips and waste material were then discharged (blown) through the two chutes. Chips were fed directly into chip trucks and the waste chips deposited on the ground next to the chipper from where the grapple skidder removed them. The acceptable chips were blown into the chip truck and the waste material deposited on the ground. It was not possible to view the tree after it had been debarked; therefore, the operator had to judge debarking quality by observing the material exiting the waste and chip chutes. Experienced operators were able to maintain a consistently good chip quality by doing this. The chip loading and transport operations were integral to the operation of the CFDDCs. All chip trucks consisted of truck tractors, with semi-trailers pulling drawbar trailers. These Australian road-train trucks were approximately 27 m long, with a gross combination mass of 75 tonnes and a TARE weight of 25 tonnes, resulting in a payload of approximately 50 tonnes. The figures differed according to configuration and design of the road train. The trucks parked along the road and were filled up from the front. If possible, the truck faced downhill so that moving forward was more energy-efficient and created less component wear. The truck moved slowly forward as a section of each bin was filled. The chip chute was also able to direct the chips into whichever part of the bin was desired. This was controlled from the cab of the CFDDC and chipping did not need to stop when one bin (trailer) was full.
Other	The Peterson Pacific CFDDC sourced its power from one engine and each flail drum had its own hydraulic motor (hydrostatic drive).

A general overview of the other components of the systems follows.

## • Felling – feller bunchers

With the exception of WAPRES, the operations used tracked, swing-to-tree, nonlevelling feller bunchers with shear felling attachments. WAPRES used a wheeled,



drive-to-tree feller buncher, with a shear felling attachment. Only one feller buncher was used per operation. Trees were felled, accumulated and placed into optimal bunches for the grapple skidders.

## Debranching – chainsaws

This was only observed at the WAPRES operation, where it was carried out when there were excessively large branches. At this operation, chainsaws were sourced and the team members themselves carried out the debranching.

# Extraction – grapple skidders

With the exception of at WAPRES, two grapple skidders with bunching grapples were used (see 'Slash removal – front-end loader' below). Bunches were collected, extracted and deposited at the infeed of the CFDDC. The skidder (or front-end loader) would also remove slash from the hydraulic bark pusher and the chipper waste chute, and either stockpile it for burning or return it to the compartment.

# Debarking, debranching and chipping – CFDDC

A detailed description of the operation can be found in Table 10 above.

# Slash removal – front-end loader

WAPRES made use of a front-end loader (FEL), as shown in Figure 20, with a log/slash grab attachment. This was used to remove slash from the infeed area and the hydraulic bark pusher and stockpile it nearby. It also assisted the grapple skidder to bring trees to the CFDDC if extraction distances were very far or when the grapple skidder had a breakdown. The front-end loader would usually work closer to the landing than the grapple skidder.



Figure 20: Front-end loader for slash removal and tree extraction



## • Chip transport – chip trucks

The chips were then transported on chip trucks, as per Figures 21a and 21b. These figures show examples of the chip trucks. The most common truck configuration was a three-axle truck tractor, with a three-axle semi trailer pulling a five-axle drawbar trailer.



Figure 21 a and b: Chip transport trucks

The equipment used in the CFDDC system is shown in the matrix in Figure 22. The matrix provides a visual indication of how the processing equipment interacts with the rest of the equipment in the system.

Locality				
Activity	Stand	Extraction route	Roadside Ianding	Forest road
Wheeled or tracked feller buncher				
Grapple skidder (and front-end loader - WAPRES)				
CFDDC				



## Figure 22: CFDDC system matrix

The details of the machines used in the CFDDC system are indicated in Table 11 below.

Activity	Machine type and detail	Machine make and model
Felling	<ul> <li>Feller buncher (WAPRES): <ul> <li>wheeled drive-to-tree</li> <li>shear felling attachment</li> <li>accumulator</li> </ul> </li> <li>Feller buncher (Dohnts, Softwood Logging): <ul> <li>tracked non-levelling</li> <li>shear felling attachment</li> <li>accumulator</li> </ul> </li> </ul>	Softwood Logging: one Caterpillar 521 WAPRES: one Tigercat 726 Dohnts: one Tigercat 822C
Extraction	Grapple skidder: • dual arch • bunching grapple	Softwood Logging: two Caterpillar 545Js WAPRES: one Tigercat 630C Dohnts: two Tigercat 630Cs
Slash removal (and tree extraction)	Front-end loader: log/slash grab	WAPRES: one Volvo L90E
Debarking, debranching and chipping	CFDDC: • three flail drums • disc chipper	Softwood Logging: one Peterson 5000H WAPRES: one Peterson 5000G Dohnts: one Peterson 5000G

#### Table 11: Machine information for CFDDC system

# 3.4.3 Chain-flail debrancher debarker & chipper (CFDD&C) (Western Australia) research site, operation and system information

The research site and conditions were the same as the CFDDCs. The chips that were produced were also transported from the compartments by means of chip trucks.

As seen in Table 12, the research consisted of three harvesting operations on separate geographical sites (Millinup, Dondydowns and Snowball) close to the town of Albany. They were all being operated by Edenborn Pty Ltd. Edenborn also ran the chip transport operation under the name of Auschip.



Dates (all 2008)	23 & 24 June	23 & 25 June	04 July
Harvesting contractor/company	Edenborn 1	Edenborn 2	Edenborn 3
Grower company	ITC	GSP	GSP
Farm	Millinup	Dondydowns	Snowball
Compartment number	13	1	
Species	E. glob.	E. glob	E. glob
Plant year	1997	1997	1997
Fell age (yrs)	11	11	11
Average tree volume	0.236 m <sup>3</sup>	0.179 m <sup>3</sup>	0.254 m <sup>3</sup>
Ground conditions	Not determined	Not determined	Not determined
Ground roughness	1 - Smooth	1 - Smooth	1 - Smooth
Slope	1 - Level	1 - Level	1 - Level

#### Table 12: CFDD&C research sites in Western Australia

The various compartments were level and obstacle-free. The soils were sandy which necessitated good road access. The compartments were planted with *Eucalyptus globulus*. The tree-size variation was large. The compartments were all harvested in winter, which as indicated, is the rainy season in Western Australia.

Table 13 shows the detailed activities that were measured during the operation of the CFDD&C.

Pre-processing	The CFDD operated within the compartment on a roadside landing. The trees were felled and extracted in the same way as the CFDD and CFDDC.
Feeding	Feeding the trees through the CFDD was the same as for the CFDD and CFDDC systems. It had an integral knuckle-boom loader for feeding trees and removing residue from the infeed area and the hydraulic bark pusher.
Debarking/ debranching	A CFDD was used to remove bark and branches. The operation of the CFDD part of the operation was similar to that documented in the Chile CFDD section, with similar flail speeds. However, the Precision Husky CFDD had four flail drums. The first three flails rotated in the direction of the tree movement and the fourth rotated in the opposite direction, functioning as a sweep.
Chipping	The processed tree lengths were then fed directly into the chipper. The disc chipper was able to chip multiple tree lengths simultaneously. It had a crane for feeding trees and removing residue ejected from the outfeed of the CFDD. A pair of outfeed rollers pushed the trees out of the CFDD towards the chipper. The two machines were aligned approximately three metres apart and the debarked and debranched trees moved straight through into the disc chipper via a set of infeed rollers. These ensured that the trees were pulled into the chipper at constant feed speed. The tree was then chipped.
Chip chute/ truck loading	The chips were fed via the chip chute into the chip truck which was parked on the road. Waste material was fed through the waste chute onto the ground from where it was removed by a grapple skidder. The chip-loading method was the same as with the CFDDC, as were

#### Table 13: CFDD&C operation



the chip-truck configurations used.

As per the CFDDC, full-tree harvesting systems were used throughout. A general overview of the components of the systems follows.

# • Felling – feller bunchers

All of the operations used tracked, swing-to-tree, non-levelling feller bunchers with shear felling attachments. Only one feller buncher was used per operation. Trees were felled, accumulated and placed in optimal bunches for the grapple skidders.

# Extraction – grapple skidders

Two grapple skidders with bunching grapples were used at all operations. Bunches were collected, extracted and deposited at the infeed of the CFDD. The skidder also removed slash from the hydraulic bark pusher and from the chipper waste chute. The slash was either stockpiled for burning or returned to the compartment, depending on grower company requirements.

# Debarking and debranching – CFDD

A detailed description of the operation can be found in Table 13 above.

# Chipping – disc chipper

A detailed description of the operation can be found in Table 13 above. Figure 23 shows the CFDD feeding into the chipper and the chips being fed via the chip chute into the chip truck. Note the grapple skidder removing residue from the waste chute.



Figure 23: CFDD, chipper and chip truck



# • Chip transport – chip trucks

The chips were then transported from the site on chip trucks, as per Figures 21a and b in the CFDDC section.

The equipment used in the CFDD&C system is shown in the matrix in Figure 24. The matrix provides a visual indication of how the processing equipment interacts with the rest of the equipment in the system.

Locality Activity	Stand	Extraction route	Roadside landing	Forest road
Tracked feller buncher	ł			
Grapple skidder				
CFDD				
Chipper				

Figure 24: CFDD&C system matrix

The details of the machines used in the CFDD&C system are indicated in Table 14 on the following page.



Activity	Machine type and detail	Machine make and model
Felling	Feller buncher: • tracked non-levelling • shear felling attachment • accumulator	Edenborn all sites: one Tigercat 845C per site
Extraction	Grapple skidder: • dual arch • bunching grapple	Edenborn all sites: two Tigercat 630Cs per site
Debarking/ debranching	CFDD: four flail drums	Edenborn all sites: one Precision Husky FD-2300-4 per site
Chipping	Chipper: disc chipper	Edenborn all sites: one Precision Husky WTC-2366 per site

### Table 14: Machine information for CFDD&C system

# 3.4.4 Dangle-head processor (DHP) (Zululand, South Africa) research site, operation and system information

The operations in Zululand were chosen because of the similarity of the site conditions, tree sizes and tree characteristics to Western Australia and Chile. The system in Zululand had been operating since 2005 and was the only one of its kind in South Africa. There were other DHP systems operating in *Eucalyptus* around the world, but the logistics of getting to this site was quicker and more cost-effective.

The compartments in which the system worked varied regarding tree size. This made it possible to use fewer compartments and still have sufficient variation. The species harvested was *Eucalyptus grandis*. Logs of 5.2 m were produced and transported by log truck to the Mondi pulp mill at Richards Bay.

The contractor owning and operating the systems was Iningi Investments and the plantations belonged to Mondi Business Paper. The plantation formed part of the Umfolozi area and the specific farm (Mill Site) was located next to the Mondi pulp mill in Richards Bay. Table 15 provides more information on the research site.



Dates (2008)	01 to 06 Sep
Harvesting contractor	Iningi Investments
Grower company	Mondi
Farm	Mill Site
Compartment number	G004B
Species	E. grandis
Plant year	2002
Fell age (yrs)	6.1
Average tree volume	0.156 m <sup>3</sup>
Ground conditions	Not determined
Ground roughness	1 - Smooth
Slope	1 - Level

#### Table 15: DHP research site in Zululand, South Africa

The various compartments were all level and obstacle-free. The soils were mostly sandy, which necessitated good road access. The average tree size was 0.156 m<sup>3</sup> per tree, but this was variable as pure *E. grandis* is not ideally suited to Zululand conditions. The compartment was harvested at the beginning of spring (September) and a full-tree harvesting system was used.

Table 16 shows the detailed activities that were measured during the operation of the DHP.

Pre-processing	The harvester heads were mounted on tracked 20-tonne construction excavators. Trees were processed one at a time and three DHPs were used in the system. Felling took place by means of a feller buncher and full-tree extraction utilised a grapple skidder. The skidder placed bunches of full trees in a row parallel to the road, but approximately one-and-a-half tree lengths from the road. The three processors worked a variable distance from each other, but always observed a safe distance of at least 50 m.
Grab and position	Each processor was positioned just ahead and to the side of each bundle. This enabled easy grabbing of the trees, unhindered slewing during processing and space for the bark, branches and tree tops to be deposited. The DHP grabbed the tree by the butt end from the top of the stack.
Debarking/ debranching	The tree would be passed up and down through the head until debarked by the feed rollers' placing pressure on the bark to loosen it. The spiralled and offset angles of and the ridges on the feed rollers spun the tree through the head, ensuring that these rollers made contact with a different part of the tree with each pass. This increased the chance of the bark being removed. If some remained after this action, the debranching knives slid underneath the bark and removed it. The tighter the wood-bark bond, the more passes were required to remove the bark. Naturally, this had an effect on productivity. If the bark came off very easily, only one pass from the butt to the top of the tree was necessary.
Topping and placing	As it passed through the processing head for the last time, the DHP pushed the debarked tree towards the road by means of its top and then topped it.

#### Table 16: DHP operation



	The debarked tree lengths were then slashed into 5.2 m lengths and loaded directly onto
	the log-transport trucks. The skidder also removed slash where the DHPs were operating
Other	and returned it to the compartment in the form of small piles, spread throughout the
	compartment. The skidder also occasionally indexed the butts of the debarked and
	debranched trees to make slashing of tree lengths into logs more accurate.

A general overview of the other components of the systems follows.

## • Felling – feller bunchers

The DHP system used a wheeled, drive-to-tree feller buncher with an accumulating, continuous disc saw. Only one feller buncher was used per operation. Trees were felled, accumulated and placed in optimal bunches for the grapple skidders.

### Extraction – grapple skidders

One grapple skidder with a bunching grapple was used for full-tree extraction. Bunches were collected, extracted and deposited in front of where the DHPs were operating.

### Debarking, debranching and topping – DHP

A detailed description of the operation can be found in Table 16 above. An example of one of the DHPs is shown in Figure 25.



Figure 25: The DHP in operation

#### Slashing and loading

A tracked, construction excavator-loader, operating with a slasher (as per Figure 26), crosscut the debarked and debranched trees into 5.2 metre logs and either loaded them directly onto the log trucks or stacked them if no trucks were available.



# Log transport

As per Figure 27, a three-axle rigid truck with a four-axle drawbar trailer was used to transport the 5.2 metre logs to the pulp mill.



Figure 26: Debarked tree slashing, and Figure 27: Log transport truck

The equipment used in the DHP system is shown in the matrix in Figure 28. The matrix provides a visual indication of how the processing equipment interacts with the rest of the equipment in the system.

Locality Activity	Stand	Extraction route	Roadside landing	Forest road
Wheeled feller buncher				
Grapple skidder				
DHP				
Slasher loader				



### Figure 28: DHP system matrix

The details of the machines used in the DHP system are indicated in Table 17 below.

Activity	Machine type and detail	Machine make and model
Felling	<ul><li>Feller buncher:</li><li>wheeled drive-to-tree</li><li>continuoaus disc saw</li><li>Accumulator</li></ul>	One Tigercat 720D
Extraction	Grapple skidder: • dual arch • bunching grapple	One Tigercat 630C
Debarking, debranching and topping	Construction excavator carrier: <ul> <li>tracked</li> </ul> <li>Dangle-head processor: <ul> <li>two feed rollers</li> <li>four debranching knives (two moveable and two fixed)</li> </ul> </li>	Two Volvo EC210Cs One Hitachi Zaxis 200 All with SP 591LX harvester heads
Slashing and log-truck loading (occasional log stacking)	Slasher loader: • tracked • swing-to-tree • bar-and-chain slasher	One Volvo EC210C with slasher

### Table 17: Machine information for DHP system

## 3.4.5 Harvester (Zululand, South Africa) research site and system information

The research site selected for the harvester system was adjacent to the site where the DHP system was operating, but in a different compartment. The compartments were too small to allow both the DHP and harvester to operate together. The research sites in South Africa were virtually identical to the DHP site and those in Western Australia and Chile. The compartment in which the system operated evidenced highly variable tree size. This was compounded by its being a coppice compartment, although the stem form was good. As with



the DHP compartments, this natural variation made it possible to carry out the research in one compartment only. The species harvested was a *Eucalyptus grandis x camaldulensis* clone, producing logs of 5.2 m, which were transported by log truck to the Mondi pulp mill in Richards Bay. The contractor owning and operating the systems was Iningi Investments and the plantations belonged to Mondi Business Paper. As per the DHP system, the plantation formed part of the Umfolozi area and the specific farm (Mill Site) was located next to the pulp mill in Richards Bay. Table 18 provides more information on the research site.

Dates (2008)	01 to 06 Sep
Harvesting contractor	Iningi Investments
Grower company	Mondi
Farm	Mill Site
Compartment number	G001B
Species	E. grandis x camaldulensis
Plant year	2001
Fell age (yrs)	6.8
Average tree volume	0.139 m <sup>3</sup>
Ground conditions	Not determined
Ground roughness	1 – Smooth
Slope	1 – Level

 Table 18: Harvester research site in Zululand, South Africa

The terrain and sandy conditions were the same as described for the DHP system. The average tree size was  $0.139 \text{ m}^3$  per tree, but this was variable because of the *E. grandis x camaldulensis* coppice, as well as the site's varying from one side of the compartment to the other. The compartment was harvested in the beginning of spring (September). A CTL harvesting system was used. Because the harvester processes immediately after felling, it was not possible to manipulate BWBS as was done in the other research.

Table 19 shows the detailed activities that were measured during the operation of the harvester.

Table 19	: Harvester	operation
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Pre-processing	The harvester worked on a five-row felling system. It straddled the stumps of the third row. If there was no tree mortality, the harvester would be able to reach 10 standing trees without moving the carrier. Some minor movements did take place, however, to enable optimal slewing and ensure the operator had good sight of the trees.
Grab and fell	One tree was felled and processed at a time.
Debarking/ debranching	After the tree had been felled, it was fed up and down through the head by means of feed rollers. This continued until an acceptable debarking quality was achieved. Debarking took place in the same way as discussed in the DHP system.
Topping/	The operator then zeroed the optimisation computer at the butt of the tree and crosscut the



crosscutting	tree into 5.2 m lengths. No bearer logs were used to raise the stack off the ground to
	facilitate easier forwarder loading and less slash being loaded. Log stacks were placed to
	the left of the extraction route, over the 4 <sup>th</sup> and 5 <sup>th</sup> row stumps. The forwarder would then
	load from these stacks and transport logs to the roadside landing. They would be placed
	here until they were scheduled to be transported to the mill.
	The slash was placed in front of the harvester, which then travelled over it as it moved
Deposit residue	forward. This was also the extraction route for the forwarder, which travelled over the slash
	to protect the soil.
	At the end of each swathe, the harvester turned and harvested in the opposite direction.
Other	When the harvester started harvesting the five rows adjacent and parallel to the row just
	harvested, the logs were placed on top of the existing stacks, thus creating larger log
	bundles to optimise forwarder productivity.

A general overview of the other system components follows:

# • Fell and process – harvester

As indicated above and shown in Figure 29, tracked, single-grip harvesters felled, debranched, debarked and crosscut the tree into 5.2 m lengths, creating log stacks at the stump inside the compartment.



Figure 29: The harvester in operation



## • Extraction – forwarder

A forwarder with a 20-tonne payload was used to load the logs inside the compartment and extract them to a roadside landing, where they were stacked for transport.

## Roadside loading

A tracked construction excavator-loader loaded the logs onto the log trucks.

## Log transport

As per the DHP system, a three-axle rigid truck with a four-axle drawbar trailer was used to transport the 5.2 metre logs to the pulp mill.

The equipment used in the harvester system is shown in the matrix in Figure 30. The matrix provides a visual indication of how the processing equipment interacts with the rest of the equipment in the system.

Locality Activity	Stand	Extraction route	Roadside Ianding	Forest road
Tracked harvester				
Forwarder				104 87-49

Figure 30: Harvester system matrix

The details of the machines used in the Harvester system are indicated in Table 20 on the following page.



Activity	Machine type and detail	Machine make and model
Fell and process	Construction excavator carrier: tracked Harvester head: • two feed rollers • four debranching knives (two moveable and two fixed)	One Hitachi Zaxis 200 with an SP 591LX harvester head
Extraction	Forwarder: eight-wheel drive	One Tigercat 1075

#### Table 20: Machine information for the Harvester system

# 3.5 Productivity data collection

The productivity data analysis section consists of measuring instruments, sample design and method, data collection methods and fieldwork, initial data analysis, regression analysis, identification of outliers, and regression analysis with outliers removed.

## 3.5.1 Measuring instruments

The measuring instruments used in the trials, as well as the reasons for their selection and a description of how they were used, are set out in Table 21.

Description of measuring instrument	Reason for use		
Diameter tape	To take DBH measurements (at 1.37 m) for tree-volume calculations		
Vertex hypsometer	To take eight measurements for tree-volume calculations		
Diameter calliper	To measure DBHs of the trees in the sample areas to classify trees into different volume classes		
30 m tape	To measure extraction distances covered by the skidders and forwarder, as well as to confirm vertex height measurements once the tree had been felled		
Hatchet	To measure BWBS at various parts of the tree		
Work-study stopwatch	To take time-research measurements, which were recorded in cmins. Fly-back and continuous time was used.		

Table 21: Measuring instruments and reasons for their use


Description of measuring instrument	Reason for use
Pre-printed work-research templates	The times were recorded in pencil.
Video camera	To record the operation of the processing machines when measuring other trees or taking personal breaks. Work-research data were then collected from the videos.
Notebook using a pencil	To record measurements

# 3.5.2 Sample design and sampling method

The productivity of the CFDD, CFDDC, CFDD&C, DHP and harvester needed to be determined. As discussed in a previous section, it was not necessary to determine the productivity of the other machines in the systems. Productivity was determined by measuring the amount of time taken to process a tree or bundle of trees. It was necessary to record the volume, form and BWBS of each tree processed, as these were predicted to have an effect on productivity.

#### 3.5.2.1 Individual tree-volume measurements

The trees that would be processed during the research were identified in consultation with the harvesting supervisor. A minimum of 30 trees were selected for sampling for volume calculations at each research site. It was not possible, and not desirable, to take the sample from the entire compartment. This was for two reasons:

- Mostly, harvesting had already commenced, resulting in much of the compartment's having already been felled.
- Variation of growth conditions in the compartment meant that the overall compartment-sample results might not reflect the actual research site's conditions.

Individual tree-volume measurements needed to be accurate, as this was expected to be the one of the main drivers of system productivity. A diameter tape was used for DBH measurements and readings were taken at 1.37 m above the ground (Bredenkamp, 2000). Height measurements were recorded for every tree selected, using a Vertex hypsometer. The hypsometer was calibrated each time before a measurement was taken.



The DBH and height measurements were then entered into a Microsoft Excel spreadsheet (Microsoft Corporation, 2003). The model devised by F.X. Schumacher and F.S. Hall in 1933 to determine tree volume was used for each tree sampled (Bredenkamp, 2000). The coefficients used for the volume equations for the various research sites and species are included in Table 22 (Adapted from Bredenkamp, 2000, p170).

Table 22: Coefficients used for Schumacher and Hall standing tree volume equations
(adapted from Bredenkamp, 2000, p170)

Species	Technology		Coefficients			Author of
	. comerce gy	b <sub>0</sub>	<b>b</b> 1	f	<b>b</b> <sub>2</sub>	original equation
E. globulus	CFDD (Chile) CFDDC (Australia) CFDD&C (Australia)	-10.2253	2.0427	0	0.8478	Bredenkamp, 1994
<i>E. grandi</i> s (General), 50 mm top	DHP (S. Africa)	-10.8120	2.1513	0	1.0007	Coetzee, 1992
E. grandis x camaldulensis	Harvester (S. Africa)	-10.6435	1.9185	0	1.1494	Du Plessis, 1996

All volumes were calculated in metres cubed as solid volume under bark using the following formula:

 $\ln V = b_0 + b_1 \ln (dbh + f) + b_2 \ln H$ 

Where	In	=	natural logarithm to the base e
	V	=	stem volume (m <sup>3</sup> , under-bark)
	dbh	=	breast-height diameter (cm, over-bark)
	f	=	correction factor
	Н	=	tree height (m)

These individual tree-volume measurements were used to model the relationship between DBH and height, using simple linear regression. The values of lower and upper tree-volume for each tree-volume class were inserted into the model for further analysis.

Stand density was not determined from the sample as it was not necessary for the research. The general planting espacement for each site was obtained from the relevant harvesting operational plans and verified infield for record purposes.



# 3.5.2.2 Marking of trees

Each tree that would be processed as part of the research was marked with spray-paint, a different colour being allocated to each tree-volume class. A diameter calliper, the accuracy level of which proved sufficient for the purposes of the research, was used to determine DBH instead of a diameter tape. Two measurements were taken for each tree at 90 degree angles to each other and then averaged. The resulting diameter reading was then checked against the volume-class sheet to determine between which lower and upper DBH limits it fell, thus identifying the tree-volume class it belonged to. The tree was then marked with the same colour of spray-paint as the corresponding tree-volume class.

The trees were marked on both sides to ensure that one side was always visible during the time research. With the full-tree systems, marking took place as high up the tree as possible to avoid the grapple skidder removing the bark where the marks were. Figure 31 shows an example of the tree-volume class marking that took place.



Figure 31: Tree-volume class markings

# 3.5.2.3 Felling and processing

With the full-tree systems (CFDD, CFDDC, CFDD&C and DHP), the trees were felled by means of a feller buncher. The trees felled at a specific time on a particular day were demarcated and drawn on a rough map. The grapple-skidder operator was not permitted to extract any of these trees without the researcher's permission. This was to ensure that trees to be used in the time research were not accidently processed. Time from felling to processing varied from immediate processing with the harvesters to eight days with certain of the CFDD trees. Processing is always immediately after felling if a harvester has been



used, but with the full-tree system processing technologies, the aim was to allow a portion of the felled trees to lie unprocessed in an attempt to increase the BWBS. Processing took place in the commercially acceptable method and this was monitored using time-and-motion work-study techniques.

### 3.5.2.4 Selective felling trial

When collecting data on the CFDD in Chile, selective felling and bundling of trees that were in the same tree-volume category was attempted. This would have given a very reliable indication of productivity levels that could be expected for different tree-volume classes. However, this was very time-consuming and disrupted the operations to the point where it was no longer possible to proceed. Also, space for all the different tree-volume class bundles was problematic, as the feller buncher had to manoeuvre between both standing trees and bundles of trees. With tree-volume classes that were in the minority, the feller buncher had to travel long distances to build a bundle that was of sufficient size for the grapple skidder to extract.

Selective felling was not attempted in Australia for two reasons. Firstly, it was clear from the attempt in Chile that it was not a feasible option. Secondly, apart from one, the feller bunchers in Australia were tracked machines. It was impossible for them to fell selectively between standing machines or to manoeuvre backwards and forwards to create bundles of trees of the same tree-volume class.

# 3.5.2.5 Testing for BWBS prior to processing

In order to determine the effect of BWBS on the productivity of the processing machines, it was first necessary to determine the BWBS of the trees before they were processed. If the time delay between felling and processing was the same for all the research, it would not have been possible to determine the effects of BWBS, as the BWBS would have been the same.

To overcome this problem, the time delay between felling and processing was manipulated. Some of the trees from the sample area were processed immediately after felling, while others were left to lie in the compartment for some time. Generally, the longer the tree is left after felling, the more difficult it is to remove the bark. This is influenced by many factors, such as the strength of the bark-wood bond while the tree is still standing, soil moisture content, atmospheric temperatures and humidity. This controlled delay enabled a much wider range of BWBS to be tested.



Owing to the length of time spent at each site, it was not always possible to manipulate BWBS to obtain a sufficiently large sample of trees for each BWBS class for each processing technology being analysed. For example, if, because of site conditions, the trees maintained a lower BWBS class throughout the research period regardless of time after felling, then it would not be possible to evaluate the poor BWBS classes. Indeed, if trees already had a high BWBS class at the time of felling, it was not possible for BWBS to improve, but only to become worse. The result would be an absence of data for the low BWBS classes in that particular sample.

# 3.5.3 Data collection methods and fieldwork

Each research site was physically visited to collect data. The harvesting supervisor assisted with measuring of trees with the CFDD (Chile), but with the CFDDC and CFDD&C (Australia), no assistance was available. In Zululand, South Africa, a student was present who assisted with both tree measurements and data collection for the DHP and harvester technologies.

Upon arrival at each site, time was taken to gain an understanding of the system being researched. This consisted of speaking to the supervisors and machine operators to assimilate the responsibility of their jobs, the dynamics of their machines and the operation as a whole. The actual operation was observed for approximately an hour. The operating method and the machine operators were appraised to assess work technique and competency, and the preliminary sample was recorded.

# 3.5.3.1 Tree-class definitions for data collection

Table 23 shows the different classes of data that were collected while observing the processing operations.



Tree-volume class (m <sup>3</sup> )	BWBS class	Debarking-quality class	Tree-form class
$\begin{array}{c} 1. < 0.050\\ 2. 0.051 - 0.099\\ 3. 0.1 - 0.199\\ 4. 0.2 - 0.299\\ 5. 0.3 - 0.499\\ 6. > 0.5\\ \hline \end{tabular} {\bf Note: Classes 2 \& 3}\\ {\bf combined for harvester:}\\ {\bf 3. 0.051 - 0.199} \end{array}$	<ol> <li>Very good</li> <li>Good</li> <li>Medium</li> <li>Poor</li> <li>Very poor</li> </ol>	<ol> <li>Good</li> <li>Medium</li> <li>Poor         <ul> <li>(Also if a particular part of the tree is not being debarked, e.g. top or butt)</li> </ul> </li> </ol>	<ol> <li>Good</li> <li>Medium</li> <li>Poor</li> </ol>

#### Table 23: Data collected during processing equipment observations

It was relatively easy to classify each tree for the harvester and DHP. Because tree lengths were processed individually, the productivity data for each tree could be measured and correlated with the different classes. However, multi-tree (or bundle) processing by means of the CFDD, CFDDC and CFDD&C needed to be treated differently. Different numbers of trees and differently sized trees with different BWBS and form classes were being processed simultaneously. The unit of time recorded was of how long it took to process one bundle. Even though the characteristics of each tree were known, the time allocation for a specific tree could not be established because it was not possible to group trees with the same characteristics together. Therefore, some method needs to be devised to overcome this shortcoming. The method used is described under section 3.4.3.2. below. The description of tree-size classes, BWBS classes, debarking-quality classes and form classes are described below.

Bundle sizes were simply measured as the number of tree lengths being processed during one work cycle or the number of tree lengths fed through at once.

#### Tree-size class

The trees were assigned to one of six volume classes, ranging from less than 0.05 m<sup>3</sup> to greater than 0.5 m<sup>3</sup>. The harvester only had five tree-size classes, as classes 2 and 3 were combined and renamed 3. This was due to a misallocation of the upper DBH boundary of tree-size class 2, and the lower DBH boundary of class 3. Therefore, the midpoint tree-size for this new class was recalculated to be 0.0125 m<sup>3</sup>. See Section 3.6 for more detail.



#### BWBS-class descriptions

BWBS classes were calculated in an attempt to determine the strength of the bark-wood bond and how this affected the productivity of the different processing machines. Once the trees had been felled, a BWBS test was carried out manually with a hatchet, as can be seen in Figure 32. The bark was loosened by making a cut in the cambium down to the wood, perpendicular to the length of the tree, at the DBH height. The back of the hatchet was used to loosen the bark above the cut. A section of the loose bark, approximately 15 cm wide, was lifted by hand and pulled directly away from the tree, causing the bark to detach in a strip. Depending on the BWBS, the strip would range in length from very short to very long before it separated from the tree. The length of the strip of bark determined the BWBS class that is indicated in Table 24. These tests were carried out on various tree sizes and different positions on the tree (butt, mid-bole and top). The trees were tested again before processing and any changes were documented. Trees were processed from between a few hours and eight days after felling.



Figure 32: Example of BWBS-class testing

Table 24 provides a description of how each BWBS class was derived.



#### Table 24: BWBS class description

BWBS class	Description
1. Very good	The bark comes off in a very long strip that can reach into the canopy before it severs (>10 m)
2. Good	The bark comes off in long strips of half of the height of the tree (approximately from 4 to 10 m)
3. Medium	The bark comes off in medium lengths of between one and four metres
4. Poor	The bark comes off in short lengths of up to one metre
5. Very poor	The bark will not come off by hand; it needs to be chiselled off by means of the hatchet

#### Tree-form class descriptions

Tree-form class calculations were derived from a combination of branchiness factors and actual stem form. The classes used were based on those described by Spinelli, et al. (2002b), as shown in Table 25.

Form class	Branch density	Maximum branch diameter	Stem formation
F1	Light	< 30mm	Straight
F2	Dense	< 30mm	Straight
F3	Light	>30mm	Light sweep
F4	Dense	>30mm	Marked sweep
F5			Malformed

### Table 25: Tree-form class description

(Spinelli, et al., 2002b, p.72)

Spinelli, et al. (2002b) had the maximum branch diameter as 30 mm. This branch size was considered too small, as all the processing machines were capable of removing branches with a larger diameter. A maximum branch diameter of 50 mm was used, as infield measurements of branches remaining after processing indicated that this was the diameter at which branches became difficult to remove. The class, therefore, gave an indication of the number of branches, size of branches and stem sweep or severe malformation.

For this research, using five different form classes was not practical, as it became difficult to distinguish between the form classes as the trees were being processed. Thus, these five form classes were consolidated into three, as per Table 26.



Form class	Branch density	Maximum branch diameter	Stem formation
F1 – good	Light and dense	< 50mm	Straight
F2 – medium	Light and dense	> 50mm	Light to marked sweep
F3 – poor	Light and dense	Any diameter	Malformed

# Table 26: Form class description for the research(adapted from Spinelli et al, 2002b, p.72)

### Debarking-quality class description

Debarking-quality classes were calculated by estimating the amount of residual bark left on the tree after debarking. This was a subjective estimate as it was not possible to remove bark samples, weigh them and then correlate the results with accurate percentages. Table 27 provides a description of how each debarking-quality class was derived.

### Table 27: Debarking quality class description

Debarking-quality class	<b>Description</b> (residual bark content = bark as a percentage of total volume)
1. Good	All bark is removed from the stem: residual bark content of less than 0.5 % achieved
2. Medium	Strips of residual bark remain: residual bark content of less than 1 % achieved
3. Poor	Sections of the tree have not had bark removed: residual bark content of more than 1 %

Figures 33 and 34 show good and poor debarking quality.



Figure 33: Good debarking quality, and Figure 34: Poor debarking quality

Debarking quality is not a variable-affecting productivity; it is an output or reflection of the operating method and other factors influencing debarking. The reason for considering debarking quality was to ensure that the productivity determined from the work-research measurements could be achieved with acceptable debarking quality. When logs or chips are



delivered to a mill, the average bark content of the load should not be higher than the mill specification. All of the mills which consumed timber or chips from the research sites had bark tolerances, measured as volume of bark per volume of chips, with a maximum of one per cent. In the research, the debarking quality was measured at individual tree level, but was averaged thereafter to see whether the overall debarking specification would be met. The measuring of debarking quality was subjective, as it was not possible to correlate the bark remaining on individual trees with a percentage of a truck load of chips or even of a chip pile.

### 3.5.3.2 Data capturing and data editing

The effects of tree volume, bundle size, BWBS, form and debarking quality on time and, therefore, productivity were determined for all the research sites. Time-and-motion research was conducted on all of the operations. Statistical analysis was then carried out on the relationship between time and quantity produced. The time data were collected at the element level. Cycle times were broken down into time elements representative of the technology and operating method being used (Spinelli and Visser, 2008). This was done in order to isolate parts of the cycle that might be susceptible to influence by external factors (such as tree size) in an attempt to improve the accuracy of the models developed. The specific elements used for each technology are included in the subsection 3.4.3.1 above.

For the time-and-motion research, a combination of cumulative and fly-back timing methods was used (Kanawaty, 1992). The time for each element was recorded, using an electronic stopwatch, and cumulative elapsed time was recorded at the end of each research session, both by direct observation. Video recordings were also taken while measuring trees, marking trees or testing BWBS. However, the colour markings on each tree were very difficult to discern from the video images in the multi-tree processing operations, making use of video data not possible. Timing error was noted and was found to be well within acceptable work-study norms (Katawaty, 1992). The time was manually recorded on pre-printed work-research data sheets.

All the operators had been working with their machines for at least six months and were experienced and sufficiently skilled. The operators were assumed to be equally proficient. The researcher used his experience to determine whether operators could be classified as 'average workers', as defined by the International Labour Office (ILO) in Geneva, Switzerland (Kanawaty, 1992). Operators were instructed to work at their normal pace.

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Traditionally, forest-engineering research has focused on productive and non-productive delays (Spinelli and Visser, 2008). Recently, delays encountered during research have been split into mechanical, operator and other delays (Spinelli and Visser, 2008). Any delays caused by the research itself were excluded (e.g. stopping the machines to take notes). For the purpose of this research, the delays were split into the three categories mentioned above and as defined by Spinelli and Visser (2008). All delays that fell into these categories were included, regardless of the delay length. Spinelli and Visser (2008) found that most delaying events with regard to harvesters lasted fewer than 15 minutes (94 per cent). Therefore, if all delays of under 15 minutes were ignored, the final results would be skewed. For this reason, all delays were recorded, regardless of their length. Other time-delay factors that affected machine utilisation included chain replacement, waiting for trees, refuelling and mechanical interruptions, usually for preventative maintenance.

The capturing of data for the multi-stem processing technologies preparing bundles differed slightly from the method used for the single-tree processors. As trees were fed through the CFDD or CFDDC, the tree characteristics were visually observed and noted:

- o bundle size,
- $\circ$  individual tree size, according to the spray-paint colour on the stem,
- o form, as trees were fed into the machine,
- o debarking quality, as the trees exited the machine.

Simultaneously, the time taken to process the bundle was recorded. The same information was recorded for the DHP and harvester, except that all measurements were carried out at the individual tree level, as single trees were processed at a time.

#### Data transfer

The data for each different machine was then transferred into separate Microsoft Excel workbooks (Microsoft, 2003). Each workbook contained all the information from infield data collection as follows:

- $\circ$  the section of the compartment from which the trees came;
- o the date the trees were felled;
- o the date the trees were processed;
- the cycle number;
- the cycle elements;
- o the total cycle time (including averaged relevant delays);
- o delay times;



- o delay category;
- reason for the delay;
- total number of trees in the cycle;
- individual tree-size class;
- o individual tree-BWBS class at the time of felling;
- individual tree-BWBS at the time of processing;
- individual tree-form class;
- o individual debarking-quality class;
- o other general research conditions, such as climatic and terrain factors.

At the start of the CFDD research, an attempt was made to record feed-roller damage to the trees. Occasionally the feed rollers struggled to pull large trees in the CFDD and scraped into the butt of the tree until the operators used the crane to pull the tree further into the machine. Chain-flail damage – trees that were excessively debarked, resulting in damage to the wood fibre – was also recorded. However, it was not possible for one person to collect so much information without compromising the quality of the pertinent data. Feed-roller and chain-flail damage seldom occurred and was not considered to be of high importance for the objectives of the research.

Error checking

The data were then examined for obvious errors made during recording or while transferring information to the Excel workbook. Any recording errors were either corrected or removed.

The many different tree sizes and characteristics occurring in one bundle, with only one time recorded for all these trees, posed an important challenge. The method to overcome the problem with the CFDD, CFDDC and CFDD&C was as follows:

- the individual tree sizes in each cycle were added together to get a total tree-volume per cycle;
- the individual tree sizes were taken to be the midpoint-sized tree for a particular class.

For example, tree-size class 3 consisted of trees between 0.1 and 0.199 m<sup>3</sup> per tree. All the midpoint-size classes used are shown in Table 28.



Tree-volume class (m <sup>3</sup> )	Midpoint-volume class (m <sup>3</sup> )
1. < 0.050	0.025
2. 0.051 - 0.099	0.075
3. 0.1 – 0.199	0.15
4. 0.2 – 0.299	0.25
5. 0.3 – 0.499	0.4
6. >0.5	0.55
Note: Classes 2 & 3 combined into new 3:	
3. 0.051 – 0.199	0.125

Table 28: Midpoint tree volume per tree size class

In the example described for tree size class 3, the midpoint was calculated as being 0.15 m<sup>3</sup> per tree. Therefore, the total volume per cycle was the sum of the midpoint tree sizes for each tree according to its size class. The total volume for the cycle was then divided by the number of trees in that cycle to obtain an average tree size for the cycle. The BWBS, form and debarking-quality classes of the individual trees in each cycle were then averaged to create an average BWBS, form and debarking-quality class per cycle. The total cycle time was also divided by the number of trees in the cycle to obtain an average processing time per tree. By carrying out the analysis in this way, it was possible to take into account the specific characteristics of each tree in the bundle being processed and determine what effect that had on the overall productivity.

The data in the Excel workbooks were then sorted into a format whereby summary statistics could be carried out. The data for all the processing technologies were placed into one Excel workbook from the individual machine workbooks. The information that was transferred from each machine was at the cycle level and included the name of the processing machine, the cycle number for a specific technology, the number of trees per cycle (bundle size), cycle time, average tree-volume class, average BWBS class, average form class, average debarking-quality class, total bundle volume and actual average tree volume in each bundle. These data were then imported into a STATISTICA software package for more detailed statistical analysis.

#### 3.5.3.3 Productive-cycle elements per processing technology

The work-research elements identified for the various processing technologies are presented below. The CFDD, CFDDC and CFDD&C have been combined as the same elements are used. All time measurements were recorded in centi-minutes.



• Work research elements for the CFDD, CFDDC and CFDD&C

The productive-cycle elements recorded for the CFDD, CFDDC and CFDD&C were:

- Feed trees the cycle commenced when the grab touched the trees lying at the infeed of the processing machine. The butts were lifted and fed into the infeed rollers. Big trees were lifted to aid feeding.
- Debranch and debark as the butts of the trees passed through the infeed rollers, the debranching and debarking element commenced. When the top of the tree passed through the infeed rollers, the debranching and debarking element terminated. However, as is normally the case, if more trees were fed into the machine while the previous trees were still passing through the infeed rollers, a new debarking cycle commenced. This enabled rapid debarking elements.
- Remove residue the grab was used to move residue from the infeed area and hydraulic pusher. Normally, this occurred while debarking took place, but if there was excessive residue, it took place without any trees being debarked.
- Work research elements for the DHP

The productive cycle elements that were recorded for the DHP are outlined below.

- Move to tree After dropping the top of the previous tree, the boom extended to the next tree at the top of the bunch. The element ended when the head, with open debranching knives, touched the next tree on the bunch that would be processed.
- Grab tree The debranching knives closed and the tree was lifted from the bunch and slewed into position.
- Debark/debranch The feed rollers started to feed the tree backwards and forwards through the head. This continued until the bark had been removed according to the mill specifications.
- Top tree The crosscut saw was activated and the top of the tree was removed. The head was slewed to where the top was to be deposited. The debranching knives and feed rollers opened and released the top onto the residue pile.
- Change position The excavator moved backwards and forwards on the landing to position itself better to process or to move to a new bundle of trees that needed to be processed. The initial and final movements of the tracks indicated the start and the finish of this element.



#### • Work research elements for the harvester

The productive cycle elements that were recorded for the harvester are described below.

- Move to tree After dropping the top and other residue from the previous tree, the boom extended to the next tree. The cycle ended when the head, with open debranching knives and feed rollers, touched the next standing tree.
- Fell tree The debranching knives and feed rollers closed around the tree. The felling cut was made and the tree fell towards the ground.
- Debark/debranch The cycle commenced when the feed rollers started to move. They fed the tree backwards and forwards through the head. This continued until the bark had been removed according to the mill specifications.
- Crosscut –The crosscut saw was activated to zero the computer when the head was positioned at the butt of the tree. The tree was fed through the head and crosscut until the entire tree had been crosscut into logs. Occasionally, especially with larger trees, the harvester would start crosscutting before the top half of the tree had been debarked. This would result in subelements of debarking/debranching and crosscutting.
- Top tree The crosscut saw was activated and the top of the tree removed. The head was slewed to where the top and other residue was deposited. The debranching knives and feed rollers opened and released the top onto the residue pile.
- Change position The harvester moved forward to position itself better to fell and process the next set of trees. When the harvester reached the end of a rack, it turned to start harvesting in the opposite direction. The initial and final movements of the tracks indicated the beginning and the end of this element.

# 3.6 Data analysis

Time-research data collected from the research sites were examined using descriptive statistics, which investigated relationships between average tree volume, bundle size, BWBS, form, debarking quality and hourly machine production. The statistical summary was carried out in Microsoft Excel, with more detailed analysis in STATISTICA. The sample size (number of observations) required for each processing machine was determined using the equation from the ILO as set out below (Kanawaty, 1992).



$$n = \left(\frac{40\sqrt{n'\sum x^2 - \left(\sum x\right)^2}}{\sum x}\right)^2$$

Where:

- *n* = the sample size required for a 95 per cent confidence level with an error margin of five per cent.
- n' = the number of observations in the preliminary study.

$$\sum$$
 = sum of values.

*x* = observation value.

Fifty preliminary observations were timed for each processing machine. The formula outlined above was applied to the results. The sample size in terms of the number of observations and the number of trees processed by each processing machine researched can be seen in Table XX. The multi-stem handling processors had much higher numbers of trees processed as many trees were handled at the same time. The research data sample size exceeded the minimum required for the 95 per cent level of confidence for all the processing machines.

Processing machine	No. observations	No. trees processed
CFDD	875	3793
CFDDC	1786	2903
CFDD&C	1609	3939
DHP	547	547
Harvester	430	450

Table XX: Sample size per processing machine

#### 3.6.1 Initial data analysis

For the summary statistics in Excel, the productivity was determined in cubic metres per PMH at the cycle level. The mean, standard deviation, variance and sample size were determined for each combination and the results were tabulated and described. Combinations with sample sizes of less than 10 were highlighted in yellow and sample sizes of between 10 and 19 were highlighted in red. This was done to draw attention to small sample sizes which could potentially influence the results. Results from smaller samples



should be interpreted more cautiously. In a small sample, for example, an outlier can easily distort the results.

Debarking quality was also examined for each of these combinations to try to explain some of the results that did not follow the general trend of the data.

A separate model was developed for each processing technology. The specific variables per cycle included processing machine, cycle time, tree-volume class, BWBS class, form class, debarking-quality class, average actual tree-volume per bundle, the bundle volume, the bundle size (number of trees) and productivity (m<sup>3</sup>/PMH). Sorting the data was not important as the models developed were based on the actual tree sizes and not the tree-size classes.

### 3.6.1.1 Scatterplot investigation of productivity relationships

Once the dataset of each technology had been imported into STATISTICA, scatterplots were used to investigate the form and strength of relationship between the dependant variable (productivity) and independent variables. The scatterplots were used to investigate whether the various variables were relevant in explaining productivity. Scatterplots of bundle size versus productivity and average tree volume versus productivity were compiled. The results for each technology are shown in the various figures below. Figures 38 and 39 represent the CFDD and show that productivity increased for increasing average tree volume and also for increasing bundle size. The productivity increased from approximately 50 m<sup>3</sup> per PMH in small trees of 0.075 m<sup>3</sup> to 100 m<sup>3</sup> per PMH in large trees of 0.40 m<sup>3</sup>, while the productivity increased from approximately 45 m<sup>3</sup> per PMH when the bundle consisted of one tree, to 100 m<sup>3</sup> per PMH when eight trees per bundle were processed.



Figure 35: CFDD scatterplot of average tree volume versus productivity, and Figure 36: CFDD scatterplot of bundle size versus productivity



Figures 40 and 41 represent the CFDDC and show that there was a slight upward trend in productivity for increasing average tree volume. The productivity increased from 40 m<sup>3</sup> per PMH in small trees of 0.075 m<sup>3</sup> to 80 m<sup>3</sup> per PMH in large trees of 0.55 m<sup>3</sup>. However, it should also be noted that the data is very variable with huge ranges in productivity for any specific average tree volume. There was no increase in productivity as the bundle size increased. This was unexpected and could possibly be due to the operators' processing fewer trees in a bundle, but feeding bundles into the machine more frequently.



Figure 37: CFDDC scatterplot of average tree volume, and Figure 38: CFDDC scatterplot of bundle size

Figures 42 and 43 represent the CFDD&C and show that there were productivity increases as the bundle size and tree volume increased. The productivity increased from approximately 30 m<sup>3</sup> per PMH in small trees of 0.075 m<sup>3</sup> to 80 m<sup>3</sup> per PMH in large trees of 0.55 m<sup>3</sup>, while the productivity increased from approximately 30 m<sup>3</sup> per PMH when the bundle consisted of one tree, to 60 m<sup>3</sup> per PMH when five trees per bundle were processed.



Figure 39: CFDD&C scatterplot of average tree volume, and Figure 40: CFDD&C scatterplot of bundle size



Figures 44 and 45 represent the DHP and harvester and show that there were productivity increases as tree volume increased. The DHP and harvester process single stems and there is therefore no graph for bundle size versus productivity. The productivity increased from approximately 12 m<sup>3</sup> per PMH in small trees of 0.075 m<sup>3</sup> to 64 m<sup>3</sup> per PMH in large trees of 0.45 m<sup>3</sup> with the DHP, and the productivity increased from approximately 3.5 m<sup>3</sup> per PMH in small trees of 0.45 m<sup>3</sup> with the harvester.



Figure 41: DHP scatterplot of average tree volume, and Figure 42: Harvester scatterplot of average tree volume

From Figures 38 to 45, one can conclude that there is a relationship between average tree volume and productivity, and also bundle size and productivity. These variables can therefore be included in a regression model explaining productivity.

Bundle size and tree volume were then plotted against each other. This only applied to the CFDD, CFDDC and CFDD&C, as the DHP and harvester did not process bundles. Figures 46a-c show two-dimensional scatterplots of the resultant relationships. All three graphs show a decrease in average tree size as the bundle size increased. This was expected as the operator made bigger bundles of smaller trees.







Figure 43a: CFDD, Figure 46b: CFDDC and Figure 46c: CFDD&C - all scatterplots of average tree volume against bundle size

#### 3.6.1.2 Examination of the distribution of productivity variables

Histograms were created in STATISTICA to examine the distribution of the relevant variables. The histograms for each of these variables for each technology can be found in Annexure A. For the CFDD, all three variables were distributed approximately normally. The most frequently occurring productivity level for the CFDD was between 60 and 80 m<sup>3</sup> per PMH. The most frequent tree volume for the CFDD was between 0.1 and 0.2 m<sup>3</sup> per tree, followed by between 0.2 and 0.3 m<sup>3</sup> per tree. The most frequently occurring bundle size for the CFDD was four trees per cycle.

For the CFDDC, productivity was slightly skewed towards the right, with higher frequencies for the lower productivity levels. The most frequent productivity for the CFDDC was between 20 and 60 m<sup>3</sup> per PMH and there was a long tail towards the higher productivity levels. The most frequent tree size was between 0.1 and 0.2 m<sup>3</sup>. However, the sizes between 0 and 0.1 m<sup>3</sup>; 0.2 and 0.3 m<sup>3</sup>; and 0.5 and 0.6 m<sup>3</sup> were also often observed. This last value reflects the



very big tree sizes that were encountered on two of the research sites. With the CFDDC, the most common bundle sizes consisted of only one tree per cycle, with a long tail towards the right (positively skewed). This reflected the bigger trees found on many of the sites and an operating method where fewer trees were fed into the machine, but the <u>bundles</u> were fed more frequently.

With the CFDD&C, the most common productivity level was between 20 and 60 m<sup>3</sup> per PMH, but with a longer tail towards the higher productivity levels. The most frequent tree size was between 0.1 and 0.2 m<sup>3</sup> and the most frequent bundle size was two trees per cycle, followed by three trees per cycle. With the DHP, the most frequent productivity was between 10 and 20 m<sup>3</sup> per PMH. However, there was a slightly lower second peak of between 40 and 50 m<sup>3</sup> per PMH (bimodal). The most frequent average tree volume was between 0.2 and 0.3 m<sup>3</sup>. With the harvester, the most frequent productivity was between 15 and 20 m<sup>3</sup> per PMH. A second peak occurred between 5 and 10 m<sup>3</sup> per PMH. The most frequent tree volume was between 0.2 and 0.3 m<sup>3</sup>.

# 3.6.2 Regression analysis

Regression models that described the effect of tree and bundle sizes on productivity were then developed to find and describe significant relationships. The model developed needed to show the processing-technology productivity in relation to tree size, as well as bundle size, for the CFDD, CFDDC and CFDD&C. Bundle size and tree volume were used as independent variables and were related to machine productivity as m<sup>3</sup> per PMH. In order to ensure that the model was valid and accurate, the assumptions in the model were validated and the input-output transformations for the model were compared to the real system information used to build the model.

#### 3.6.2.1 Regression model construction

The scatterplots, which were used to explore relationships (whether there is a relationship and also the form of the relationship), suggested that relationships between independent variables and productivity might be quadratic rather than linear for some processing technologies. Therefore, square effects were included. It is not unreasonable to suspect that average tree volume and bundle size might have an interactive effect on productivity (see *Section 3.4.4 – Initial data analysis*) and, because of this, the interaction term was also included in the model-building process. Thus, the various models that were constructed for each processing technology examined the productivity variables, the square effects of each



variable and the interaction between the variables. These models were constructed in sequence and were as follows:

- o main effects model (MEM): average tree volume and bundle size;
- main effects and interaction model (MEIM): average tree volume and bundle size and the interaction between these two;
- main effects and square effects model (MESEM): average tree volume and average tree volume squared, as well as bundle size and bundle size squared;
- main effects, square effects and interaction model (MESEIM): average tree volume and average tree volume squared; bundle size and bundle size squared; and the interaction between average tree volume and bundle size.

The coefficient of determination (R-squared value) of each model was examined. The R-squared value is an indicator of goodness of fit. It measures how well the estimated regression line fits the observed machine productivities. In order for it to be acceptable to introduce new factors into the model, the adjusted R-squared has to increase. The results of the adjusted R-squares for each successive model for each processing technology are outlined in Table 29.

Model	CFDD	CFDDC	CFDD&C	DHP	Harvester
МЕМ	0.5518	0.3395	0.4768	0.7275	0.8881
MEIM	0.5962	0.3751	0.5683		
MESEM	0.6014	0.3902	0.5596	0.7513	0.8951
MESEIM	0.6168	0.3918	0.5814		

Table 29: Adjusted R-squared examination per model per processing technology

The interaction model could not be used by the DHP and harvester technologies because no bundles were processed. In all instances, except for MESEM for the CFDD&C, the adjusted R-squared value increased. Therefore, it is acceptable to add new variables to the model. However, the MESEM for the CFDD&C decreased. In this instance, the addition of the square effects did not improve the model significantly and was therefore not included. The productivity regression equation that was constructed from the regression is shown below.

Productivity  $(m^3/PMH) = \beta_0 + (\beta_1 * Ave tree vol) + (\beta_2 * (Ave tree vol)^2) + (\beta_3 * Bundle size) + (\beta_4 * (Bundle size)^2) + (\beta_5 * Ave tree vol * Bundle size)$ 



### 3.6.2.2 Productivity coefficients of the regression model

The regression coefficients were established for each processing technology. These estimated coefficients are given in Table 30 below. These coefficients were substituted into the regression model above.

Effect	CFDD	CFDDC	CFDD&C	DHP*	Harvester*
Intercept (β <sub>0</sub> )	-28.601	-17.167	-10.419	-6.856	0.3269
Average tree volume (β <sub>1</sub> )	266.053	188.718	158.233	229.563	69.2628
Bundle size (β <sub>2</sub> )	12.251	24.654	8.759		
Average tree volume <sup>2</sup> (β <sub>3</sub> )	-365.449	-152.547	-192.348	-201.501	-34.0318
Bundle size <sup>2</sup> (β <sub>4</sub> )	-0.759	-3.130	-0.708		
Average tree volume x Bundle size ( $\beta_5$ )	35.407	23.341	47.509		

Table 30: Coefficients of the productivity model for each processing technology

\* Bundle size is not applicable

The coefficients follow a similar trend for each processing technology, with the intercept having a small negative value. Average tree-volume and bundle size have positive values, indicating that as tree and bundle size increased, productivity also increased. The coefficients for average tree-volume and average tree-volume squared were very large, indicating that tree volume was a very important factor in determining productivity. Average tree-volume squared and bundle size squared have negative values, indicating that the productivity increase is non-linear for both of these variables. However, these two effects played a much smaller role in dtereming productivity as can be seen by their smaller values. The larger the value of the coefficient for the interaction between bundle size and tree volume, the more the gradient of the productivity curve for different bundle sizes will vary. Therefore, CFDD&C and CFDD have more variable gradients than the CFDDC.

The p-value's for each coefficient were also examined. The regression coefficients were all significant at the five per cent level of significance, with the exception of the harvester intercept. Because the harvester intercept co-efficient is not significant, it has not been used in the harvester-productivity equation.

The model developed above was used to determine processing technology productivity as per the conditions recorded in the research. The estimated values produced by the model and the real research values were then compared.



### 3.6.2.3 Validation of assumptions of normality

The assumptions of normality and homoscedasticity of the error terms in the regression analysis were examined. These assumptions were tested by analysing the residual terms resulting from the regression model.

The graphs showing the differences between the observed productivity values and the productivity values predicted by the model are shown for each technology in Figures 47a-e.





Figure 44a: CFDD, Figure 47b: CFDDC, Figure 47c: CFDD&C, Figure 47d: DHP and Figure 47e: Harvester – all observed productivity versus predicted productivity values



The predicted productivity versus observed productivity evaluates how well the model fits the data. The model is able to predict more accurately at lower productivity levels. With the bundle-fed processing machines, if a new bundle was placed at the infeed immediately after a previous bundle had been placed, it created a spike in the productivity of the previous bundle. The result is a very short cycle time in relation to the volume being fed through the processor. This creates very high productivity levels for those specific cycles, which is reflected in the graphs. At very low and very high levels of productivity, the model is generally under-predicting, with the exception of the harvester. This could be caused by outliers and has been investigated further below.

The test for normality is carried out by constructing a normal probability plot for residuals. When examining the plot, the most emphasis should be placed on the central values and not the extremes (Montgomery, 1984). If the assumptions are valid, the fitted line in a normal probability plot would be a straight line. One could then assume that the residual term is normally distributed. The test for normality of error terms (residuals) is shown in Figures 48a-e.







Figure 45a: CFDD, Figure 48b: CFDDC, Figure 48c: CFDD&C, Figure 48d: DHP and Figure 48e: Harvester – all normality of error terms

At the extremes of the data and at certain positions along the line, the terms were not lying along the line. Therefore, the assumptions of normality were not met, as it appeared that outliers were affecting the error terms for all the different technologies. Outliers, therefore, needed to be identified and removed.

The investigation of homoscedasticity of the error terms is shown in Figures 49a-e. The plot of residuals (error terms) versus the predicted mean values checks for homoscedasticity (Gujarati, 1999). For the assumptions to be valid, the plot should be random without clear recognisable patterns.









Figure 46a: CFDD, Figure 49b: CFDDC, Figure 49c: CFDD&C, Figure 49d: DHP and Figure 49e: Harvester – all homoscedasticity of error terms

The variance is not constant and, therefore, the assumption of homoscedastic variance has not been met. Once again, it appeared that outliers were responsible and needed to be identified and removed.

# 3.6.3 Identification of outliers

The data of each processing technology were once again handled separately. The data were sorted by tree size and productivity only. New tree-size classes were created as per Table 32.



Tree-size class	Tree-size range
1	0.0 to 0.099 m <sup>3</sup>
2	0.10 to 0.199 m <sup>3</sup>
3	0.20 to 0.299 m <sup>3</sup>
4	0.30 to 0.399 m <sup>3</sup>
5	0.40 to 0.499 m <sup>3</sup>
6	0.50 to 0.599 m <sup>3</sup>

#### Table 31: New tree-size classes for outlier removal

The existing data already had specific tree sizes, so besides sorting, no data manipulation was necessary. The first and third quartiles for productivity were determined for each treesize class for each processing technology. The interquartile range was then determined by subtracting the first quartile value from the third quartile value. One-and-a-half times the interquartile range was added to the third quartile value and subtracted from the first quartile value. Any productivity figures above or below these values were deemed to be outliers. These were highlighted in the data and removed.

#### 3.6.3.1 Scatterplot investigation of productivity relationships with outliers removed

Once the dataset of each technology had again been imported into STATISTICA, scatterplots were once again used to investigate the nature and strength of dependencies between independent variables and the dependant variable, as well as to investigate relationships, for model development and to predict productivity. The x-axis (bundle size and average tree volume) was independently plotted as two-dimensional scatterplots against the y-axis (the productivity per PMH). The results for each technology are shown in the various tables below. Figures 50a-h represent all the processing technologies.







Figure 47a: CFDD scatterplot of average tree-volume, outliers removed, Figure 50b: CFDD scatterplot of bundle size, outliers removed, Figure 50c: CFDDC scatterplot of average tree-volume, outliers removed, Figure 50d: CFDDC scatterplot of bundle size, outliers removed, Figure 50e: CFDD&C scatterplot of average tree-volume, outliers removed, Figure 50f: CFDD&C scatterplot of bundle size, outliers removed, Figure 50g: DHP scatterplot of average tree-volume, outliers removed and Figure 50h: Harvester scatterplot of average tree-volume, outliers removed

The outlier removal slightly improves the fit of all the processing machines. The decrease in productivity with increasing bundle size for the CFDDC (Table 50d) could be due to the feeding method, where large trees were fed through individually, but in quick succession.



Small trees were fed through as bundles, with a longer time delay before the next bundle was processed. The small number of bunches with many trees could also be skewing the data slightly.

Once again, the tree volume and bundle size were then plotted against each other (only for CFDD, CFDDC and CFDD&C). Figures 51a-c show two-dimensional scatterplots of the resultant relationships.





Figure 48a: CFDD, Figure 51b: CFDDC and Figure 51c: CFDD&C – all scatterplots of average tree volume against bundle size, outliers removed

As expected, all three technologies processed fewer trees per bundle as the tree size increased. It is to be noted that for a fixed average tree volume, there was a lot of variation in bundle size. Although the relationship is negative, it is not very strong.



# 3.6.3.2 Examination of the distribution of productivity variables with outliers removed

Histograms were then again created in STATISTICA to examine whether the distribution of the data were normal when outliers were removed. The histograms for each of these variables for each technology can be found in Annexure A. As a reference, Annexure A includes the histograms with the outliers included and removed. The histogram data distributions with outliers removed are almost exactly the same as with the outliers included. The model developed was used to determine productivity of processing technology with the outliers removed, as per the conditions recorded in the research. The estimated values produced by the model and the real research values (both with outliers removed) were then compared. Once the outliers had been removed, the assumptions were again tested, using the two methods described above (that is, determining if error terms were normally distributed and determining homoscedasticity of the error terms).

# 3.6.4 Regression analysis with outliers removed

Regression analysis was done on the data with the outliers removed. Models were once again constructed as per the method previously described. The sequence of model construction was the main effects model (MEM), main effects and interaction model (MEIM), main effects and square effects model (MESEM) and main effects, square effects and interaction model (MESEIM).

The results of the adjusted R-squares for each successive model for each processing technology are outlined in Table 33.

Model	CFDD	CFDDC	CFDD&C	DHP	Harvester
МЕМ	0.5883	0.3634	0.4788	0.7585	0.9152
MEIM	0.6376	0.3830	0.5697		
MESEM	0.6557	0.4065	0.5904	0.7801	0.9230
MESEIM	0.6680	0.4062	0.6031		

Table 32: Adjusted R-squared examination per model per processing technology with outliers removed

Apart from MESEIM for the CFDDC, the adjusted R-squared value increased. Therefore, it was acceptable to add new variables to the model because the adjusted R-squared value would also increase. The only exception was the MESEIM for the CFDDC, which decreased.



Therefore, the MESEIM should not be used and the addition of all of the variables did not improve the model accuracy. The adjusted R-squared values for all of the models and technologies increased over the original model results, which included outliers. This means that the removal of outliers improved the fit of the data.

Research that concentrates on the variables affecting the productivity of harvester machines found it rare for one productivity variable to describe more than 50 per cent of the variation in the data. Low variability description is common for forestry machines, because element and cycle times are affected by many factors that are difficult to record and estimate (Spinelli and Hartsough, 2001). An example of such a factor is operator concentration.

# 3.6.4.1 Productivity coefficients of the regression model with outliers removed

New regression coefficients were then determined for the models. The coefficients of the model for each processing technology are outlined in Table 34 below and show the significance of the coefficients.

Effect	CFDD	CFDDC	CFDD&C	DHP	Harvester
Intercept (β₀)	-31.130	-19.723	-18.175	-5.555	0.1641
Average tree volume ( $\beta_1$ )	280.271	218.570	193.666	217.321	69.5225
Bundle size ( $\beta_2$ )	13.660	27.188	14.504		
Average tree volume <sup>2</sup> ( $\beta_3$ )	-382.485	-164.051	-235.663	-183.513	-34.9054
Bundle size^2 (β₄)	-0.910	-3.388	-1.645		
Average tree volume x Bundle size ( $\beta_5$ )	31.081	-2.533	33.512		

# Table 33: Coefficients of the productivity model for each processing technology with outliers removed

Except for the interaction between average tree volume and bundle size for the CFDDC, all coefficients were significant at the five-per-cent level of significance. This interaction will therefore not be included in the final model for the CFDDC.



The most noticeable change in the coefficients can be found in the CFDDC and CFDD&C. The  $\beta_1$  coefficient (average tree volume) has increased from 189 to 219 and 158 to 194 for the CFDDC and CFDD&C respectively. Therefore, as tree size increased, there was a more pronounced increase in productivity than when the outliers were included. The  $\beta_3$  (average tree volume squared) coefficient still plays a largely negative role, even though it has decreased slightly from when the outliers were included. This indicates that as the tree size becomes larger for a given bundle size, the productivity increase will be slow.

The  $\beta_2$  (bundle size) coefficient for the CFDD&C also markedly increased from 8.8 to 14.5, indicating increased productivity with more trees per bundle for a given tree size. However, the effect is clearly not as large as with tree size. The  $\beta_4$  (bundle size squared) coefficient for all the multi-stem processing technologies plays a much smaller role, but it is still significant. The  $\beta_5$  (interaction) coefficient has decreased with the outliers removed, most notably for the CFDDC (from 23.3 to -2.5) and this coefficient is no longer significant. The insignificant coefficient for the interaction term of the CFDDC shows that the gradient of the productivity curve is not variable for different bundle sizes. There is a significant interaction effect between average tree volume and bundle size for the CDFF and CFDD&C.

The graphs showing the differences between the observed productivity values and the productivity values predicted by the model are shown for each technology in Figures 52a-e. All the data should fall on a 45 degree line. The model is able to predict more accurately at lower productivity levels.









Figure 49a: CFDD, Figure 52b: CFDDC, Figure 52c: CFDD&C, Figure 52d: DHP and Figure 52e: Harvester - all observed productivity versus predicted productivity values, outliers removed

# 3.6.4.2 Validation of assumptions of normality with outliers removed



This test for normality of error terms is shown in Figure 53a-e.





Figure 50a: CFDD, Figure 53b: CFDDC, Figure 53c: CFDD&C, Figure 53d: DHP and Figure 53e: Harvester – all normality of error terms, with outliers removed

The normal probability plot of residuals checks for the assumption of normality. With the outliers removed, the error terms now lie along the straight line. The assumption of normality was therefore found to have been met.



Homoscedasticity of the error terms was tested again, as per Figures 54a-e





Figure 51a: CFDD, Figure 54b: CFDDC, Figure 54c: CFDD&C, Figure 54d: DHP and Figure 54e: Harvester – all homoscedasticity of error terms, with outliers removed

The plot of residuals versus the predicted values checks for homoscedasticity. There was constant variance of the residuals from the zero line for the predicted values of each processing technology. The assumption of homoscedastic variance was met. Therefore, the productivity equations developed can be used to predict the productivity of all of the various processing technologies for different tree sizes and bundle sizes.

# 3.7 Cost data analysis

To determine the costs of harvesting per m<sup>3</sup>, it is necessary to divide the cost of operating the machine (usually per hour) by the production achieved during that time period (Akay and Sessions, 2004). To determine the machine rate, the following information is required:

- the ownership costs (depreciation, interest, insurance and scheduled operating time);
- o operating costs (maintenance, fuel, lubricants, tyre- or track-replacement costs); and


 labour or machine-operator costs (wages, salaries, legislated costs and other labour overheads).

These factors are influenced by many variables. For example, the repair-cost factor is influenced by operators abusing equipment, difficult terrain and the inherent reliability of the machine. A further example is fuel consumption, which is influenced by load size, engine size, operator skill and operating conditions. Hence, the accuracy of the results of a machine costing depends upon the quality of the information used in the costing.

Jarck (1965) classified the accuracy of information used in machine costings into three categories: empirical data (long-term cost records), good estimates from knowledgeable sources and unknown (questionable or rule-of-thumb sources). For the purpose of the research, empirical data was used as far as possible. However, not all the sources required to substantiate this research have been empirically investigated and some information recorded offers the best estimates available from knowledgeable sources. Costing information was placed into the Forestry Solutions mechanised harvesting system costing model developed in Microsoft Excel (2003). All costings are included in Annexure C.

The input assumptions into the costing were obtained from various sources. Table 36 shows the sources of the different factors used in the cost calculations described under the results. Apart from the CFDDC, the same machines and models used during the research have been used for the costings. The Morbark 2455 was used to calculate the CFDDC costing, owing to a lack of response from the South African Peterson agents.

Machine-cost factor	Source
Capital cost of machine	As indicated in text
Machine life (machine hours)	As indicated in text
Residual values (% of capital employed)	Brinker, et al. (2002)
Machine utilisation	Brinker, et al. (2002)
Insurance rates	Brinker, et al. (2002)
Repair-cost factor	Brinker, et al. (2002)

 Table 34: Information sources for machine-cost factors



Machine-cost factor	Source
Fuel consumption	Grobelaar (2000)
Oil and lubrication	Grobelaar (2000)
Operator rates (cost to company)	As indicated in text
Overhead costs	Grobelaar (2000)

# 3.7.1 Ownership costs

The various ownerships assumptions and costs of the machines and systems used in the harvesting system cost calculations are described below.

# 3.7.1.1 Capital costs of equipment

New machine prices were collected from agents in South Africa. The capital cost of the machines considered all the logistical costs of transporting the new machines to the point of use (Miyata, 1980). For this research, the point of use was Richards Bay, where the DHP and harvester worked during the research trials. Because most of the equipment across the trial sites was of the Tigercat brand, most costs were sourced from Afrequip, their South African agents (G. Olsen, Tigercat international sales manager, South Africa, personal communication [email], 27 September 2010). This ensured that fair comparisons were made between systems. Exceptions to Tigercat were:

- Morbark CFDD (M. Custers, Ritlee Xecutech managing director, South Africa, personal communication [email], 5 October 2010);
- Precision Husky CFDD&C (F. Breytenbach, Afrequip general manager, South Africa, personal communication [email], 27 September 2010);
- STIHL chainsaw (H. Hutton, National sales manager of STIHL South Africa, personal communication [conversation], 7 October 2010);
- Bell three-wheeled logger (D. Howe, Bell Equipment general manager sales: forestry and sugar, South Africa, personal communication [conversation], 25 September 2010);
- SP harvesting and processing head (T. van Eeden, SP agent, South Africa, personal communication [conversation], 5 October 2010);



 Hitachi – harvester and processor carrier (T. van Eeden, personal communication [conversation], 5 October 2010).

The machine capital costs used in the system costings are shown in Table 37 below.

Machine type	Machine brand and model	Capital cost (US\$)
Wheeled feller buncher	Tigercat 720E	315,717
Grapple skidder	Tigercat 630D	394,798
Three-wheeled logger	Bell 220E Telelogger	80,500
Slasher loader	Tigercat T234 with slasher	381,224
Forwarder	Tigercat 1075B	571,139
CFDD	Morbark 2455	714,371
CFDDC	Morbark 2355	1,059,368
CFDD for chipper below	Precision Husky 2300-4	734,324
Chipper	Precision Husky 2366	589,848
DHP and harvester	Hitachi Zaxis 200 with SP 591	428,571

 Table 35: Capital cost of machines in US\$

# 3.7.1.2 Machine life and depreciation

A machine life of 15,000 productive machine hours (PMH) was used in the cost calculations (Howe, personal communication, 2010; Olsen, personal communication, 2010), with a depreciation period of five years, which was based on the annual utilisation.

# 3.7.1.3 Residual value

A residual value of 20 per cent of the machine purchase price was used in all costings (Brinker, et al., 2002).



# 3.7.1.4 Interest rate

The interest rate was eight per cent, which was the current prime interest rate in South Africa at the time of the costing.

#### 3.7.1.5 Insurance

Insurance rates per machine were obtained from Brinker, et al. (2002) and are included in Table 38 below. The insurance rate varies per machine due to the different risk profiles of the various machines.

(Brinker, et al., 2002)				
Machine	Percentage of purchase price			
Grapple skidder	5%			
Feller buncher	4.5%			
Harvester, DHP and forwarder	4%			
CFDD & CFDDC & chipper	2%			
Three-wheeled logger	2%			
Slasher loader	1.5%			

Table 36: Insurance (percentage of purchase price) costs for the various machines used

3.7.1.6 Scheduled machine hours (SMH)

All machines were scheduled to work two shifts of eight hours each per day. The SMH per day was therefore 16 hours. Systems were scheduled to work six days per week. An additional 13 days was removed from the balance of the days available in the year to make provision for public holidays and other possible non-productive time (for example, weather or mill-related delays). Therefore, the machines were scheduled to work for 300 days per year, or 4,800 SMH.



# 3.7.2 Operating costs

The various operating assumptions and costs of the machines and systems are described below.

# 3.7.2.1 Machine utilisation

A machine-utilisation rate of 65 per cent was used (Brinker, et al., 2002). This describes the percentage of SMH that the various machines will actually be working. Even though delays were measured during the field research, these values were not used to determine machine utilisation. To determine machine utilisation levels accurately, the research needed to be carried out over a longer period. For example, the CFDD-based systems process from one landing for some time before moving and setting up at a new landing. If the time taken to carry out the move and setup is incorrectly proportioned to productive time, then an incorrect machine-utilisation figure will be used, which will affect system costs. Therefore, published figures for machine utilisation were used. A machine utilisation of 65 per cent would result in 3,120 PMH being used out of the available 4,800 SMHs. The equivalent would be 5.2 PMH per eight hour shift. However, the systems would have to be balanced and this could change the final utilisation figure.

# 3.7.2.2 Repair-and-maintenance factor

The repair-and-maintenance cost factor has also been taken from Brinker, et al. (2002). Table 39 below shows the factors used per machine. It is calculated as a percentage of the capital cost of the machine, divided over the economic life of the machine. The repair-and-maintenance cost used in the costings included the total cost of purchasing and running a full workshop and doing daily infield maintenance on the machines. Tyre-and-track replacement is also included. However, the repair-and-maintenance figure does not distinguish between labour cost, back-up vehicle cost and the cost of spare parts, tyres and tracks.



Machine	Percentage
Feller buncher	100%
Grapple skidder	90%
Forwarder	100%
Slasher stacker	90%
CFDD, CFDDC, Chipper	100%
Three-wheel loader	100%

#### Table 37: Repair-and-maintenance cost factors

#### 3.7.2.3 Parts not included in the repair-and-maintenance factor

Table 40 gives all the additional consumable parts that were not included in the repair-cost factor, but needed to be included in the machine cost calculations. The costing considers how many of each part are required, the economic life of each part, as well as the cost of each part.

Machine	Part	Cost each	Number required	Life (PMH)	Source
Feller buncher	Cutting teeth	\$9,300.00	1 (set)	2,500	Olsen, personal communication, 2010
CFDD	Chains	\$8.00	78 per flail	30 (Precision 40 hrs)	Nantz, personal communication, 27 Sept, 2010
CFDDC	Knives	\$24.40	12	50	Nantz, personal communication, 2010
Slasher	Bar and sprocket	\$714.00	1	350	Olsen, personal communication, 2010
Slasher	Chain	\$195.00	1	70	Olsen, personal communication, 2010
Harvester/ processor	Bar and sprocket	\$400.00	1	200	Olsen, personal communication, 2010
Harvester/ processor	Chain	\$145.00	1	50	Olsen, personal communication, 2010

 Table 38: Additional parts important for the costings



#### 3.7.2.4 Fuel consumption

The diesel price per litre was R8.19 (US\$1.17), which was the current price at the pump in South Africa. Fuel cost is measured as litres consumed per PMH. The fuel (diesel) consumption figures described by Grobelaar (2000) have been used in the cost calculculations. They are based on a factor (0.268) multiplied by the nominal power (kW) of the machine and an engine-load factor. The 0.268 multiplied by the nominal power determines the fuel consumption at full engine speed. The load factor is used to reduce this factor to a level more representative of the operating conditions. A load factor of 40 per cent (an amount which is often used in contract agreements) was used with the feller buncher, grapple skidder and forwarder, as they were deemed to be executing above-average work. The load factors for the other machines ranged from 50 to 60 per cent and reflect the heavier work loads of these machines in relation to their engine sizes. Grobelaar (2000, p.293) described it as "heavy work in hard jobs". A load factor of 20 per cent was used with the chipper, as this is a high-capacity machine that has a very low volume of trees fed through per hour in relation to its potential. The load factor of 20 per cent is described by Grobelaar (2000, p.293) as "average work load". The figures used are outlined in Table 41 below.

Machine	kW	Factor	Load factor	Fuel cons/ PMH
Tigercat 720E	142	0.268	0.4	15.2
Tigercat 630D	194	0.268	0.4	20.8
Bell 220E Telelogger	49	0.268	0.5	6.6
Tigercat T234 with slasher	129	0.268	0.5	17.3
Tigercat 1075B	205	0.268	0.4	22.0
Morbark 2455	354	0.268	0.6	56.9
Morbark 2355	783	0.268	0.5	104.9
Precision Husky 2300-4	432	0.268	0.5	57.9
Precision Husky 2366	875	0.268	0.2	46.9
Hitachi Zaxis200 with SP 591	118	0.268	0.6	19.0

Table 39: Diesel consumption rates per machine

#### 3.7.2.5 Oil and lubrication costs

Table 42 shows the rates used in the cost calculation to determine the cost of lubrication for all machines as a percentage of the fuel cost. The cost is calculated as a percentage of the fuel cost per PMH. It is based on whether the machine has no hydraulics, simple hydraulics or extensive hydraulics.



Machine	Lubricant, % of fuel cost
Feller buncher, grapple skidder, forwarder, three- wheeled loader, slasher loader, CFDD, CFDDC, disc chipper	15%
Harvester, DHP, chainsaw	20%

# Table 40: Cost of lubricants as a percentage of fuel cost(adapted from Grobelaar, 2000, p.293)

# 3.7.3 Machine-operator wages

The operator wage rate was set at \$1,700.00 per month (\$9.80 per hour), which is an industry norm in South Africa (F. Oberholzer, CMO harvesting contractor owner, South Africa, personal communication [conversation], 30 September 2010). The chainsaw-operator wage for the topping function in the CFDD system was \$700.00 per month (\$4.03 per hour). The hourly rate reflected in the costing includes this figure, as well as an additional US\$15.76 for the daily operating costs of a chainsaw (Oberholzer, personal communication, 2010). The operator costs are cost-to-company amounts and therefore include all overheads. The working days were calculated at 21.67 days per month. Owing to the machines operating six days per week and 300 days per year, additional operators would need to be available in the system, as operators need time off, would have to take annual leave and, possibly, sick leave. An allowance for this has been made in the costing by allocating 1.1 operators for each machine per shift. The operator wages reflect as a cost per PMH in the Excel costing models.

# 3.7.4 Overheads and other costs and assumptions

The various overhead assumptions and costs of the machines and systems are described below.

# 3.7.4.1 Overhead costs

A 10 per cent overhead cost (Grobelaar, 2000) has been added to the base harvesting machine costs.



# 3.7.4.2 Other costs and assumptions

Other general assumptions used in the Excel costing model are shown in Table 43

Log length	5.2 m
Average slope	Level to moderate
Ground roughness	Smooth
Extraction distance (all systems)	250 m
Exchange rate	US\$1.00 = ZAR7.00
Machine moves with low-bed per year	4 moves @ US\$1,300 per move

 Table 41: Other general assumptions used in the systems costings

# 3.7.5 Cost data analysis conclusion

The systems were then balanced to ensure that the annual volume for each machine in the system was the same. Because each machine has a different productivity for a given tree size, the annual volume output per machine would differ. Balancing can be by increasing productivity or the SMHs. Alternatively, more machines can be added to the system (Stokes & Hartsough, 1993). Balanced systems incur the lowest cost, as long as there is sufficient machine capacity to overcome temporary system imbalances. There also has to be enough buffer stock between machines to allow them to continue for a period after the machine before or after them has stopped unexpectedly. The results of the Excel based machine and system costings are included in the results section, and copies of costings are included in Annexure C.

# 3.8 Shortcomings and sources of error

The CFDD operator did not pay sufficient attention to using the tools at his disposal to increase productivity and improve debarking quality. The operator tended to feed the same number of trees through per cycle for a given average tree size, regardless of the debarking quality. It is uncertain why the operator behaved like this. By changing the number of flails on each drum, flail speeds, feed speeds and number of trees per cycle, an optimal productivity for a given set of operating conditions could be achieved. However, this is not thought to have affected the research results.

When measuring the trees infield for the harvester, a sample was taken to determine the tree volumes within the compartment. These volumes were used to determine the DBH cutoff points for tree size class. A mistake was made in determining the upper cut-off DBH for



the class 2 tree size and, therefore, also the lower cut-off point in the class 3 tree size. This resulted in an incorrect marking of trees infield. The mistake was only discovered after the trees had been processed. This made it necessary to combine tree-size classes 2 and 3 into one class, which was renamed class 3. This created class had a new midpoint tree size of 0.125 m<sup>3</sup>.



# 4 Results and discussion

The results-and-discussion section has been structured to provide an overview of descriptive statistics results for all the processing machines. Following this, the results for each processing machine have been presented separately. Then the statistical results are presented and these culminate in the productivity models. Productivity data is then entered into the Excel based costing models to determine the United States dollar (\$) costs per cubic metre (m<sup>3</sup>) of timber harvested. This is followed by a discussion of the results as evidenced by both processing machine and tree size.

# 4.1 Processing machine productivity: results and discussion

The sample size and average tree size were presented in Section 3 (Research design and methodology). The mean cycle times for all the processing machines are set out in Table 44 below.

CFDD, CFDDC and CFDD&C	Mean cycle time (minutes)	Average trees per bundle
CFDD	0.68	4.33
CFDDC	0.52	1.63
CFDD&C	0.39	2.45
DHP	0.44	1
Harvester	1.00	1

# Table 42: Mean cycle times for processing machines

Table 44 shows that the CFDD tended to have a much higher cycle time (0.68 min/cycle) than the CFDDC (0.52 min/cycle) and CFDD&C (0.39 min/cycle). This can be attributed to more trees being fed through simultaneously, with a longer delay until the next bundle was fed through. Other differences between these machines are due to the differences in the average tree size best accommodated by each processing technology. The cycle time for the DHP was very low (0.44 min/cycle) in relation to the harvester (1.00 min/cycle), due to no felling, cross-cutting or topping elements taking place, as well as a shorter debarking cycle. This low cycle time reflected a good BWBS (indicated below) and good form. To investigate the importance of this, a summary of the average BWBS and form factors has been provided in Section 4.1.2 and 4.1.3 to determine whether these aspects had any effect on the productivity levels achieved.



# 4.1.1 Effect of tree-size class on productivity

The productivity figures described for all processing machines included all data for a specific tree-size class, regardless of BWBS, form or quality produced. Productivity was expected to increase as tree-size class increased, as long as the tree size remained within the physical limits of the machine. A brief overview of the productivity results is given below, with a more detailed discussion in the sections covering the individual processing machines.

Figure 55 shows the different productivity levels of the different processing machines per tree-size class, as per the summary of statistical results.



Figure 52: Processing technology productivity per tree-size class

Figure 55 shows that the CFDD had the highest overall productivity levels across all tree size classes, especially in the larger tree-size classes. It had the lowest productivity of all the multi-stem processors in tree-size class 1. The CFDD&C and CFDDC productivity was very similar across all tree-size classes. However, the CFDDC productivity was slightly higher in the smaller tree-size classes. Tree-size class 5 of the CFFDC was slightly lower than that of the CFDD&C, but then the CFDDC had a much higher productivity in tree-size classe 6. The DHP had much higher productivity than the harvester for all tree-size classes: this is most noticeably with the large tree-size classes. These general trends are discussed in more detail in the sections that follow.



# 4.1.2 Effect of only BWBS class on productivity

From the analysis run in Microsoft Excel (2003), to determine whether any results could be obtained by examining the productivity achieved for each BWBS class (ignoring tree-size class), the results did not add any value to the research as tree-size class was the main factor affecting productivity. Each BWBS class was principally influenced by the dominant tree-size class in that BWBS class. Figure 56 provides the average BWBS class occurring for each processing technology. The CFDD generally had the highest BWBS class (3.8) to process and the DHP the lowest (2.6). The BWBS values were sufficiently close together to ignore their effect on productivity. However, if the DHP and harvester were to work in trees with very high BWBS classes, it was expected that the productivity levels would be closer together. This is discussed in greater detail later in this chapter. An opportunity exists for more detailed research on the effects of BWBS on productivity to be undertaken. Annexure B provides the results of some of the summarised statistics for BWBS.





# 4.1.3 Effect of form class on productivity

Figure 57 gives the average form class for each processing technology. These form values were calculated by summing the form class values for each machine and dividing the result by the number of trees processed. Almost all data for the various processing technologies were found in form class 1. The harvester processed the trees with the lowest average form class (1.0) and the CFDDC the trees with the highest (1.3). The other processing technologies processed trees with an average form class of 1.1. This lack of variation made



it impossible to monitor the effect of form class on productivity. For the effects of form on productivity to be known, further research would have to take place.



Annexure B provides the results of some of the summarised statistics for form class.

#### Figure 54: Average form class for each processing technology

#### 4.1.4 Debarking quality

Poor debarking quality occurs due to the various processing machine's being unable to remove all bark from the tree. This could be due to a number of factors:

- $\circ$  the operator not processing the tree for long enough;
- o too many trees being processed in multi-stem machines simultaneously;
- trees with differing BWBS being fed through the multi-stem machine simultaneously;
- small trees being propelled through the multi-stem machines together with larger trees. Under these circumstances, the feed rollers could not gain sufficient grip on and control over the small trees to ensure proper debarking.

Annexure B provides the results of some of the summarised statistics for the debarkingquality class.



# 4.1.5 Productivity-model results

The productivity models developed in STATISTICA were used to determine machine productivity. The productivity-model results for processing technology are discussed in the sections below.

#### 4.1.5.1 Productivity-model result risks when considering bundle size

For each technology, a table was set up in Microsoft Excel (2003) that illustrated productivity for the different tree-size classes and bundle-size combinations (between 1 and 10 trees per bundle). Every combination of the above values was entered into the equation. Some coefficients were not relevant or proved insignificant and were excluded, for example:

- o bundle size with the DHP and harvester;
- o bundle size and tree-size interaction with the CFDDC model;
- an intercept for the harvester mode.

As per the data-analysis section, the model was accurately able to predict productivity within the range of tree-sizes encountered during the research. The productivity tables developed in the sections below, on the other hand, was able to predict productivity levels for all treeand bundle-size combinations, whether they were practically possible or not. Therefore, the model was trying to make productivity predictions in some cases for tree- and bundle-size combinations that had not been encountered in the research and are not even possible. For example, it is not possible to put 10 trees, each measuring 0.55 m<sup>3</sup>, through a machine at one time. It is also very unlikely that only one tree of 0.025 m<sup>3</sup> would be fed through the machine at a time. In situations such as these, it is quite likely that the model would produce unrealistic productivity results. Interpretation is therefore required to determine where the model is producing realistic values and where not.

To identify the unrealistic productivity outputs, it was necessary to overlay the occurrence of actual combinations of tree- and bundle sizes encountered in the research over the results offered by the productivity-model matrix. The sections on the individual processing technologies discussed below also provide an indication as to the extent to which each model is limited.

The average bundle size encountered during the research for each tree-size class had to be used in the productivity equations to make final predictions for productivity and tree-size. It was not possible to use a modelled bundle-size result as it was not possible to determine



which bundle size was preferable. Figure 58 shows the average bundle sizes found in each tree-size class for each of the machines that processed bundles.



Figure 55: Average bundle size per tree-size class value per processing technology

In Figure 58, small sample sizes are identified by the yellow (n = 10 to 19) and red (n < 10) tabs. Bundle sizes processed by the CFDD were larger than those of the CFDDC and CFDD&C. With regard to the CFDD, bundle sizes for the 0.025 m<sup>3</sup> tree-sizes are small, but increase in size up to the 0.15 m<sup>3</sup> trees. This was not expected and is due to a small sample size in this tree-size class. Even though the 0.075 m<sup>3</sup> tree size of the CFDD is not highlighted as having a small sample size, only 44 bundles were processed as opposed to tree-size classes 3 to 5, which all have sample sizes greater than 119. It is unlikely in that 0.075 m<sup>3</sup> trees would have fewer trees per bundle than the 0.15 m<sup>3</sup> trees. In general, the CFDD&C had marginally (between 0 and 0.8 more trees per bundle) larger bundle sizes than the CFDDC. The CFDD&C had a small sample size in the 0.55 m<sup>3</sup> class (class 6). However, the trend of the data does not seem to indicate this as being problematic. The process that was followed for each processing technology is discussed in the sections outlining individual results.

The results of the summarised statistics that show the productivity results for the processing technologies are discussed below. In all of the figures in the sections below, a red data point indicates that the sample size was less than 10 and the yellow data point shows that the sample size was between 10 and 19. An enlarged data point indicates that more than 50 per cent of that tree-size and BWBS-class combination had quality classes of 2 and 3. It is important to remember that quality-class 2 still falls within mill specifications (half to one per



cent), but class 3 does not meet the specifications (more than one per cent). Thereafter, the detailed statistical results are presented.

# 4.1.5.2 Chain-flail debrancher debarker (CFDD): productivity results

The productivity results of the CFDD are discussed below.

#### 4.1.5.2.1 CFDD productivity per tree-size class

Table 45 provides the summary of statistical results for the CFDD. The productivity figure offers all data for a specific tree-size class, regardless of BWBS, form or debarking quality produced.

Tree-size				n % of	
class	Mean	Std dev	n	sample	Variance
1	13.07	9.90	12	1.37	98.02
2	36.49	13.68	44	5.03	187.12
3	69.57	28.37	411	46.97	805.06
4	83.33	27.66	289	33.03	765.20
5	89.46	26.96	119	13.60	727.10
6				0	

#### Table 43: Summary of statistical results: CFDD

Tree-size class 1 of the CFDD had a small sample size of 12. Most of the trees of the CFDD were found in tree-size class 3 (47 per cent), followed by class 4 (33 per cent). The standard deviation for the CFDD varies from 9.9 to 28. The lower standard deviations occurred in the smaller tree-size classes and the higher standard deviations in the larger tree classes. The productivity results are explained further with Figure 59, which shows the productivity of the CFDD when considering tree-size class only.





Figure 56: CFDD productivity per tree-size class

As indicated in the research design and methodology section, no tree-size class 6 trees were found in the research. As with the tree-size and BWBS combinations above, this is based upon examination of the Microsoft Excel (2003) worksheet data and no modelling has taken place. Tree-size class 1, indicated in yellow, has a sample size of less than 20 and should be interpreted with caution. It is, however, following the productivity trend demonstrated by the remainder of the graph. There is a rapid increase in productivity over the first three tree-size classes, then productivity increase starts to taper off from class 4. There is a very large difference in productivity from tree-size class 1 (13 m<sup>3</sup> per PMH) to tree-size class 5 (89 m<sup>3</sup> per PMH).

The CFDD struggled with large trees. Often the operator would feed the bundle into the machine and then have his attention diverted elsewhere (for example, to the residue pile). He would not notice that the infeed rollers were not able to pull the trees in. Only once this was noticed would the operator then pull the tree into the machine, using the crane. It is expected that relatively minor design changes would be able to rectify these large-tree infeed problems with the CFDD. These machines are relatively new in *Eucalyptus* and it does not appear that the problem of a slippery bole (for example, when the infeed rollers have removed some of the bark), has yet been mastered.

Additional points that could affect the productivity results of the CFDD are outlined below.

 For bigger trees to be pulled into the CFDD easily, the trees needed to be at the same level as the infeed rollers. At the same time, the tree had to be lifted by the crane so that the larger butt-end half of the tree was parallel to the ground. The straighter the path of the trees through the machine, the easier the infeed. If the trees



entered at an angle off the horizontal, the infeed rollers struggled to pull the bigger trees in.

- If the trees were not spread out during the infeed, debarking quality reduced, with the smaller trees being poorly debarked.
- If too many trees were fed through the CFDD at once, some of the bark tended to be ejected at the out-feed.

#### 4.1.5.2.2 Modelled productivity results: CFDD

Table 46 provides the modelled productivity for different tree- and bundle-size combinations.

Trees per	Tree-size in m <sup>3</sup>					
bundle	0.025	0.075	0.15	0.25	0.4	0.55
1	-10.8	2.8	19.7	35.6	45.0	37.2
2	0.9	16.1	35.3	54.3	68.3	65.2
3	10.8	27.5	49.1	71.1	89.9	91.4
4	18.8	37.1	61.0	86.2	109.6	115.8
5	25.1	44.9	71.2	99.4	127.5	138.3
6	29.5	50.9	79.5	110.9	143.6	159.1
7	32.1	55.1	86.0	120.5	157.8	178.0
8	32.9	57.4	90.6	128.2	170.3	195.1
9	31.9	57.9	93.5	134.2	180.9	210.4
10	29.0	56.6	94.5	138.3	189.7	223.9

 Table 44: CFDD modelled productivity data for tree- and bundle-size combinations

In Table 46, the tree sizes indicate the tree-size classes used in the data collection and all tree-size combinations were modelled, regardless of whether or not they were practically possible. The table clearly shows that some of the productivity figures cannot be achieved in reality. For example, tree-size 0.025 m<sup>3</sup> and bundle-size 1 have a negative productivity figure of -10.8 m<sup>3</sup> per PMH and tree-size 0.55 m3 and bundle-size 10 have an impossibly high figure of 223.9 m<sup>3</sup> per PMH.

To identify where the model has predicted productivity correctly, all tree- and bundle-size combinations that occurred during the research have been highlighted in green in Table 46. This helps to explain the unrealistic data for the large tree- and bundle-size combinations, but does not explain the small tree- and bundle-size combinations. To understand the data better, the productivity result for the average bundle size encountered within each tree-size class has been reflected in red print.



In Table 46, the bundle size for each tree class has been rounded up or down to the nearest class. For example, the actual bundle size for tree-size class 1 (0.075 m<sup>3</sup> tree) was 2.83 trees, but this has been rounded up to 3 trees per bundle. The result of this process gives an indication of the productivity for each average bundle size per tree-size class actually encountered in the research. The productivity result for tree-size 0.025 m<sup>3</sup> trees is low. The reason for this is the very small sample size in this tree-size class (n = 12). The table also seems to indicate that there would be a reduction in productivity with large trees of 0.55 m<sup>3</sup>. However, there is no actual data to verify this premise.

Figure 60 was then produced from the productivity model, which used the exact average bundle size (not rounded off) for each tree-size class.



Figure 57: CFDD modelled productivity using actual bundle sizes per class

Figure 60 shows that no 0.55 m<sup>3</sup> trees were encountered during the research. The CFDD was capable of very high productivity levels, although the productivity began to taper off at a tree size of 0.25 m<sup>3</sup>. This suggests that approximately 0.4 m<sup>3</sup> was the maximum tree size that the machine could process comfortably. Because of the small sample size for trees of 0.025 m<sup>3</sup>, and the lack of data for trees of 0.55 m<sup>3</sup>, only the four intermediate tree sizes were used in the system-costing section. The model worked well in these four tree sizes.

# 4.1.5.3 Chain-flail debrancher debarker chipper (CFDDC): productivity results

The productivity results of the CFDDC are discussed below.



# 4.1.5.3.1 CFDDC productivity per tree-size class

Table 47 provides the summary of statistical results. The productivity figure shows all data for a specific tree-size class, regardless of BWBS, form or debarking quality produced.

Tree-size				n % of	
class	Mean	Std dev	n	sample	Variance
1	23.99	15.57	106	5.94	242.57
2	35.42	16.39	296	16.57	268.60
3	48.19	20.21	495	27.72	408.50
4	53.70	26.46	220	12.32	700.00
5	58.21	21.49	397	22.23	461.90
6	76.12	33.44	272	15.23	1118.10

Table 45: Summary of statistical results: CFDDC

Table 47 shows that the largest tree-size class was class 3 (28 per cent), but this was closely followed by tree-size class 5 (22 per cent). Increasing variation occurred as the tree-size class became larger (243 in class 1 to 700 in class 4). The standard deviation for the CFDDC varied from 16 to 33. As indicated, the lower standard deviations occurred in the smaller tree-size classes and the higher standard deviations in the larger tree-size classes due to their increased variability in cycle times.

Figure 61 shows CFDDC productivity per tree-size class.



Figure 58: CFDDC productivity per tree-size class



Figure 61 shows that the CFDDC had large sample sizes for each tree-size class. It evidenced relatively high productivity even in tree-size class 1 (24 m<sup>3</sup> per PMH), with a steady productivity increase to tree class 5 (58 m<sup>3</sup> per PMH). Tree-size class 6 for the CFDDC did not seem to follow the trend of productivity increase with tree-size class increase. There appears to be a spike in productivity with these very large trees. It could be that the CFDDC used in the research was able to handle large trees very well: indeed, the researcher observed that the CFDDC was able to feed large trees in easily, while the CFDD and CFDD&C were not able to pull such trees in effectively. The operators of the CFDDCs had also been working on these machines for some time and that, combined with a longer development period in *Eucalyptus*, could have resulted in the higher productivity in both the small and large tree-size classes.

Additional points that could affect the productivity results of the CFDDC are outlined below.

- As with the CFDD, the straighter the path of the trees through the machine, the easier the infeed.
- If too many trees were fed through the CFDDC at a time, the trees could potentially not debark properly and the chips could have high bark content.
- Even though the Australian operators saw merit in leaving the bigger branches and tops infield (to improve the productivity of the skidder and CFDDC, and to reduce the amount of slash being handled at the landing), the lack of chainsaw operators prevented this from happening.

# 4.1.5.3.2 Modelled productivity results: CFDDC

Table 48 provides the modelled productivity for different tree- and bundle-size combinations.

Trees	Tree-size in m <sup>3</sup>						
per	0.025	0.075	0.15	0.25	0.4	0.55	
bundle	0.025	0.075	0.15	0.25	0.4	0.55	
1	9.4	19.5	33.2	48.5	65.3	74.7	
2	26.5	36.6	50.2	65.5	82.3	91.7	
3	36.7	46.8	60.4	75.7	92.5	101.9	
4	40.2	50.3	63.9	79.2	96.0	105.4	
5	36.9	47.0	60.6	75.9	92.7	102.1	
6	26.8	36.9	50.5	65.8	82.6	92.0	
7	9.9	20.1	33.7	49.0	65.8	75.2	
8	-13.7	-3.6	10.0	25.3	42.1	51.5	
9	-44.1	-34.0	-20.4	-5.1	11.7	21.1	
10	-81.3	-71.2	-57.5	-42.3	-25.5	-16.1	

Table 46: CFDDC modelled productivity data for tree- and bundle-size combinations



Table 48 shows the same procedure has been followed as with the CFDD. The table shows that the model was not able to predict the productivity accurately when very large bundle sizes were involved, even with small tree sizes. This makes sense, as very few large bundle sizes were encountered during the research, as may be seen from the data highlighted by the green shading.

The results in red print in Table 48 for tree-sizes 0.025 m<sup>3</sup> and 0.075 m<sup>3</sup> per tree showed very similar productivities. This is due to the rounding of the bundles sizes and would not occur when using actual bundle sizes for each tree size.

Figure 62 was then produced from the productivity model, using the exact average bundle size (not rounded off) for each tree-size class.



Figure 59: CFDDC modelled productivity using actual bundle sizes per class

The difference in the productivity of tree-sizes 0.025 and 0.075 m<sup>3</sup> are now evident, where Table 48 did not show this difference. The CFDDC showed a steady increase in productivity from small to large tree sizes (32.5 to 74.7 m<sup>3</sup>/PMH). This indicates that the CFDDC could process very small trees productively and that the maximum machine capacity for processing larger trees had not yet been met. It would be possible to carry out system costings on all of the tree-size categories, as the model predictions are all good.



# 4.1.5.4 Chain-flail debrancher debarker and chipper (CFDD&C): productivity results

The productivity results of the CFDD&C are discussed below.

#### 4.1.5.4.1 CFDD&C productivity per tree-size class

Table 49 provides a summary of statistical results for the CFDD&C. The productivity figure outlines all data for a specific tree-size class, regardless of BWBS, form or debarking quality produced.

Tree-size class	Mean	Std dev	n	n % of sample	Variance
1	17.97	10.48	53	3.29	109.83
2	30.07	14.04	302	18.77	197.10
3	40.80	16.21	877	54.51	262.80
4	48.79	20.95	258	16.03	438.90
5	59.21	25.34	106	6.59	642.00
6	59.80	23.61	13	0.81	557.30

#### Table 47: Summary of statistical results: CFDD&C

Table 49 shows that tree-size class 6 of the CFDD&C had a small sample size of 13. The largest class was class 3 at 55 per cent of the sample. The remaining classes were lower. The standard deviation for the CFDD&C ranged from 10.5 to 25. The lower standard deviations occurred in the smaller tree-size classes and the higher standard deviations in the larger tree-size classes. Figure 63 shows CFDD&C productivity per tree-size class.







The productivity of the CFDD&C increased steadily from tree-size class 1 (18 m<sup>3</sup> per PMH) to tree-size class 5 (59.8 m<sup>3</sup> per PMH). The productivity for class 6 (60 m<sup>3</sup> per PMH) is almost the same as for class 5. This was not expected and is due to the small sample size of fewer than 20 trees (as indicated by the yellow bar in Figure 63). The CFDD&C was not tested at the upper extremes of the tree sizes, but there were large sample sizes for tree-size class 5 and below.

As with the CFDD, the CFDD&C struggled to feed large trees into the machine. The operator would feed the bundle into the machine and then divert his attention elsewhere (for example, to the residue pile or chip truck) and not notice that the infeed rollers were not able to pull the trees in. Only once this was noticed would the operator pull the tree into the machine, using the crane. It is expected that, like the CFDD, relatively minor design changes could rectify these large-tree infeed problems with the CFDD&C system. These machines were also relatively new in *Eucalyptus* at the time of the research and it appears that they had not quite mastered the problem of a slippery bole when the infeed rollers had removed some of the bark.

Additional points that could affect the productivity results of the CFDD&Care outlined below.

- The four flails of the CFDD may not have been necessary as the bark was detaching fairly easily. However, should BWBS become very poor, the four flails may become especially important to maintain high productivity.
- Occasionally, trees wedged themselves against the entrance of the chipper and the chipper crane dislodged them and fed them in.
- Unless there was a tree wedged or slash had to be moved away from the outfeed of the CFDD or the waste chute of the chipper, the chipper operator was largely idle.

# 4.1.5.4.2 Modelled productivity results: CFDD&C

Table 50 provides the modelled productivity for different tree- and bundle-size combinations.



Trees per	Tree-size in m <sup>3</sup>					
bundle	0.025	0.075	0.15	0.25	0.4	0.55
1	0.2	10.4	23.5	36.7	47.8	48.3
2	10.6	22.5	38.1	54.7	70.8	76.3
3	17.7	31.3	49.4	69.4	90.5	101.1
4	21.6	36.8	57.4	80.7	106.9	122.5
5	22.1	39.0	62.1	88.8	120.0	140.6
6	19.4	37.9	63.5	93.6	129.8	155.4
7	13.3	33.5	61.7	95.1	136.3	167.0
8	4.0	25.9	56.5	93.3	139.6	175.3
9	-8.6	14.9	48.1	88.2	139.5	180.2
10	-24.6	0.7	36.4	79.8	136.2	181.9

#### Table 48: CFDD&C modelled productivity data for tree and bundle size combinations

With Table 50. the same procedure was followed as with the CFDD. The model was not able to predict the productivity when very large bundle sizes were involved – even when the bundles were made up of small trees – as these had not been encountered in the research. When investigating the figures in red print, it becomes evident that the productivity of tree-size 0.55 m<sup>3</sup> (class 6) was very low (48.3 m<sup>3</sup> per PMH). This is due to a very small sample size (n = 13).

Figure 64 was then produced from the productivity model, which used the exact average bundle size (not rounded off) for each tree-size class.







In Figure 64, the CFDD&C showed a steady increase in productivity from the smaller to the larger tree sizes. The productivity for tree-size 0.025 m<sup>3</sup> was low at 15.9 m<sup>3</sup> per PMH. The productivity steadily increased from tree-size 0.025 m<sup>3</sup> to 0.4 m<sup>3</sup> (61.3 m<sup>3</sup> per PMH). It does appear that the maximum machine capacity for processing larger trees had not yet been met, but the lack of data for 0.55 m<sup>3</sup> trees makes this difficult to confirm. Apart from 0.55 m<sup>3</sup> trees, it would be possible to carry out system costings on all other tree sizes.

# 4.1.5.5 Dangle-head processor (DHP): productivity results

Because the DHP was a single-tree processing technology, bundle size was not applicable.

#### 4.1.5.5.1 DHP productivity per tree-size class

Table 51 provides the summary of statistical results. The productivity figure covers all data for a specific tree-size class, regardless of BWBS, form or debarking quality produced.

Tree-size class	Mean	Std dev	n	n % of sample	Variance
1	4.13667	1.053691779	6	1.109057	1.110266
2	11.62016	2.79422673	46	8.502773	7.8
3	18.10968	4.168914468	159	29.39002	17.4
4	43.26392	10.38421083	285	52.68022	107.8
5	54.89744	8.630957948	45	8.31793	74.5
6				0	

 Table 49: Summary of statistical results: DHP

In Table 51, tree-size class 1 for the DHP had a small sample size of six trees. The DHP mostly processed trees in tree-size class 4 (53 per cent), with class 3 next at 29 per cent. The standard deviation for the DHP varied from 1 to 10. The lower standard deviations occurred in the smaller tree-size classes and the higher standard deviations in the larger tree-size classes.

Figure 65 shows the productivity per tree size of the DHP.





Figure 62: DHP productivity per tree-size class

Figure 65 shows that productivity remained relatively low for tree-size classes 1 to 3 (4 to 18 m<sup>3</sup> per PMH). Productivity then increased rapidly for classes 4 and 5 (43 and 55 m<sup>3</sup> per PMH). There were no class 6 trees found in the research. It is more than likely this exponential increase in productivity is due to the DHP being a single-tree processing technology, dominated by the debarking element in the work cycle. Because the debarking element consumed such a large proportion of the work cycle, increases in tree size caused large increases in productivity.

Tree-size class 1 was very small (fewer than 10 trees), but still seemed to follow the trend of the graph in Figure 65. It appears that the productivity at class 6 was starting to taper off, but only the presence of class 6 trees would have been able to confirm this. The DHP did not work in any BWBS class 5 trees, and in very few BWBS class 4 trees. It is highly likely that the productivity curve would have been significantly lower had the DHP worked predominantly in BWBS classes 4 and 5.

Additional points that could affect the productivity results of the DHPare outlined below.

 Only one grapple skidder was required because it was able to place more inventory in front of the DHPs than the CFDDs or CFDDCs. The DHPs took some time to work through the stockpile, as they only processed one tree at a time. Had the DHP run out of timber, it could easily have moved along the processing area to where other trees had been placed by the grapple skidder.



- Should the grapple skidder have had an extended breakdown, the DHPs were fully functional as harvesters. They could then have started felling and processing trees along the edge of the compartment.
- Even though sufficient labour was available to top trees and remove large branches, it was not used. This is mainly due to the shorter period between tree felling and debarking. The feller buncher did not work with large buffer stocks between it and the DHP. Had it done so, the BWBS would have become strong and the productivity of the DHPs would have dropped.

#### 4.1.5.5.2 Modelled productivity results: DHP

Because the DHP only processed single trees at a time, bundle sizes were not investigated. Figure 66 shows the results of the modelled productivity.



Figure 63: DHP modelled productivity per tree size

Figure 66 shows that the negative productivity value of -0.2 m<sup>3</sup> per PMH for tree-size 0.025 m<sup>3</sup> is due to the very small sample size (n = 6). The productivity predictions for the remainder of the tree sizes are good. There were large productivity increases from tree-size 0.075 m<sup>3</sup> (9.7 m<sup>3</sup> per PMH) to 0.4 m<sup>3</sup> (52.0 m<sup>3</sup> per PMH). Productivity appeared to be tapering off at tree-size 0.55 m<sup>3</sup>, which could indicate that the physical limitations of the machines were being reached. Only tree-size 0.025 m<sup>3</sup> would have to be excluded from the system's costings.



# 4.1.5.6 Harvester (CTL): productivity results

The productivity results of the Harvester are discussed below.

#### 4.1.5.6.1 Harvester productivity per tree-size class

Table 52 provides the summary of statistical results. The productivity figure contains all data for a specific tree-size class, regardless of BWBS, form or debarking quality produced.

Tree-size				n % of	
class	Mean	Std dev	n	sample	Variance
1	2.11853	0.362244	21	4.666667	0.131221
2				0	
3	8.395013	1.49414	112	24.88889	2.2
4	17.61269	2.134215	201	44.66667	4.6
5	24.48229	3.067869	112	24.88889	9.4
6	29.62448	5.374509	4	0.888889	28.9

#### Table 50: Summary of statistical results: harvester

Table 52 shows that tree-size class 6 for the harvester had a small sample size of four trees. The harvester had tree-size class 4 as the dominant class (45 per cent), followed by both classes 3 and 5 (at 25 per cent) (again note that class 3 consisted of both tree-size classes 2 and 3). The standard deviation for the harvester varied from 0.4 to 5. The lower standard deviations occurred in the smaller tree-size classes and the higher standard deviations in the larger tree-size classes.

An additional point that could have affected the productivity results of the harvester was that the harvester operator's view was more restricted with the construction-type excavators than it would have been with purpose-built forestry excavators.

# 4.1.5.6.2 Modelled productivity results: harvester

As per the DHP, the harvester only processed single trees at a time, and therefore bundle sizes were not investigated. Figure 67 shows the results of the modelled productivity.





Figure 64: Harvester modelled productivity per tree size

Tree-size 0.025 m<sup>3</sup> is not highlighted in Figure 67 as having a small sample size, but it's sample size was relatively small (n = 21), which could possibly be influencing the model at the very small tree sizes. However, as indicated in the literature review, harvesters do have very low productivity when processing very small trees. Tree-size 0.55 m<sup>3</sup> also had a very small sample size (n = 4), although the productivity graph does appear to be following the correct trend. However, when investigating the performance of the harvester at this tree size, there was a tapering off of productivity. Therefore, the modelled productivity figure for tree-size 0.55 m<sup>3</sup> should be used with care. Tree-size 0.025 m<sup>3</sup> and 0.55 m<sup>3</sup> should not be used in the system costings.

# 4.1.5.7 Productivity summary of results of processing equipment

The standard deviation was always lower in the smaller tree-size categories and increased with tree size. The high standard deviations found for the processing equipment are typical for research carried out on this type of forestry equipment because of high variability within the cycle time and bundle size (Spinelli, et al., 2002a).

The single-tree processing technologies of the DHP and harvester had the lowest standard deviations. As tree size increased and many trees were processed at once, so the standard deviation increased. This is to be expected as the harvester and DHP have certain cycle elements that are fixed, regardless of tree size. However, as tree size increased with these two machines, the debarking/debranching element consumed a progressively larger percentage of the total cycle time, thus increasing the variation in cycle time and therefore increasing the standard deviation.



With the CFDD, CFDDC and CFDD&C, the standard deviations were higher as there was only one dominant work element (debarking/debranching). This is a naturally variable element because of the complexity of removing the bark and the speed of the trees through the machine. Smaller trees being fed through showed less variation as there tended to be a more consistent feed of trees into the machine. As tree size increased, feeding of new trees into the machine while the previously introduced trees were still being processed could occur at any time, making the cycle length variable. Also, because few big trees were fed through per cycle, the effect of new trees being fed while the other tree/s was/were still being processed was compounded. Further research will be required into the influence of the individual cycle elements to determine whether it is necessary to try to reduce this variation. Figure 68 shows the productivity results in m<sup>3</sup> per PMH for all of the processing technologies.



Figure 65: Processor modelled productivity based on tree size

In Figure 68, the enlarged yellow and red tab points signify small sample sizes of less than 10 and 20 respectively. As indicated in the sections above, the 0.025 m<sup>3</sup> and 0.55 m<sup>3</sup> of the CFDD; the 0.55 m<sup>3</sup> of the CFDD&C; the 0.025 m<sup>3</sup> of the DHP; and the 0.025 m<sup>3</sup> and 0.55 m<sup>3</sup> of the harvester would not be used in the costing because small sample sizes resulted in incorrect productivity results. Owing to so many of the very small (0.025 m<sup>3</sup>) and very large (0.55m<sup>3</sup>) tree sizes not being suitable, it was decided to carry out all further evaluations on tree sizes 0.075 m<sup>3</sup>, 0.15 m<sup>3</sup>, 0.25 m<sup>3</sup> and 0.4 m<sup>3</sup>. This was not deemed problematic, as it is unlikely for *Eucalyptus* pulpwood operations to function in such small or large trees.



Figure 69 on the following page shows the same modelled processor productivity as Figure 68, but excludes the smallest and largest tree sizes. This was the information that would be used in the Excel based machine and systems costings.



# Figure 66: Modelled processor productivity excluding large and small tree sizes

Considering Figure 69, additional points that could affect the productivity results are outlined below.

- Excluding the 0.075 m<sup>3</sup> tree size (very similar to the CFDDC at approximately 40 m<sup>3</sup> per PMH), CFDD had the highest overall productivity, increasing more quickly than for any of the other processing equipment, but flattening off at 0.4 m<sup>3</sup> per PMH.
- The CFDDC productivity remained slightly higher than the CFDD&C throughout the range of tree sizes.
- The DHP productivity started low (9.7 m<sup>3</sup> pr PMH), but followed a steep gradient to 52.0 m<sup>3</sup> per PMH in 0.4 m<sup>3</sup> trees. It is interesting that the DHP productivity for 0.4 m<sup>3</sup> trees differed from the CFDD&C and CFDDC by only 10 m<sup>3</sup> per PMH and 15 m<sup>3</sup> per PMH respectively. It is predicted that the gap would become much wider with a very high BWBS class. This requires further research.



In relation to the other processing equipment, the harvester productivity for the 0.075 m<sup>3</sup> tree size was very low (5.0 m<sup>3</sup> per PMH) and had the flattest of all the productivity gradients, only reaching 22.2 m<sup>3</sup> per PMH in 0.4 m<sup>3</sup> trees.

To conclude the section on productivity results, even though the productivity models were able to include bundle size as an input variable, the average bundle size per tree-size class encountered during the research had to be used. The predictions based on tree size were very good where the sample size was large enough. Owing to small sample sizes in the research data, tree-size classes 1 and 6 were not used for cost calculations.

# 4.2 Cost of systems: results and discussion

The cost results presented in Section 4.2 are all based on balanced systems for each processing technology for each tree size evaluated. The cost results of the individual machines and the systems in which they operated are presented first, followed by cost comparisons. Even though the costs per PMH are indicated, this financial figure only becomes valuable when combined with the productivity achieved and is usually the most important result for forest managers. The systems selected were the same as those used in the trials, but these are highlighted again when the results of each processing technology are discussed below. The productivity information obtained in the research for the processing equipment was used in the system costings. Forestry Solutions work-study data (Forestry Solutions, 2010) were used for the remainder of the machines in the system.

An important consideration when comparing the costs is that comparisons are being made between two different products – logs and chips. This will be discussed further under the summary discussion of the results.

# 4.2.1 CFDD system cost results

The system cost results for the CFDD are described below.

# 4.2.1.1 CFDD system cost results: productivity figures used

The productivity figures obtained from Section 4.1 and used in the system costing per machine and per tree size can be found in Table 53.



Machine or activity	0.075m <sup>3</sup> /tree (m3/PMH)	0.15m <sup>3</sup> /tree (m3/PMH)	0.25m <sup>3</sup> /tree (m3/PMH)	0.40m <sup>3</sup> /tree (m3/PMH)
Feller buncher	34.2	56.3	76.1	98.1
Grapple skidder	31.6	46.8	55.6	69.2
CFDD	40	69.8	86.4	95.1
Logger	24	36	50	64.8
Slash	48	75	93.8	120

#### Table 51: Productive rates of the CFDD system equipment per tree-size class

#### 4.2.1.2 CFDD system cost results: balancing

Figure 70 shows the number of machines required to balance the system, as well as the annual volume required, for each tree size. Two feller bunchers were required for all tree sizes except 0.40 m<sup>3</sup>, which required two. Two grapple skidders, one CFDD, two loggers and one slasher were required for all the tree sizes. Annual system production increased from 130,000 m<sup>3</sup> to 300,000 m<sup>3</sup> as tree size increased. This is due to all the machines in the system becoming more productive in larger trees.



Figure 67: CFDD machine and volume requirements per system and tree size

The system balancing in Figure 70 took place around the CFDD as it was the most productive machine. Only one CFDD was required for each tree size. Theoretically, slightly more than one feller buncher was required for felling with the first three tree sizes, which,



practically, meant two were used. The lowest cost was obtained by fully utilising the CFDD, which still made it cost-effective to include two feller bunchers. This is clearly shown in Figure 71, which shows machine utilisation.



Figure 68: Machine utilisation per CFDD system per tree size

Figure 71 shows that the utilisation of the feller buncher for the first three tree sizes was just under 40 per cent. In practice, the feller buncher might have an increased SMH to try to avoid purchasing a second machine. The feller buncher might also be carefully managed in an attempt to achieve a higher utilisation percentage within the planned SMH. For 0.4 m<sup>3</sup> trees, only one feller buncher was required, which increased its utilisation to over 60 per cent.

The grapple skidders also experienced low utilisation through the tree sizes. All systems that included the flail method of debarking used a minimum of two grapple skidders. This is due to the hot nature of the system. Little stock could be kept at the infeed of the CFDD or CFDDC. If the grapple skidder broke down and there were only one in the system, the CFDD or CFDDC would have to stop working almost immediately. For the same reason, two Bell three-wheeled loggers were also required in the system, regardless of their individual utilisations. The CFDD or CFDDC would be able to work for slightly longer than if a grapple skidder had broken down, but there would soon be a mass of debarked tree lengths congesting the landing and stopping the entire system.


There was a steep increase in the volume required both to balance the system and to keep the machines sufficiently utilised as the tree size increased. For 0.075 m<sup>3</sup> trees, 125,000 m<sup>3</sup> was required, but this increased to nearly 300,000 m<sup>3</sup> for 0.4 m<sup>3</sup> trees.

#### 4.2.1.3 CFDD system cost results: costs per PMH

Table 54 shows the results of the machine costs per PMH for the CFDD.

	Ownership cost (\$/PMH)	Machine operating cost (US\$/PMH)	Operator costs (\$/PMH)	Overhead costs (\$/PMH)	Total cost (\$/PMH)	Total cost (\$/yr)
Feller buncher	44.26	48.07	46.02	13.83	152.18	277,578
Grapple skidder	52.24	54.31	28.87	13.54	148.96	293,483
CFDD (0.075m <sup>3</sup> )	52.81	188.25	16.75	25.78	283.60	884,820
Logger	7.16	16.25	20.15	4.36	47.92	124,289
Slasher	33.14	48.27	20.13	10.15	111.69	289,974
Feller buncher	41.77	47.91	43.45	13.31	146.45	282,958
Grapple skidder	44.20	53.91	24.44	12.25	134.80	313,821
CFDD (0.15m <sup>3</sup> )	52.81	188.25	16.75	25.78	283.60	884,820
Logger	6.15	15.97	17.30	3.94	43.36	130,983
Slasher	29.65	48.06	18.02	9.57	105.30	305,482
Feller buncher	45.45	48.15	47.27	14.09	154.95	275,190
Grapple skidder	42.45	53.82	23.47	11.97	131.71	319,285
CFDD (0.25m <sup>3</sup> )	52.81	188.25	16.75	25.78	283.60	884,820
Logger	6.89	16.18	19.39	4.25	46.70	125,861
Slasher	29.93	48.08	18.18	9.62	105.80	304,138
Feller buncher	26.69	46.94	27.76	10.14	111.53	337,267
Grapple skidder	48.04	54.10	26.55	12.87	141.56	303,269
CFDD (0.40m <sup>3</sup> )	52.81	188.25	16.75	25.78	283.60	884,820
Logger	8.09	16.51	22.78	4.74	52.13	119,597
Slasher	34.81	48.37	21.15	10.43	114.77	283,608

Table 52: CFDD system machine costs per PMH

Table 54 shows that because only one feller buncher was used for the 0.40 m<sup>3</sup> trees, it was better utilised than with the other tree sizes where two feller bunchers were required. This translates into a lower cost per PMH for this tree size (\$112 versus \$150 per PMH), as the ownership and operator costs were more diluted. The grapple-skidder costs varied between \$130 and \$150 per PMH because of utilisation levels as two grapple skidders were used



with each tree size. The CFDD costs per PMH stayed constant at \$284 because utilisation was constant per tree size. This is considerably higher than the other machines in the systems and is mainly due to higher machine-operating costs. The Bell three-wheel loggers and slasher had a relatively stable cost of around \$50 and \$110 per PMH respectively, again owing to the relatively stable utilisation levels of these two machines.

# 4.2.1.4 CFDD system cost results: costs per m<sup>3</sup>



System and machine costs per m<sup>3</sup> for each tree size are indicated in Figure 72 below.

Figure 69: CFDD system cost results per m<sup>3</sup> for different tree sizes

Figure 72 indicates that the total cost per m<sup>3</sup> was \$20.61 for 0.075 m<sup>3</sup> trees. There was then a sharp drop to 0.15 m<sup>3</sup> trees, where the cost was \$12.16 per m<sup>3</sup>. The cost decrease slowed after this, with 0.25 m<sup>3</sup> trees costing \$9.74 per m<sup>3</sup> and 0.40 trees, \$7.93 per m<sup>3</sup>. As indicated previously, the small sample size of 0.075 m<sup>3</sup> trees resulted in unusually low tree numbers per bundle, which resulted in productivity being lower than expected. If this gap in the data were researched further, it is likely that higher productivity would result in the 0.075 m<sup>3</sup> tree class, which would result in lower costs per m<sup>3</sup>.As can be seen in Figure 72, the machine with the highest cost per m<sup>3</sup> across all the tree sizes was the CFDD. This is most pronounced with the 0.075 m<sup>3</sup> tree size (\$7.11/m<sup>3</sup>). The feller buncher costs per m<sup>3</sup> for 0.40 m<sup>3</sup> trees were four times less than that of 0.075 m<sup>3</sup> trees (\$1.14 versus \$4.46). The grapple skidder costs per m<sup>3</sup> for 0.40 m<sup>3</sup> trees were less than half those of the 0.075 m<sup>3</sup> trees (\$2.05 versus \$4.71). After the CFDD, the feller buncher and grapple skidder cost the most per m<sup>3</sup>.



The two poorly utilised feller bunchers (the exception was the 0.40 m<sup>3</sup> trees, which only had one feller buncher) and grapple skidders per system contributed to this cost, but within the system, the overall cost per m<sup>3</sup> was optimised. All feller bunchers and skidders, with the exception of the one feller buncher in 0.40 m<sup>3</sup> trees, had utilisation percentages below 50 per cent.

# 4.2.2 CFDDC system cost results

The system cost results for the CFDDC are described below.

#### 4.2.2.1 CFDDC system cost results: productivity figures used

The productivity values used in the system costing per machine and per tree size can be found in Table 55. These values were obtained from Section 4.1. The feller buncher and grapple skidder productivity figures are the same as those in the CFDD system (Table 53).

Table 53: Productive rates of the CFDDC system equipment per tree-size class

Machine or activity	0.075m <sup>3</sup> /tree (m3/PMH)	0.15m <sup>3</sup> /tree (m3/PMH)	0.25m <sup>3</sup> /tree (m3/PMH)	0.40m <sup>3</sup> /tree (m3/PMH)
Feller buncher	34.2	56.3	76.1	98.1
Grapple skidder	31.6	46.8	55.6	69.2
CFDDC	39.1	47.4	59.7	67.4

## 4.2.2.2 CFDDC system cost results: System balancing

Figure 73 shows the number of machines needed to balance the system, as well as the annual volume required, for each tree size. One feller buncher was required for all tree sizes except 0.075 m<sup>3</sup>, which required two. Two grapple skidders and one CFDDC were required for the different tree sizes. Annual system production increased from 150,000 m<sup>3</sup> to 210,000 m<sup>3</sup> as tree size increased. This is due to all the machines in the system becoming more productive in larger trees.





Figure 70: CFDDC machine and volume requirements per system and tree size

As can be seen in Figure 74, the systems were balanced around the CFDDC as it was the most productive machine and the largest potential bottleneck in the system.



Figure 71: Machine utilisation per CFDDC system per tree size

Figure 74 shows that the utilisation of the CFDDC remained a constant 65 per cent for all the tree sizes. Apart from tree-size 0.075 m<sup>3</sup>, which required two feller bunchers, all the tree sizes had the same system requirements for machines. For tree-size 0.075 m<sup>3</sup>, a scenario was run whereby the utilisation of the CFDDC was reduced so that only one feller buncher



would be required. This resulted in higher system costs than if two feller bunchers had been included, but the CFDDC was fully utilised. The effect of using two feller bunchers for this tree size is illustrated by the low utilisation of the two machines, merely 37 per cent. Again, two grapple skidders were forced into the system for the same reasons provided in the CFDD system balancing. This resulted in low utilisation of the two skidders, less than 40 per cent, for all tree sizes.

The volume requirements increased from 120,000 m<sup>3</sup> per year for 0.075 m<sup>3</sup> trees to 210,000 for 0.40 m<sup>3</sup> trees.

## 4.2.2.3 CFDDC system cost results: costs per PMH

Table 56 shows the results of the machine costs per PMH for the CFDDC.

	Ownership cost (\$/PMH)	Machine operating cost (US\$/PMH)	Operator costs (\$/PMH)	Overhead costs (\$/PMH)	Total cost (\$/PMH)	Total cost (\$/yr)
Feller buncher	45.33	48.14	29.35	12.28	135.10	240,581
Grapple skidder	53.51	54.38	29.58	13.75	151.22	290,807
CFDDC (0.075m <sup>3</sup> )	78.32	281.69	18.13	37.81	415.96	1,297,781
Feller buncher	30.79	47.20	19.94	9.79	107.72	282,402
Grapple skidder	65.29	54.97	36.10	15.64	172.00	271,076
CFDDC (0.15m <sup>3</sup> )	78.32	281.69	18.13	37.81	415.96	1,297,781
Feller buncher	33.02	47.35	21.38	10.17	111.92	273,598
Grapple skidder	61.52	54.78	34.01	15.03	165.35	276,571
CFDDC (0.25m <sup>3</sup> )	78.32	281.69	18.13	37.81	415.96	1,297,781
Feller buncher	37.70	47.65	24.42	10.98	120.75	258,482
Grapple skidder	67.79	55.10	37.48	16.04	176.41	267,774
CFDDC (0.40m <sup>3</sup> )	78.32	281.69	18.13	37.81	415.96	1,297,781

Table 54:	CFDDC s	svstem	machine	costs	per	РМН
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Table 56 shows that the feller-buncher costs per PMH for tree size 0.075 m<sup>3</sup> were higher than those of the larger tree sizes. This was due to lower utilisation levels because two machines were used (\$135 per PMH versus less than \$121 for the rest). The feller bunchers were not working sufficient hours to dilute the higher ownership and operator costs per PMH.



The grapple-skidder cost per PMH slowly increased as the tree size increased (\$151 for 0.075 m<sup>3</sup> trees to \$176 for 0.40 m<sup>3</sup> trees). This was due to the grapple skidders becoming more productive in larger trees, which reduced the utilisation rate. The CFDDC costs per PMH stayed constant, regardless of tree size, as the utilisation rate was constant at 65 per cent. Compared to the other machines in the system, the CFDDC cost per PMH was high, more than double that of the grapple skidder and feller buncher. This is mainly due to the high machine operating costs.

## 4.2.2.4 CFDDC system cost results: costs per m<sup>3</sup>

In the CFDD system above, the costs refer to dollars per  $m^3$  of logs produced at the roadside. With the CFDDC system, the costs refer to dollars per  $m^3$  of chips produced at the roadside. System and machine costs per m3 for each tree size are indicated in Figure 75 below. The total cost per  $m^3$  decreased from \$19.43 for 0.075 m<sup>3</sup> trees to \$9.96 for 0.40 m<sup>3</sup> trees.



Figure 72: CFDDC system cost results per m<sup>3</sup> for different tree sizes

As per Figure 75, the CFDDC had the highest individual machine cost per m<sup>3</sup> across all the tree sizes by some margin. The cost for the CFDDC reduced by approximately \$4.50 between 0.075 m<sup>3</sup> and 0.40 m<sup>3</sup> tree sizes. The feller-buncher cost for the 0.075 m<sup>3</sup> trees was considerably higher than for the other tree sizes. This is due to low utilisation of two feller bunchers compared with high utilisation of only one feller buncher with each of the other tree



sizes. Again, two grapple skidders were used in each system. Therefore, the cost reduction with increasing tree size was only a result of higher productivity in larger trees.

# 4.2.3 CFDD&C system cost results

The system cost results for the CFDD&C are described below.

#### 4.2.3.1 CFDDC&C system cost results: productivity figures used

The productivity figures used in the system costing per machine and per tree size can be found in Table 57. These values were obtained from Section 4.1.

Machine or activity	0.075m <sup>3</sup> /tree (m3/PMH)	0.15m <sup>3</sup> /tree (m3/PMH)	0.25m <sup>3</sup> /tree (m3/PMH)	0.40m <sup>3</sup> /tree (m3/PMH)
Feller buncher	34.2	56.3	76.1	98.1
Grapple skidder	31.6	46.8	55.6	69.2
CFDD	29.4	44.2	53.3	61.3
Chipper	29.4	44.2	53.3	61.3

Table 55: Productive rates of the CFDD&C system equipment per tree-size class

## 4.2.3.2 CFDD&C system cost results: balancing

Figure 76 shows the number of machines needed to balance the system, as well as the annual volume required for each tree size. One feller buncher, two grapple skidders, one CFDD and one chipper were required for the different tree sizes.







Figure 76 shows that the number of machines stayed constant across the entire tree-size range, with five machines required per system. As indicated in the section on balancing the CFDD system, two skidders were forced into the system, but only one of all the other machines was required per system. This is due to the productivity rates of all these machines being higher than that of the CFDD&C. The volume required per system ranged from approximately 90,000 m<sup>3</sup> for the 0.075 m<sup>3</sup> trees to 191,000 m<sup>3</sup> for the 0.40 m<sup>3</sup> trees.



Figure 77 shows machine utilisation within each system.

Figure 74: Machine utilisation per CFDD&C system per tree size

Figure 77 illustrated that the system was balanced around the CFDD and chipper as they were the most expensive machines to operate per PMH, as can be seen in the system-cost section below. Because the CFDD fed straight into the chipper, they had exactly the same utilisation. Utilisation for the CFDD and chipper was 65 per cent for all the tree sizes, apart from tree size 0.075 m<sup>3</sup>, where the utilisation for both machines was 64.2 per cent. This is slightly lower because the annual volume used for all the different processing-technology systems and the various tree sizes within them have been rounded down to the nearest 500 m<sup>3</sup>. This rounded figure is easier to work with and is a more realistic reflection of volume that would be allocated in practice. The feller buncher was better utilised in the 0.075 m<sup>3</sup> trees (55 per cent), but the utilisation dropped as the tree size increased, ending at 41 per cent for the 0.40 m<sup>3</sup> trees. This indicates that, relative to the other machines in the system, the feller buncher was more productive as the tree size became larger. Grapple-skidder utilisation



stays fairly constant at approximately 30 per cent for all the tree sizes. In theory, only one grapple skidder should be required for all the tree sizes, but, as mentioned earlier, the system risks associated with grapple-skidder downtime are too high.

#### 4.2.3.3 CFDD&C system cost results: costs per PMH

Table 58 shows the system machine costs per PMH for each tree size.

	Ownership cost (\$/PMH)	Machine operating cost (US\$/PMH)	Operator costs (\$/PMH)	Overhead costs (\$/PMH)	Total cost (\$/PMH)	Total cost (\$/yr)
Feller buncher	30.49	47.18	19.74	9.74	107.16	283,681
Grapple skidder	71.86	55.31	39.73	16.69	183.59	262,890
CFDD (0.075m <sup>3</sup> )	54.96	190.95	18.36	26.43	290.70	895,815
Chipper	44.15	109.97	18.36	17.25	189.73	584,668
Feller buncher	33.04	47.35	21.40	10.18	111.97	273,505
Grapple skidder	70.04	55.21	38.72	16.40	180.37	265,006
CFDD (0.15m <sup>3</sup> )	54.29	190.93	18.13	26.33	289.68	903,809
Chipper	43.61	109.95	18.13	17.17	188.86	589,242
Feller buncher	37.00	47.60	23.96	10.86	119.42	260,509
Grapple skidder	68.93	55.16	38.11	16.22	178.42	266,348
CFDD (0.25m <sup>3</sup> )	54.29	190.93	18.13	26.33	289.68	903,809
Chipper	43.61	109.95	18.13	17.17	188.86	589,242
Feller buncher	41.84	47.89	26.84	11.62	127.79	248,868
Grapple skidder	74.57	55.44	41.22	17.12	188.35	259,940
CFDD (0.40m <sup>3</sup> )	54.29	190.93	18.13	26.33	289.68	903,809
Chipper	43.61	109.95	18.13	17.17	188.86	589,242

Table 56: CFDD&C system machine costs per PMH

Table 58 shows that the constant utilisation percentage of the CFDD and chipper kept the costs per PMH constant for each tree-size. The CFDD, the machine with the highest cost in all the systems (approximately \$190 per PMH), had a total cost of \$290 per PMH, while the



chipper cost was \$189 per PMH. This is mainly due to high operating costs of the CFDD. Operating cost per PMH was also the highest cost component per PMH for the chipper. These two machines had high fuel consumption rates and the costs of chains were high for the CFDD. With the feller buncher, the total cost per PMH increased with tree size as utilisation increased. Decreasing tree size (hence, utilisation) resulted in fewer machine hours per annum into which the fixed and operator costs could be divided. The total costs per PMH for the grapple skidder stayed fairly constant across all the tree sizes, fluctuating from \$178 to \$188 per PMH. This is due to the utilisation of the grapple skidders remaining fairly constant.

## 4.2.3.4 CFDD&C system cost results: costs per m<sup>3</sup>

The CFDD&C cost results per m<sup>3</sup> reflect the cost of chips at the roadside. System and machine costs per m<sup>3</sup> for each tree size are indicated in Figure 78 below. Included in Figure 78 is a table which reflects the exact values of the individual graph columns.



Figure 75: CFDD&C system cost results per m<sup>3</sup> for different tree sizes

Figures 78 shows that at \$25.30, the system cost per m<sup>3</sup> was very high in 0.075 m<sup>3</sup> trees. There was a large cost reduction per m<sup>3</sup> to \$16.70 in 0.15 m<sup>3</sup> trees. Thereafter, the cost reduction per m<sup>3</sup> slowed, reaching \$13.77 in 0.25 m<sup>3</sup> trees and \$11.84 in 0.40 m<sup>3</sup> trees. The CFDD had the highest cost per m<sup>3</sup> component of the system across all the tree sizes. CFDD costs per m<sup>3</sup> ranged from \$9.90 in 0.075 m<sup>3</sup> trees to \$4.73 in 0.40 m<sup>3</sup> trees. This is followed by the chipper, whose costs per m<sup>3</sup> ranged from \$6.46 in 0.075 m<sup>3</sup> trees to \$3.09 in 0.40 m<sup>3</sup>



trees. When comparing the CFDD&C system with other infield chipping systems, the costs of the CFDD and chipper would need to be combined. There was one feller buncher and two grapple skidders in all the systems. Machine productivity in different tree sizes was responsible for the cost differences.

## 4.2.4 DHP system cost results

The system cost results for the DHP are described below.

## 4.2.4.1 DHP system cost results: productivity figures

The productivity figures used in the system costing per machine and per tree size can be found in Table 59. These values were obtained from Section 4.1.

Machine or activity	0.075m <sup>3</sup> /tree (m3/PMH)	0.15m <sup>3</sup> /tree (m3/PMH)	0.25m <sup>3</sup> /tree (m3/PMH)	0.40m <sup>3</sup> /tree (m3/PMH)
Feller buncher	34.2	56.3	76.1	98.1
Grapple skidder	31.6	46.8	55.6	69.2
DHP	9.7	22.9	37.3	52
Slash	48	75	93.8	120

Table 57: Productive rates of the DHP system equipment per tree-size class

## 4.2.4.2 DHP system cost results: balancing

Figure 79 shows the number of machines needed to balance the system, as well as the annual volume required, for each tree size.





Figure 76: DHP machine and volume requirements per system and tree size

Figure 79 shows that the DHP system had varying machine numbers for different tree sizes, ranging from five machines for 0.15 m<sup>3</sup> trees to six for 0.075 and 0.25 m<sup>3</sup> trees and seven for the 0.40 m<sup>3</sup> trees. Three DHPs were utilised for the 0.075 m<sup>3</sup> trees, but thereafter only two were needed. It was unnecessary to force two grapple skidders into the DHP systems, as a single skidder was able to build up a bank of stock in front of the DHPs. In the case of a grapple-skidder breakdown, this stock would be available to be processed. Also, in the case of an extended grapple-skidder breakdown, the DHPs could move into the compartment to start felling and processing trees into logs if the trees were close to a road. Should the trees be far from a road, the DHPs could produce debarked tree lengths, which the grapple skidder would extract once the breakdown had been overcome. However, two skidders were used for the 0.25 and 0.40 m<sup>3</sup> tree sizes, because of the high production per hour of the two DHPs, necessitating additional extraction capacity. Apart from 0.40 m<sup>3</sup> trees, one feller buncher was required for the other tree sizes. Indeed, the DHPs were so productive at the 0.40 m<sup>3</sup> tree size that two feller bunchers were required. Only one slasher was required for all tree sizes, as this machine's productivity was higher than that of all the other machines. The volume required per annum per system increased greatly from 91,000 m<sup>3</sup> for 0.075 m<sup>3</sup> trees to  $324,000 \text{ m}^3$  for  $0.40 \text{ m}^3$  trees.

Figure 80 shows machine utilisation per DHP system per tree size.





Figure 77: Machine utilisation per DHP system per tree size

Figure 80 shows that the systems have all been balanced around the DHPs. These machines had utilisation rates of 65 per cent (the 0.075 m<sup>3</sup> tree size is 64.8 per cent owing to rounding down to the nearest 500 m<sup>3</sup>). Feller-buncher utilisation was above 50 per cent for tree sizes 0.075 to 0.25 m<sup>3</sup>. Because two feller bunchers were required for the 0.40 m<sup>3</sup> trees, the utilisation dropped to 34 per cent to reflect the shared volume. Grapple-skidder utilisation was high in 0.075 and 0.15 m<sup>3</sup> trees, at 60 per cent and 64 per cent respectively. However, the utilisation dropped for 0.25 and 0.40 m<sup>3</sup> trees (44% and 49% respectively) as two skidders were used. The slasher utilisation increased as the tree size became larger, ranging from 39 per cent for 0.075 m<sup>3</sup> trees, which required greater use of the slasher.

#### 4.2.4.3 DHP system cost results: costs per PMH

Table 60 shows the system costs per PMH for each machine for various tree sizes.



	Ownership cost (\$/PMH)	Machine operating cost (\$/PMH)	Operator costs (\$/PMH)	Overhead costs (\$/PMH)	Total cost (\$/PMH)	Total cost (\$/yr)
Feller buncher	30.49	47.18	32.10	10.98	120.75	319,669
Grapple skidder	34.68	52.67	19.85	10.72	117.93	337,915
DHP (0.075 m <sup>3</sup> )	34.54	64.68	16.81	11.60	127.63	396,922
Slasher	51.26	56.57	27.71	13.55	149.09	281,281
Feller buncher	31.88	47.27	33.58	11.27	124.01	313,895
Grapple skidder	32.61	52.57	18.66	10.38	114.21	348,125
DHP (0.15 m <sup>3</sup> )	34.43	64.67	16.75	11.59	127.44	397,613
Slasher	38.68	50.39	27.50	11.66	128.23	243,763
Feller buncher	26.40	46.92	27.79	11.11	111.22	340,079
Grapple skidder	47.51	53.35	27.20	12.81	140.86	294,609
DHP (0.25 m <sup>3</sup> )	34.43	64.67	16.75	11.59	127.44	397,613
Slasher	29.66	49.75	21.09	10.05	110.56	274,063
Feller buncher	48.88	48.37	51.46	14.87	163.58	270,132
Grapple skidder	42.33	53.08	24.24	11.96	131.61	308,918
DHP (0.40 m <sup>3</sup> )	34.43	64.67	16.75	11.59	127.44	397,613
Slasher	27.23	49.58	19.36	9.62	105.79	285,668

#### Table 58: DHP system machine costs per PMH

Table 60 shows that the total cost per PMH of feller bunchers was higher for the large, 0.40 m<sup>3</sup> trees (\$164 compared with approximately \$120 for the other tree sizes), as two feller bunchers were required for this tree size. As indicated above, these two feller bunchers had low utilisation levels, which increased the ownership and operator component per PMH. Similarly, the grapple skidders evidenced higher total costs per PMH for the 0.25 and 0.40 m<sup>3</sup> trees (\$141 and \$132 per PMH respectively) compared with the costs for 0.075 and 0.15 m<sup>3</sup> trees (\$118 and \$114 per PMH respectively). Two skidders were required in each of these systems compared with only one needed for the two smaller tree sizes. Once again, it is the ownership and operator components which contributed to this increase.

The total cost per PMH of the DHP was the same for most tree sizes owing to the same utilisation levels. There was, however, a minor variance in the 0.075 m<sup>3</sup> trees because of the



marginally lower utilisation. The total cost per PMH for the slasher reduced as tree size increased, decreasing from \$149 per PMH for 0.075 m<sup>3</sup> trees to \$106 for 0.40 m<sup>3</sup> trees. The machine was used for more hours per year with larger trees, which diluted the ownership and operator costs.

## 4.2.4.4 DHP system cost results: costs per m<sup>3</sup>

The DHP system produced logs stacked on the roadside. System and machine costs per m<sup>3</sup> for each tree size are indicated in Figure 81 below.



Figure 78: DHP system cost results per m<sup>3</sup> for different tree sizes

Figure 81 shows that the cost per m<sup>3</sup> in 0.075 m<sup>3</sup> trees was very high in relation to the other tree sizes. The costs per m<sup>3</sup> reduced from \$23.53 in 0.075 m<sup>3</sup> trees to \$11.94 in 0.15 m<sup>3</sup> trees. The cost per m<sup>3</sup> reduction from 0.15 m<sup>3</sup> trees to 0.25 m<sup>3</sup> was still high, decreasing to \$8.60 per m<sup>3</sup>. Thereafter, the cost reduction to 0.40 m<sup>3</sup> (\$6.91) was not as pronounced, but this is still a very low system cost per m<sup>3</sup> with regard to the smaller tree sizes. In the DHP system, the DHP had the highest cost per m<sup>3</sup> for the range of tree sizes. This was most pronounced in the 0.075 m<sup>3</sup> trees, where the DHP cost alone was \$13.16 per m<sup>3</sup>. As the tree size increased, the cost-per-m<sup>3</sup> differential between the DHP and the other machines in the system narrowed. With 0.40 m<sup>3</sup> trees, the DHP was only marginally more expensive per m<sup>3</sup> than the feller buncher and grapple skidder (\$2.44 versus \$1.67 and \$1.91 respectively). The feller-buncher cost per m<sup>3</sup> in 0.40 m<sup>3</sup> trees was higher than in 0.25 m<sup>3</sup> trees (\$1.67 versus \$1.46). Although the feller-buncher cost in 0.40 m<sup>3</sup> trees was expected to be lower, two feller



bunchers were required for these large trees, which resulted in lower machine utilisation and, therefore, slightly higher costs. Even though the feller-buncher costs per m<sup>3</sup> in this tree size were slightly higher, the overall system cost had reduced. Similarly, the grapple-skidder costs per m<sup>3</sup> in the 0.25 m<sup>3</sup> and 0.40 m<sup>3</sup> trees were not as low as expected. This is due to two grapple skidders having been utilised with these two tree sizes as opposed to only one for the smaller tree sizes.

#### 4.2.5 Harvester system cost results

The system cost results for the harvester are described below.

#### 4.2.5.1 Harvester system cost results: productivity figures

The productivity figures used in the system costing per machine and per tree size can be found in Table 61. These values were obtained from Section 4.1.

 Table 59: Productive rates of the Harvester system equipment per tree-size class

Machine or activity	0.075m <sup>3</sup> /tree (m3/PMH)	0.15m <sup>3</sup> /tree (m3/PMH)	0.25m <sup>3</sup> /tree (m3/PMH)	0.40m <sup>3</sup> /tree (m3/PMH)
Harvester	5	9.6	15.2	22.2
Forwarder	25.2	35.7	40.5	51.8

## 4.2.5.2 Harvester system cost results: balancing

Figure 82 shows the number of machines needed to balance the system, as well as the annual volume required, for each tree size.





Figure 79: Harvester machine and volume requirements per system and tree size

The number of harvesters decreased from six for the 0.075 m<sup>3</sup> trees to five for the 0.15 m<sup>3</sup> trees and to four for the 0.25 m<sup>3</sup> and 0.40 m<sup>3</sup> trees. Only one forwarder was required for each system, so the number of harvesters decreased with each tree-size reduction. The annual volume requirements increased from 78,500 m<sup>3</sup> in 0.075 m<sup>3</sup> trees to 162,000 m<sup>3</sup> in 0.40 m<sup>3</sup> trees.

Figure 83 shows the utilisation levels of the various machines in each system for each tree size.







All previous processing-technology systems were balanced around the processing equipment. Figure 83 shows that with the harvester system, the lowest cost per m<sup>3</sup> was obtained by balancing the systems around the forwarder. The forwarder utilisation was 65 per cent for all the tree sizes. The harvesters showed reduced utilisation levels as the tree size increased. For the 0.075 m<sup>3</sup> trees, the harvester utilisation was 65.4 per cent. This is 0.4 per cent higher than the utilisation figures indicated in the assumptions. Had a third harvester been included in this tree-size scenario, utilisation levels of the harvesters would have been too low and the costs would have become very high. In reality, a forest-machine owner would not purchase an additional machine if the utilisation level was a few decimal points away from the indicated maximum utilisation level. For tree sizes greater than 0.075 m<sup>3</sup>, the utilisation levels of the harvesters did decrease from 60 per cent for 0.15 m<sup>3</sup> trees to 58 per cent for 0.25 m<sup>3</sup> trees and to 51 per cent for 0.40 m<sup>3</sup> trees.

#### 4.2.5.3 Harvester system cost results: costs per PMH

		r			1	
	Ownership cost (\$/PMH)	Machine operating cost (US\$/PMH)	Operator costs (\$/PMH)	Overhead costs (\$/PMH)	Total cost (\$/PMH)	Total cost (\$/yr)
Harvester (0.075 m3)	28.50	59.42	16.65	10.46	115.03	361,217
Forwarder	45.89	69.34	18.23	13.35	146.81	458,039
Harvester (0.15 m3)	30.97	59.57	18.08	10.86	119.48	345,367
Forwarder	45.89	69.34	18.23	13.35	146.81	458,039
Harvester (0.25 m3)	32.39	59.65	18.92	11.10	122.06	337,267
Forwarder	45.89	69.34	18.23	13.35	146.81	458,039
Harvester (0.40 m3)	36.91	59.91	21.55	11.84	130.20	315,810
Forwarder	45.89	69.34	18.23	13.35	146.81	458,039

Table 62 shows the harvester machine costs per PMH.

Table 60: Harvester system: machine costs per PMH

Table 62 shows that as the harvester worked in larger trees, its utilisation dropped slightly owing to system balancing and, therefore, the cost per PMH increased. This was due to the ownership and operators' costs not being diluted as much. The total cost per PMH increased



from \$115 per PMH for 0.075 m<sup>3</sup> trees to \$130 for 0.40 m<sup>3</sup> trees. The utilisation of the forwarder stayed the same and, therefore, the total costs per PMH remained at \$147 per PMH for all the tree sizes.

#### 4.2.5.4 Harvester system cost results: costs per m<sup>3</sup>

The harvester system produced logs at the roadside. System and machine costs per m<sup>3</sup> for each tree size are indicated in Figure 84 below.



Figure 81: Harvester system costs per m<sup>3</sup> for different tree sizes

Figure 84 shows that the total cost differences between the harvester system operating in small and large trees were very pronounced. Costs in 0.075 m<sup>3</sup> trees were \$28.84 per m<sup>3</sup>. This dropped to \$16.57 per m<sup>3</sup> in 0.15 m<sup>3</sup> trees, \$11.67 per m<sup>3</sup> in 0.25 m<sup>3</sup> trees and \$8.70 per m<sup>3</sup> in 0.40 m<sup>3</sup> trees. The largest cost per m<sup>3</sup> reduction was between 0.075 m<sup>3</sup> and 0.15 m<sup>3</sup> trees.

The harvester was the main driver of the harvesting-system costs, as the cost difference between the harvester working in 0.075 m<sup>3</sup> and 0.40 m<sup>3</sup> trees was only \$2.99 per m<sup>3</sup>. The difference in harvester costs over the same tree-size range was \$17.14. The harvester cost alone in the 0.075 m<sup>3</sup> trees was \$23.01 per m<sup>3</sup>. It is clear that tree size had a very large effect on harvester productivity, as the reduced cost per m<sup>3</sup> in large trees was achieved with lower machine utilisation.



# 4.3 Summary discussion of results

Table 63 shows the costs per m<sup>3</sup> per tree size for all of the processing technology systems. The interpretation of Table 63 takes place below Figure 85.

	Tree-size (m <sup>3</sup> )					
	0.075m <sup>3</sup>	0.15m <sup>3</sup>	0.25m <sup>3</sup>	0.40m <sup>3</sup>		
CFDD system	20.61	12.16	9.76	7.93		
CFDDC system	19.43	14.39	11.42	9.96		
CFDD&C system	25.30	16.70	13.77	11.84		
DHP system	23.53	11.94	8.60	6.91		
Harvester system	28.84	16.57	11.67	8.70		

Table 61: Processing technology systems costs per tree size

Table 63 can be viewed in conjunction with Figure 85 which gives a graphical presentation of the results.



Figure 82: Processing technology systems costs per tree size

Figure 85 shows there is not one single system which is more cost-effective per m<sup>3</sup> across all the tree sizes. What is common for all systems is the initial high cost in 0.075 m<sup>3</sup> trees, ranging between \$19.43 per m<sup>3</sup> for the CFDDC system and \$28.84 for the harvester system, a difference of \$9.41 per m<sup>3</sup>. The cost differences in the larger 0.40 m<sup>3</sup> trees are much lower, ranging from \$6.91 per m<sup>3</sup> for the DHP system and \$11.84 per m<sup>3</sup> for the CFDD&C, a difference of only \$4.93 per m<sup>3</sup>. It is interesting to note that the cost per m<sup>3</sup> differences between the systems had already narrowed with the 0.15 m<sup>3</sup> trees: the difference between



the most expensive (CFDD&C) and most cost-effective (DHP) is \$4.67 per m<sup>3</sup>. This difference is then maintained through to the largest tree size of 0.40 m<sup>3</sup>.

## 4.3.1 Summary discussion of results for the various processing machine systems

A summary discussion of the results is discussed below. This section provides an overview of the system results per processing technology. Due to five systems being researched, it was necessary to separate them into sub-sections. The summary discussion of results which compares the different processing technology systems takes place per tree size in Section 4.3.2.

## 4.3.1.1 DHP: summary discussion of results

With regard to tree sizes of 0.15 m<sup>3</sup> and larger, the DHP system had the lowest cost, closely followed by the CFDD system. This was unexpected as single-tree processing technologies are often perceived to be higher cost options. An important point to note is that, on average, the DHP processed trees with a BWBS class of 2.6 and the CFDD processed trees with a BWBS class of 3.8. The DHP was more sensitive to BWBS than the CFDD. This became clear during processing, as often the DHP only required one pass to debark the tree. As the BWBS class increased, more passes were required to remove the bark. This caused the productivity per m<sup>3</sup> to drop very rapidly.

Poor tree form also reduced the productivity of the DHP more than it did the multi-tree processing machines. The reason is that with the DHP, the tree had to be tightly gripped and handled, as opposed to being fed through a large chamber that could accommodate crooked and forked trees, as well as trees with large branches. The form class encountered during the research was good. Therefore, the results presented for the DHP are only applicable to situations where the BWBS class is lower than 3 and the form class is good.

## 4.3.1.2 CFDD: summary discussion of results

The CFDD managed to produce low costs per m<sup>3</sup> for all the tree sizes greater than 0.075 m<sup>3</sup>. As explained previously, the cost results for tree size 0.075 m<sup>3</sup> could possibly have been lower. These low costs were achieved even while processing trees with a high BWBS class of 3.8. However, because there were quality-related issues when debarking the trees of higher BWBS classes, it is likely that the productivity and, therefore, cost per m<sup>3</sup> would not reduce should trees with a lower BWBS be processed.



This system has further potential for cost reduction, for example, through the use of a frontend-loader with a timber grab as a substitute for one skidder and one logger. This machine could be used to extract trees if the grapple skidder broke down or was undergoing scheduled maintenance. It could also help remove debarked tree lengths from the outfeed of the CFDD, should the logger not be available. This type of front-end-loader would also be more effective at handling the residue generated by the CFDD.

Further cost-improvement opportunities exist through machine modifications and better planning, for example, of landing locations. The use of the Morbark 2455 CFDD in *Eucalyptus* was new and modifications to increase the capabilities of parts such as the infeed rollers would also enhance productivity.

Removing the tops and large branches after felling with chainsaws appeared to contribute to the increased productivity of the CFDD, as more trees could be fed through in one cycle. Grapple-skidder productivity was also improved as less residue had to be removed. This was not proven scientifically, but is an observation made after visiting other operations where the trees were not topped.

#### 4.3.1.3 CFDDC: summary discussion of results

The CFDDC was expected to have higher costs than the systems which produced logs, as one more processing function (chipping) had to be carried out. However, because the chips were being produced by the same machine that debarked and debranched, the cost increase was reduced. Also, the complexities of handling debarked tree lengths and loading them onto trucks were removed as the chips were fed straight into chip trucks. This resulted in the CFDDC having the lowest system cost for 0.075 m<sup>3</sup> trees at \$19.43 per m<sup>3</sup>. The CFDDC cost curve as tree size increased was flatter than that of the other systems though, with the cost for 0.40 m<sup>3</sup> trees at \$9.96 per m<sup>3</sup>. This is still competitive, considering that no chipping had to take place at the processing plant.

#### 4.3.1.4 CFDD&C: summary discussion of results

The CFDD&C-system cost was not competitive in any of the tree sizes analysed. It had the second highest cost for 0.075 m<sup>3</sup> trees (with only the harvester system being more expensive) and proved to be the highest cost system for all larger trees. The costs of two large processing machines, each with their own operators, were not diluted sufficiently by increased productivity. For this system to be competitive, the processing machines would have to have much higher productivity levels to make up for the high costs per PMH.



The Precision Husky CFDD used in the research was fairly new in *Eucalyptus* and machine modifications would improve productivity further. For example, the trees were often not drawn into the machine by the infeed rollers: the trees would be placed and the operator would swing the crane to remove residue from the hydraulic residue discharger, but the infeed rollers could not grip the trees and pull them in. This wasted time, which reduced productivity. If the infeed rollers were modified to have better grip on the butt of a *Eucalyptus* tree, the productivity would increase substantially, especially with larger trees where the problem was most pronounced.

In Western Australia, trials have been carried out where two CFDDs feed a single chipper as the chipper is not fully productive when fed by only one CFDD (Cameron, personal communication, 2010). This system required two feller bunchers and three grapple skidders in order to keep the CFDD&Cs fed with trees and would have very high annual volume requirements. Further research needs to take place into the current CFDD&C system to see whether modifications made have increased the productivity sufficiently to reduce cost.

Importantly, if the forest manager requires a system that can produce logs, chips and potentially use harvesting residue, this system is able to meet all these needs.

#### 4.3.1.5 Harvester: summary discussion of results

The harvester system is not an option in very small trees sizes such as the 0.075 m<sup>3</sup> trees. It had the highest system cost for this tree size at \$28.84 per m<sup>3</sup>, approximately \$3.00 more expensive than the next most costly machine. It was still very expensive for 0.15 m<sup>3</sup> trees (\$16.57), costing approximately the same as the CFDD&C system. With trees of 0.25 m<sup>3</sup>, it started to become competitive at approximately the same cost as the CFDDC and less than the CFDD&C. However, it was still nearly \$2.00 per m<sup>3</sup> more than the CFDD and \$3.00 per m<sup>3</sup> more than the DHP.

That being said, the other advantages, such as improved terrain handling and lower environmental impact, could encourage companies to consider paying this cost premium on the harvester system. The harvester was cost-competitive with 0.40 m<sup>3</sup> trees. At \$8.70 per m<sup>3</sup>, it was only \$0.77 per m<sup>3</sup> more expensive than the CFDD system and \$1.79 per m<sup>3</sup> more expensive than the DHP system. Unless residue was required at the landing, it is likely that the harvester system would be selected for 0.40 m<sup>3</sup> trees, owing to the advantages mentioned above, as well the system requiring a lower density road network.



The harvester observed during the research worked in trees with very good form (class 1) and good BWBS (class 3). An increase in the form and BWBS classes would reduce the productivity of the harvester. To quantify this, further research would need to be carried out.

# 4.3.2 Summary discussion of results per tree size

A brief overview is given below of the cost results per m<sup>3</sup> for different tree sizes. The results of the different processing technologies have already been described above.

# 4.3.2.1 Summary discussion of results for 0.075 m<sup>3</sup> trees

Table 64 shows the system costs in 0.075 m<sup>3</sup> trees.

#### Table 62: System costs in 0.075 m<sup>3</sup> trees

CFDD	CFDDC	CFDD&C	DHP	Harvester
20.61	19.43	25.30	23.53	28.84

The CFDDC system was the most cost-effective with 0.075 m<sup>3</sup> trees, expenditure being slightly lower than with the CFDD system. As mentioned already, the small sample size of the CFDD in this tree-size class is probably negatively affecting the cost per m<sup>3</sup>: it could be that the CFDD system had the lowest cost in 0.075 m<sup>3</sup> trees. Compared with the other multi-tree processing systems (CFDDC and CFDD&C), the CFDD had a much larger reduction in productivity with trees ranging between 0.075 m<sup>3</sup> and 0.15 m<sup>3</sup> in size in relation to the 0.075 m<sup>3</sup> starting point of \$8.45 per m<sup>3</sup> or 40 per cent of the 0.075 m<sup>3</sup> value. This is not consistent with the other CFDDC and CFDD&C results, which had reductions of \$5.04 (26 per cent) and \$8.60 per m<sup>3</sup> (34 per cent), or with the results produced by Spinelli, et al. (2009). This is further indication the CFDD would, in fact, be the lowest cost system for 0.075 m<sup>3</sup> trees. The harvester was the most expensive system in this tree size.

## 4.3.2.2 Summary discussion of results for 0.15 m<sup>3</sup> trees

Table 65 shows the system costs in 0.15 m<sup>3</sup> trees.

Table 63: System costs in 0.15 m<sup>3</sup> trees

CFDD	CFDDC	CFDD&C	DHP	Harvester
12.16	14.39	16.70	11.94	16.57



The highest cost reductions per m<sup>3</sup> between 0.075 m<sup>3</sup> and 0.15 m<sup>3</sup> trees were found with the harvester and DHP systems. The reduction in the harvester system was \$12.27 per m<sup>3</sup> and that of the DHP system, \$11.59 per m<sup>3</sup>. The system costs per tree size were much closer to each other for the 0.15 m<sup>3</sup> tree size than the 0.075 m<sup>3</sup>, and were the closest together of all the tree sizes. The harvester and CFDD&C systems had similarly high costs at \$16.70 and \$16.57 per m<sup>3</sup> respectively, while the CFDD and DHP systems had correspondingly low costs at \$12.16 and \$11.94 per m<sup>3</sup> respectively. The CFDDC may be found approximately midway between these two groups, at \$14.39 per m<sup>3</sup>.

# 4.3.2.3 Summary discussion of results for 0.25 m<sup>3</sup> trees

Table 66 shows the system costs for 0.25 m<sup>3</sup> trees.

Table 64: System costs in 0.25 m<sup>3</sup> trees

CFDD	CFDDC	CFDD&C	DHP	Harvester
9.76	11.42	13.77	8.60	11.67

The DHP system had the lowest cost at \$8.60 per m<sup>3</sup>. This is \$1.16 lower than the CFDD system, at \$9.76 per m<sup>3</sup>. The CFDD&C was more than \$2.00 per m<sup>3</sup> higher than any of the other systems. The CFDDC and harvester systems were in-between, with costs of \$11.42 and \$11.67 per m<sup>3</sup> respectively.

# 4.3.2.4 Summary discussion of results for 0.40 m<sup>3</sup> trees

Table 67 shows the system costs in 0.40 m<sup>3</sup> trees.

Table 65: System costs in 0.40 m<sup>3</sup> trees

CFDD	CFDDC	CFDD&C	DHP	Harvester
7.93	9.96	11.84	6.91	8.70

With 0.40 m<sup>3</sup> trees, the DHP remained the lowest cost system at \$1.02 per m<sup>3</sup> lower than the CFDD system. The CFDD&C was still not competitive, but the harvester costs were much closer to those of both the DHP and CFDD, making it a contender for system selection, as mentioned above.



## 4.3.2.5 Summary discussion of results for annual volume requirements per tree size

Figure 86 gives an indication of the annual volume requirements for each processing system per tree size.



Figure 83: Annual system volume requirements per tree size

All of the systems had increased volume requirements in large tree sizes as they were more productive with large trees. The largest volume requirements occurred with the CFDD when processing trees of 0.15 m<sup>3</sup> or larger; the CFDDC in 0.40 m<sup>3</sup> trees; and the DHP in trees larger than 0.25 m<sup>3</sup>. It is possible that the contractor or company might not have sufficient volume for these systems if processing specific tree sizes or if there is insufficient volume on the terrain that these full-tree systems need to operate efficiently. The harvester was the least sensitive to annual volume across all the tree sizes, followed by the CFDD&C and then the CFDDC.

# 4.3.3 Results conclusion

Trees with longer debarking elements as a percentage of the total cycle time have much higher productivity standard deviations. This mostly applies to the CFDD, CFDDC and CFDD&C, but also to the DHP and, lastly, the harvester. Any variable which affects the debarking element when it is the element that consumes the most time in the cycle will result in high variations.



When the harvester operated in small trees, the debarking element was relatively low compared with the total cycle time. As tree size became larger and the BWBS strength higher, the debarking element consumed an increasingly higher proportion of the total cycle time. This means there was higher variation in cycle times (and, therefore, productivity). For example, if BWBS is low with the DHP, the machine picks up the tree, feeds it through the head once and then places it down. However, if the BWBS is high, the machine needs to run the tree through the head many times before placing it. Therefore, there is a rapid drop in productivity if the DHP is compared with the harvester, where the cycle time is still being buffered by many other elements. As BWBS increased, the DHP and harvester productivity per m<sup>3</sup> moved closer together.

The research results showed that the productivity equations developed for the different processing technologies were able to predict the actual harvesting productivity within the range of researched tree sizes.

Tree and bundle size played important roles in productivity determination of the various machines. Tree size was expected to play a dominant role, as this is what the literature had indicated. Bundle size was also of importance, as not feeding sufficient trees through per cycle resulted in suboptimal productivity.

With the CFDD and CFDD&C, it was still possible for an experienced operator to determine the correct number of trees per cycle by looking at the debarking quality of the debarked trees. The models provide assistance in determining the optimal number of trees of a particular size that should be fed through the multi-stem processors at one time. Knowing the correct bundle size is of specific importance to an inexperienced CFDD operator. This knowledge is also invaluable to a CFDDC operator, who has to speculate even more in an effort to determine whether optimal productivity is being achieved at the correct quality. It should be noted that the models are not able to provide an optimal bundle size for each treesize class.

It is clear that the full-tree systems with chain-flail technology, hence able to handle multiple stems throughout the system, are much less sensitive to tree-size than systems with DHP and harvester-head technology (CTL). This mass handling of trees, stems and logs compensates for situations where small tree sizes are encountered. The cost graphs for the various processing technologies demonstrate this. There is a large cost increase with the harvester system in very small tree sizes of 0.075 and 0.15 m<sup>3</sup> trees. This is due to the harvester only being able to fell and process one tree at a time.



For the type of conditions encountered in the research and when logs are required, the results show that all trees of approximately  $0.075 \text{ m}^3$  should be harvested utilising the CFDD system. If cost per m<sup>3</sup> is the primary consideration,  $0.15 \text{ m}^3$ ,  $0.25 \text{ m}^3$  and  $0.40 \text{ m}^3$  trees should be harvested with a DHP system.

When harvesting trees of 0.40 m<sup>3</sup>, the harvester system might be better. Even though this is not the system with the lowest cost, other benefits, such as reduced environmental impact and lower road-density requirements, make it an attractive option.

Should the BWBS increase above class 3 or the form factor reach class 2 or higher, the CFDD system should be selected for all the tree sizes. The DHP operated in trees with good BWBS and very good form classes and it is predicted that the harvester and DHP would have a significant reduction in productivity (with concomitant cost increases), should the BWBS or form classes increase. If forest-management policy dictates that harvester systems should be used, the only way to reduce costs would be to manage according to a regime which allowed trees to grow to a larger individual size. The administrators of a particular company would have to determine what cost premium they would be prepared to pay for the additional, non-direct cost benefits that a harvester system can offer.

If producing chips, the most cost-effective system over all the tree sizes researched is the CFDDC system. It had the lowest cost of all the systems in 0.075 m3 trees (although as discussed, it is predicted that the CFDD is actually more economical).

If making a decision whether to chip trees in the forest or at a processing facility, it is clear that the cost difference between the chipping systems and log-production systems could make chip production in the forest worthwhile.



# 5 Conclusions and recommendations

This final chapter concludes the research. The main findings are summarised and briefly discussed. The results are related to the findings of the literature review. The significance of the results to the forestry industry is indicated and recommendations for the practical application of the results in future are offered.

## 5.1 Summary and discussion of main findings

There is currently a global increase in *Eucalyptus* pulpwood plantations. Harvesting systems traditionally utilised in the northern hemisphere are being used in *Eucalyptus* pulpwood plantations worldwide. However, the small tree size and complexity of debarking *Eucalyptus* have provided harvesting with productivity and cost challenges not previously experienced in northern-hemisphere conditions.

Cut-to-length (CTL) and full-tree systems have been the two main mechanised harvesting methods available to forestry managers. CTL systems process trees into logs at the stump inside the compartment; with full-tree systems, the tree is felled and then extracted to a landing where it is processed – its top and branches remain intact. An advantage of full-tree systems is their ability to handle multiple stems, which could assist in overcoming current problems with the small, pulpwood tree sizes.

Much research has been invested in these two harvesting methods in northern-hemisphere species and conditions. The literature identified tree size as being the major driver of processing-machine productivity for all tree species. With single-stem processing machines, the relationship between tree size and productivity is direct. However, with multi-stem processing machines, the number of trees processed at one time (bundle size) influences productivity.

There is little research available on mechanised processing-machine productivity and costs in *Eucalyptus*. This investigation therefore aimed to quantify the effect that tree and bundle size has on the productivity of different processing machines in *Eucalyptus* plantation pulpwood. This was done through regression analysis, whereby productivity models that included tree size and bundle size were constructed.

The research also aimed to determine whether or not the multi-stem systems were more cost-effective in smaller tree sizes. Because the processing machines carried out different



processing functions, it was not possible to make machine or system decisions based on productivity alone. The research therefore costed out different harvesting systems associated with each processing machine for different tree sizes.

The research investigated five mechanised harvesting options that forestry managers could use in *Eucalyptus* pulpwood plantations. These systems consisted of one CTL system, one full-tree system with single-stem processing and three full-tree systems with multi-stem processing. All the full-tree systems used feller bunchers to fell trees and grapple skidders to extract them. The CTL system, researched in South Africa, used a harvester to process the trees into logs and to extract them. The full-tree system with single-stem processing, also researched in South Africa, used a dangle-head processor (DHP) to process trees into logs. The first full-tree system with multi-stem processing used a chain-flail debrancher/debarker (CFDD) to produce debarked and debranched tree lengths, which were slashed into logs. This system was researched in Chile. The remaining full-tree, multi-stem systems were researched in Western Australia. They both produced chips. The first used a chain-flail debrancher/debarker/chipper (CFDDC) and the second, a CFDD feeding into a stand-alone disc chipper (CFDD&C).

The productivity of the processing machines was measured on site, using time-and-motion study methods. The tree-size class, BWBS class and form class for each tree were identified before processing. For the multi-stem processing machines, the number of trees per bundle was measured while the bundle was being fed into the machine. Debarking quality was measured once processing had taken place. The productivity data, measured as m<sup>3</sup> per productive machine hour (PMH), was then statistically analysed using regression techniques. Productivity equations were formulated, considering tree size and bundle size, as well as the quadratic functions of these two variables and the interaction between them. Bundle size was only applicable to the multi-stem processing machines. The productivity equations use successfully predicted processing-machine productivity, using tree size and bundle size as input variables.

The first hypothesis underpinning this study offered a null and an alternative premise. Because productivity was effectively predicted, the null hypothesis was rejected and the alternative hypothesis recognised as valid:

Prediction models **are able** to relate productivity of chain-flail debrancher/ debarkers, chain-flail debrancher / debarker / chippers, chain-flail debrancher/ debarker and chippers, dangle-head processors and harvester-processing machines to tree size and bundle size.



The second hypothesis upon which this study is based led to an investigation of whether or not full-tree, multi-stem systems had lower costs than CTL and full-tree, single-stem processing systems in very small tree sizes.

The question of bundle size is complex. Inserting an increasing number of trees per bundle into the equation for a given tree size resulted in a productivity curve. It was not known exactly which bundle size should be used to predict processing-machine productivity for a given tree size, because in many cases the productivity curve continued to increase. Therefore, the actual bundle size observed during the research for each tree size class was used in the productivity prediction equation. As indicated in section 5.4 (Recommendations for the future) below, bundle size needs to be researched further.

The models provided the following productivity information:

- Apart from the 0.075 m<sup>3</sup> tree size, the CFDD had the highest overall productivity. When processing 0.075m<sup>3</sup> tree sizes, this machine reflected a similar productivity level to the CFDDC: approximately 40 m<sup>3</sup> per PMH. The CFDD productivity per PMH increased more rapidly than that of the other processing machines indeed, it proved capable of very high productivity levels, although the productivity began to taper off at a tree size of 0.25 m<sup>3</sup>. The CFDD processed 0.40 m<sup>3</sup> trees at 95 m<sup>3</sup> per PMH.
- The CFDDC, which can productively process small trees, showed a steady increase in productivity as tree sizes increased, ranging between 39.1 m<sup>3</sup> and 67.4 m<sup>3</sup> per PMH.
- Productivity levels in the CFDD&C also increased consistently from smaller (0.075 m<sup>3</sup>) to larger (0.40 m<sup>3</sup>) tree sizes: from 29.4 m<sup>3</sup> to 61.3 m<sup>3</sup> per PMH. The CFDDC productivity remained slightly higher than the CFDD&C throughout the range of tree sizes.
- DHP productivity started low (9.7 m<sup>3</sup> per PMH for 0.075 m<sup>3</sup> trees), but increased sharply to 52.0 m<sup>3</sup> per PMH with 0.40 m<sup>3</sup> trees.
- In relation to the other processing equipment, the harvester productivity for the 0.075 m<sup>3</sup> tree size was very low (5.0 m<sup>3</sup> per PMH) and had the flattest of all the productivity gradients, only reaching 22.2 m<sup>3</sup> per PMH in 0.40 m<sup>3</sup> trees.

The costs of the five systems were then calculated for different tree sizes. Costs regarding the machines (for example: ownership, operating and operator costs, overheads) were sourced for all the systems and inserted into costing models. Productivity information for other machines in the system was obtained. The results of the system costings were then summarised. Multi-stem systems were predicted to have lower costs in very small tree sizes.



The two lowest cost systems for the 0.075 m<sup>3</sup> tree-size class were the CFDD and CFDDC multi-stem systems. However, the costs of the DHP single-stem processing system in this tree-size class were lower than those of the CFDD&C.

Therefore, the null hypothesis was accepted for the second hypothesis:

Full-tree, multi-stem systems **do not** have lower costs than CTL and full-tree, singlestem processing systems in very small tree sizes.

Only if systems producing logs were taken into consideration would the null hypothesis be rejected, as the CFDD system had lower system costs for small trees than both the DHP and harvester systems.

No single system was more cost-effective than the others across all tree sizes. The key results are provided below:

- In 0.075 m<sup>3</sup> trees, the CFDDC system proved the most cost-effective, with costings slightly lower than those of the CFDD system. Indeed, all systems evidenced high costs in the 0.075 m<sup>3</sup> trees, ranging between \$19.43 per m<sup>3</sup> for the CFDDC system to \$28.84 for the harvester system, with a cost difference of \$9.41 per m<sup>3</sup> (48 per cent).
- In 0.15 m<sup>3</sup> trees, the DHP system had the lowest costs at \$11.94 per m<sup>3</sup>, with the CFDD following very closely at \$12.16 per m<sup>3</sup>. The harvester and CFDD&C systems were the most expensive at \$16.57 and \$16.70 per m<sup>3</sup> respectively, 40 per cent more expensive than the DHP system.
- In 0.25 m<sup>3</sup> trees, the DHP system had the lowest cost at \$8.60 per m<sup>3</sup>. This was followed by the CFDD system at \$9.76 per m<sup>3</sup>. The CFDD&C was the most expensive system at \$13.77 per m<sup>3</sup>, 60 per cent more expensive than the DHP system.
- In 0.40 m<sup>3</sup> trees, the cost differences between systems were lower, ranging from \$6.91 per m<sup>3</sup> for the DHP system to \$11.84 per m<sup>3</sup> for the CFDD&C, a difference of only \$4.93 per m<sup>3</sup>, but still 71 per cent higher for the CFDD&C. The costs pertaining to the CFDD system were second lowest, following the DHP, at \$7.93 per m<sup>3</sup>.

The cost-per-m<sup>3</sup> differences between the systems had already narrowed by the 0.15 m<sup>3</sup> trees, with the difference between the most expensive (CFDD&C) and most cost-effective (DHP) being \$4.67 per m<sup>3</sup>. This difference was then maintained through to the largest tree size of 0.40 m<sup>3</sup>. The largest cost reductions occurred in the harvester and DHP systems (single-tree processing), between the 0.075 m<sup>3</sup> and 0.15 m<sup>3</sup> tree-size classes. The harvester



proved to be the most expensive system for 0.075 m<sup>3</sup> trees, but was cheaper than the CFDD&C and CFDDC systems for the 0.40 m<sup>3</sup> trees.

#### 5.2 Interpretation of results in relation to the literature review

The literature review carried out in Section 2 showed that much research information on productivity and costs of mechanised harvesting systems was available for traditional northern-hemisphere species and conditions. Many variables that could affect productivity of processing machines and systems were highlighted. Tree size was consistently accentuated as the most important variable. Productivity increased and costs decreased as tree size increased for all processing machines, until the physical limitations of the machines were reached.

However, the literature also showed that little information was available on productivity and costs of mechanised harvesting of *Eucalyptus*. The existing information only considered CTL systems with harvesters and full-tree systems with CFDDCs. There was no information that considered tree size as a productivity input variable for full-tree systems with DHPs, CFDDs or CFDD&Cs.

The research results were consistent with the general literature on the effect of tree size on productivity and cost. All processing machines showed increases in productivity with increasing tree size. All systems also showed lowering of costs per m<sup>3</sup> as tree size increased.

The most comprehensive research on mechanised harvesting systems for *Eucalyptus* to date was carried out by Spinelli, et al. (2009). This research investigated tree size as a productivity variable in a CTL system utilising a harvester or a forwarder, and a full-tree system, utilising the CFDDC. The cost graphs per tree size in the Spinelli, et al. (2009) research follow very similar profiles to those of the same systems researched in this study. Both sets of research results show costs per m<sup>3</sup> from 0.075 m<sup>3</sup> to 0.40 m<sup>3</sup>.

This study confirms the findings of Spinelli., et al. (2009) that the CTL system was very expensive to operate in the small tree sizes (0.075 m<sup>3</sup>). The cost-per-m<sup>3</sup> curve gradient of the CTL system is steep down to 0.15 m<sup>3</sup> trees and then flattens out, the latter slightly more in the Spinelli, et al. (2009) research than is evidenced in this study. Therefore, this research indicates that there are greater cost advantages with the CTL system if operating in bigger trees.



Both sets of research results show the full-tree system (with CFDDC) as having the largest cost reduction from the 0.075 m<sup>3</sup> to the 0.15 m<sup>3</sup> trees, but the drop to the 0.15 m<sup>3</sup> trees is not as pronounced in this study as in the Spinelli, et al. (2009) results. From 0.20 m<sup>3</sup> trees, the cost curve gradient for a full-tree system remains fairly flat in both sets of research results.

Because the results of CTL costs in this study show a faster decrease than in the Spinelli, et al. (2009) research, there is a cross-over point at 0.25 m<sup>3</sup> per tree, where the CTL costs become lower than those of the full-tree system. At the 0.40 m<sup>3</sup> tree size, the full-tree system is slightly more expensive than the CTL system. In the Spinelli, et al. (2009) results, there is no cross-over point. At 0.40m<sup>3</sup> per tree, the full-tree system is still slightly cheaper than the CTL system.

Even though the cost profiles do cross over in this investigation, the shape of the cost curves is still very similar to that of Spinelli, et al. (2009). The shapes of the cost curves for all the other processing technologies studied in this research are very similar, with high costs in the small  $0.075 \text{ m}^3$  trees, followed by steep drops to the 0.15 m<sup>3</sup> trees and a flattening of the curve to the 0.40 m<sup>3</sup> trees. This indicates that the results are consistent with those of the most comprehensive other research carried out to date.

## 5.3 Significance of results in the forestry industry

This study, funded by the South African forestry industry, answers many queries regarding tree size and harvesting-system costs for different mechanised harvesting systems in *Eucalyptus* pulpwood and offers the industry solid information upon which to base system decisions. This information will enable the forestry manager to make more informed decisions regarding optimal harvesting systems, taking both tree size and cost into account. The productivity and cost information based on tree size is the first available on CFDD, CFDD&C and DHP systems operating in *Eucalyptus* plantation pulpwood.

## 5.4 Recommendations for the future

Because so little research on mechanised harvesting of *Eucalyptus* has been undertaken, there are many questions that still need to be addressed. Some productivity input variables for mechanised *Eucalyptus* harvesting are poorly understood.

The sample sizes in very small trees ( $<0.05 \text{ m}^3$ ) were too small to predict processingmachine productivity. If this tree size is commonly utilised by companies, more research should be conducted to quantify the productivity levels.



Multi-stem processing machines, like all other processing machines, are primarily dependant on tree size for productivity determination. However, for optimal productivity, the correct number of trees per bundle needs to be processed. As shown in this research, bundle size is affected by tree size, but the optimal number required could not be determined. It is suspected that other factors, such as BWBS and machine set-up, also contribute to productivity level, but no research has been conducted in this area. If this research were commissioned, the results would assist machine operators to optimise the productivity of each bundle processed.

The effect of BWBS on processing machine productivity could affect investment decisions. Some processing machines are thought to be less sensitive to changing BWBS than others because of their technological ability to remove high BWBS bark. The full range of BWBS classes for all processing technologies should be investigated, focusing on circumstances where BWBS is very strong (class 4 and 5). For example, this study showed that DHP productivity for 0.4 m<sup>3</sup> trees was very close to that of the CFDD&C and CFDDC. It is predicted that when the BWBS class becomes very high, this productivity gap will be much wider owing to the lower productivity of the DHP. This requires further research.

The effect of tree form (stem shape and branch size) on processing-machine productivity is also poorly understood. *Eucalyptus* that has been planted off-site, coppice stems that have been poorly managed and certain species with large branches can result in poor form. The literature has shown single-grip harvesters and DHPs to be sensitive to poor form. This is due to the strong grip that the head has to have on the tree to apply sufficient pressure to remove bark and it becomes difficult for the tree length to move through the head. Very little research has been conducted on the multi-stem processing technologies operating in *Eucalyptus*. Research needs to compare the effects of different processing machines dealing with trees of different sizes.

Because conducting research on many different machines on different continents is expensive, there is a good argument for establishing a research collaborative. Such an academic body would facilitate in-depth study without excessive travel time and costs.



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# Annexure A

Histograms of actual observation distribution for productivity, bundles size and average tree volume





### Figure 1: CFDD productivity with outliers



Figure 2: CFDD productivity without outliers









Figure 4: CFDD average tree volume without outliers



















Figure 8: CFDDC productivity without outliers









Figure 10: CFDDC average tree volume without outliers





# Figure 11: CFDDC bundle size with outliers



Figure 12: CFDDC bundle size without outliers









Figure 14: CFDD&C productivity without outliers









Figure 16: CFDD&C average tree volume without outliers









Figure 18: CFDD&C bundle size without outliers









Figure 20: DHP productivity without outliers









Figure 22: DHP average tree volume without outliers









Figure 24: Harvester productivity without outliers









Figure 26: Harvester average tree volume without outliers



# Annexure B

Additional data analysis carried out on bark-wood bond strength (BWBS), tree form and quality



## 1 Effect of combined tree size and BWBS class on productivity

Table 1 shows the results of the initial descriptive statistics analysis carried out in Microsoft Excel. The tables examine tree size and BWBS classes for each technology. The key can be found on the left of the table. The first number refers to the tree size class and the second to the BWBS. It is clear that there is still not sufficient information for all possible combinations of tree size and BWBS class for each processing technology. This is to be expected, as it is not possible to have all the combinations present in one compartment. The sample size would have to be very large to cater for this, which was not economically or practically possible. The green shaded boxes are where the sample sizes for each combination are greater than 20, yellow where the sample size is between 10 and 19, and red where it is below 10. This was done to try and take into account the possible effects that a small sample size might have on the general trends observed in the data. As indicated in the data analysis section, outliers in small sample sizes can easily affect the results. It is clear from Table 1 that certain combinations are missing from each processing technology, and that certain combinations have very small sample sizes. The results of the individual processing technologies are described under separate headings below.

 Table 1: Summary statistics results for tree size and BWBS class for the different processing technologies.



Ignoring the effect of sample size within each category, the smallest variance (0.13 to 28.9) and standard deviation (0.36 to 5.37) is found with the harvester. The DHP was next with a variance ranging from 1.33 to 68.52 and standard deviation from 1.16 to 11.59. CFDD&C variance ranged from 49.68 to 702.16 and standard deviation from 7.05 to 26.50. CFDDC variance ranged from 88.03 to 1191.41 and standard deviation from 9.38 to 34.52. CFDD variance ranged from 0.56 to 1222.4 and standard deviation from 0.75 to 34.96.



Figure 1 shows the productivity information in graph format for the various processing technologies, tree size classes and BWBS classes. The information for each processing technology is discussed in detail in the sections below. Again, the colours denote different sample sizes.

Productivity is expected to increase as tree size class increases. Within each tree size class, productivity is expected to decrease as the BWBS and form class increases. However, there are certain situations where it does differ. This is explained in more detail under each individual processing technology. The highest productivity levels can clearly be found with the CFDD and the lowest with the harvester. The DHP processor has high productivity in the larger trees (from class 4). The CFDDC and CFDD&C appear to be similar but would require more detailed examination to confirm. The smallest sample sizes for all of the processing technologies were found in the smaller and larger tree sizes. However, this is explained below.



Figure 1: Productivity graph for tree size and BWBS class combinations



## 2 Chain Flail Delimber Debarker (CFDD) productivity results

### 2.1 CFDD productivity for tree size and BWBS class combinations



Figure 2 shows the effect of tree size and BWBS class on CFDD productivity.

#### Figure 2: Effect of tree size and BWBS class on CFDD productivity.

There is a productivity increase with every increase in tree size class. However, this is only pronounced until tree size class 3. From tree size class 4, the increase in productivity is much smaller. Productivity ranges from approximately 16 m<sup>3</sup> per PMH for tree size class 1 (although caution must be exercised as the sample size is small), to 90 m<sup>3</sup> per PMH for tree size class 5. There were no trees in tree size class 6.

A drop in productivity was expected as the BWBS class increased, as the bark should theoretically be more difficult to remove. However, this did not occur. In tree size class 1 (1:4 and 1:5), the productivity increased steeply as the strippability became worse. However, the sample sizes for these two combinations are very small, with both being less than 10 cycles. Combination 2:3 also had a very small sample size. The main data set is found between combination 2:4 and 5:4. In this range, the productivity stayed stable within each tree size class, regardless of the BWBS. However, it is clear that the debarking quality is decreasing as the BWBS class increases. This is an indication that the operator is not paying enough attention to BWBS when processing. The operator is processing the same amount of trees per bundle regardless of BWBS.



## 2.2 CFDD debarking quality results



Figure 3 shows debarking quality per tree size and BWBS class combination.

### Figure 3: Debarking quality for tree size and BWBS combinations of the CFDD

The sample sizes of less than 10 were removed as it was too easy for outliers to affect the results. It is clear that the debarking quality was poor when the BWBS was class 4 and 5. The debarking quality for BWBS class 3 was good for all the tree size classes. It is therefore evident that the operators need to pay more attention to the settings on the machine (flail speeds, number of chains per flail drum and feed speeds) in order to obtain optimal debarking quality while minimising productivity losses.

# 3 Chain Flail Delimber Debarker Chipper (CFDDC) productivity results

### 3.1 CFDDC productivity for tree size and BWBS class combinations

Figure 4 shows the effect of tree size and BWBS class on CFDDC productivity.





Figure 4: Effect of tree size and BWBS class on CFDDC productivity.

The full range of tree size classes was processed; however the BWBS classes ranged from 2 to 4, with most occurring in class 3 and 4. The productivity ranged from approximately 20 m<sup>3</sup> per PMH for trees size class 1, to 80 m<sup>3</sup> per PMH for tree size class 6. The trend in the CFDDC follows what would be expected from tree size class 1 to 3. Productivity increases with increasing tree size, but decreases as the BWBS increases for each tree size class. The magnitude of the decreases in these first three tree size classes is unexpected. The productivity decrease within each tree size class is dropping by between 15 and 20% for each increase in BWBS class. It appears that the operator is being conservative, as the implications of sending chips to the customer with unacceptable bark content could be serious. Therefore, as the BWBS increases, the operator is reducing machine productivity to ensure that quality is maintained. However, the trends for tree size class 1 to 3 are not maintained for tree size class 4 to 6. The overall productivity curve is still increasing but tree size class 5 is lower than tree size: BWBS class 3:4, and then there is an increase for tree size class 6 again. Also, within these three tree size classes, an increase in BWBS actually increases productivity. It cannot be explained why this is so, as the sample sizes are relatively large, with the lowest sample size for one combination being 84 cycles. It can be speculated that with a slightly higher BWBS in bigger tress, the bark might actually be more easily removed as smaller pieces, and fall to the bottom of the machine where the hydraulic bark pusher ejects it. When the bark is more easily removed, it may come off in lengths which might become entangled in-between the stems and be fed through into the chipper. The operator was not questioned on this, as this trend was only discovered during data analysis.



## 3.2 CFDDC debarking quality results

Debarking quality could not be monitored as the debarked stems were immediately chipped due to it being an integrated machine. However, every load was checked at the wood chip yard in Albany and Bunbury, and the bark content was acceptable for all loads.

# 4 Chain Flail Delimber Debarker and Chipper (CFDD&C) productivity results

### 4.1 CFDD&C productivity for tree size and BWBS class combinations



Figure 5 shows the effect of tree size and BWBS class on CFDD&C productivity.

Figure 5: Effect of tree size and BWBS class on CFDD&C productivity

The complete range of tree size classes was found in the sample, but the sample size was very small for tree size class 1 and 6. All the BWBS classes are either a 3 or 4. It was still possible to determine debarking quality by observing the debarked trees as they moved from the CFDD out-feed into the chipper. The productivity ranged from approximately 20 m<sup>3</sup> per PMH for tree size class 1, to 60 m<sup>3</sup> per PMH for tree size classes 5 and 6. There is a steady increase in productivity with each tree size class increase. The productivity of tree size class 6 is approximately the same as tree size class 5. It is difficult to determine whether this is due to the CFDD having reached the upper limits of the tree size that it is able to process, or whether it is just due to the sample size being too small. As the BWBS class increases within



each tree size class, the productivity is reduced. Even though the productivity does reduce with increasing BWBS class, debarking quality is still lower in the higher BWBS class for each tree size.

### 4.2 CFDD&C debarking quality results



Figure 6 shows the debarking quality classes per tree size and form class combination.

### Figure 6: Debarking quality for the tree size and BWBS combinations of the CFDD&C

The debarking quality for BWBS class 3 was generally very good, regardless of tree size. The debarking quality for BWBS class 4 dropped for each tree size class, although the overall debarking quality for all combinations was still well within acceptable mill quality specifications. This was backed up by the feedback from the chip yards, which indicated that all loads were of acceptable quality.

## 5 Dangle Head Processor (DHP) productivity results

### 5.1 DHP productivity for tree size and BWBS class combinations

Figure 7 shows the effect of tree size and BWBS class on DHP productivity.





Figure 7: Effect of tree size and BWBS class on DHP productivity

All tree size classes with the exception of class 6 were found in the sample. BWBS classes 2 to 5 were found in the sample, but not for each tree size class. BWBS class 2 was only found in tree size classes 1 to 4, while the sample size of BWBS class 5 was very small and only occurred in tree size class 5. All the trees in tree size class 2 consisted of BWBS class 2. An overall increase in productivity is experienced from tree size class 1 (approximately 4 m<sup>3</sup> per PMH) through to tree size class 5 (approximately 55 m<sup>3</sup> per PMH). The sample size of tree size class 1 is small and therefore care must be taken when examining the graph. However, there is a small drop in productivity as the BWBS moves from class 2 to class 3. There is only one BWBS class for tree size class 2, so no deductions can be made regarding increases or decreases in productivity with changes in BWBS class. In tree size class 3, there is a decrease in productivity as the BWBS class increases. However, there was also a drop in debarking quality. Therefore, there may have been a decrease in productivity within this tree size class if the operator continued to debark to a higher quality. Figure 7 clearly shows this drop in debarking quality. In tree size class 4, productivity drops from BWBS class 2 to BWBS class 3, but then increases again slightly for BWBS class 4. The very small sample size for BWBS class 4 could be the reason for this. Tree size class 5 has a reduction in productivity from BWBS class 3 through to 5. BWBS class 5 is only slightly lower than BWBS class 4, but again the sample size is very small for BWBS class 5 which could be affecting the results.



## 5.2 DHP debarking quality results



Figure 8 below shows the debarking quality that was achieved with all the combinations that had sample sizes of 20 or more.

### Figure 8: Debarking quality for the tree size and BWBS combinations of the DHP

All tree size classes with BWBS of 2 had very good debarking quality. All BWBS class 3 tree sizes also tended to have good debarking quality with the exception of tree size class 3, which had the worst debarking quality of all the combinations. BWBS class 4 had lower debarking quality levels, with approximately 50% being in debarking class 2. Debarking quality class 3 only occurred in tree size class 3, and the proportion was very low (approximately 10% of that sample). Optimal productivity within each tree size class of the DHP occurs when the operator has to pick up the tree up off the deck, and only feed it through the head once in one direction. The top is cut off and dropped. This results in very fast cycle times. Because the operators are pushed for productivity, as the BWBS class increases, they are hesitant to feed the tree through the head again, which would now require an additional pass to the butt and back to the top, regardless of whether the bark was removed in the second pass. The operator is therefore inclined to leave more bark on the tree with higher BWBS classes rather than feed the tree through the head again.

### 6 Harvester (CTL) productivity results

### 6.1 Harvester productivity for tree size and BWBS class combinations

Figure 9 shows the effect of tree size on the productivity of the harvester.





Figure 9: Harvester (CTL) system machine costs per PMH

All the tree size classes had BWBS class 3. It was not possible to manipulate BWBS with the harvester as the trees are processed immediately after felling. The productivity levels range from approximately 2.5 m<sup>3</sup> per PMH for tree size class 1, up to 30 m<sup>3</sup> per PMH for tree size class 6. Caution must also be exercised when looking at the smaller tree size classes as class 2 is absent. This was due to the error made during the allocation of trees into volume classes in the field. This error was discussed under "Shortcomings and sources of error" in the research design and methodology chapter. If there was a tree size class 2 and 3, the graph would be flatter with the lower productivities of class 1 to 3, and then start to rise rapidly from tree size class 6. Tree size class 6 had a very small sample size. The lack of variation in the BWBS class for different tree size classes was surprising, as often the smaller suppressed trees have a higher BWBS class. This did however make productivity comparisons between tree size classes easier. Even though the productivity from tree size class 4 is high, the increase is not as great as with the DHP due to the debarking element of the harvester consuming less of the cycle time.

### 6.2 Harvester debarking quality results

There is no figure to explain debarking quality as the trees were all debarked to debarking quality level 1. The good debarking levels achieved are due to trees being processed immediately after felling and good operator technique.



# Annexure C

# Harvesting systems costing summaries



CFDD System – Tree volume 0.15m<sup>3</sup>


SYSTEM	:	CFDD
OPERATION	:	Stump to landing
STUDY FOR	:	MSc
PREPARED BY	:	McEwan



Activity	Stand	Extraction route	Roadside Landing	Forest Road	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)					\$2.60	217 500	2	2	7	300
Grapple Skidder (Tigercat 630D)					\$2.89	217 500	2	2	4	300
CFDD (Morbark 2455)					\$4.07	217 500	1	2	2	300
Bell 220E Telelogger			<b>*</b>		\$1.20	217 500	2	2	4	300
Tracked loader with slasher deck (Tigercat T234)			A		\$1.40	217 5 <mark>0</mark> 0	1	2	2	300
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				TOTAL	\$12.16		8		20	



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FIXED COSTS	85.22	13 722	164 663	329 326	58.2%	Number of Operators		7					
Hp	34.42	5 542	66 507	133 014	23.5%		-						
Crew	43,45	6 996	83 949	167 898	29.7%	Machine Hours		3 864					
Licence	7,35	1 184	14 207	28 415	5.0%	Capital Employed		631 434					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		126 287					
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Lubrication	2.67	430	5 154	10 309	1.8%								
Maintenance	21.05	3 389	40 668	81 336	14.4%								
Relocation	2.69	433	5 200	10 400	1.8%								
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MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED.	: C : F : M : M ARE ESTIMAT	Grapple Si Full tree ex MSc McEwan TES, SITE SP	kidder (Tige xtraction	ercat 630D) SUME FULLY TR	AINED OP	ERATORS					CORDIAN CONTRACT		
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Acoust Ho's				83 186	11580	other	0	0	0		Time and a Half per week	3.0	Hre
1 2 HP Calculation		_		05 100	0.545	other	0	0			Double Time per Week	3.0	Hre
Desidual Value @		L	20.00%	78.060	11580	Fuel Cost		1	24 34	ISS/mhr	Shift or Other Allowance	0.00	liseida
Interest per annum		L	20.00 /5	8.00%	0.000	Oil Cost			3.85	ISS/mbr	Annual Normal Time	61 744	USE
Dayment period				0.00%	months	Turas/Tracks/Dissing /	Cost		0.00	ISS/mh-	Annual Time and a Half	2 200	11580
Payment period				6 020	liste	Appired Fiel Costs	JUSI			ice.	Annual Time and a Han	2 200	10335
Monality payment				0 950	0345	Annual Luba Costs			9 409	1000	Annual Boour	2 340	11080
1 3 OPERATING HOURS						Annual Ture/Track/Dia	ning Cost		0 430 0	1000	Annual Shift or Other Allowanas		11000
Tatal Dave				205		2 2 VEHICLE MAINTE	NANCE COSTS	-	010	13-20	Total Annual Crew Cost		11580
Meekaad Dave				50		Maint % Can Cost/mar	hine life (mhris)	L	90%		Total Crew Cost per Machine Hr	24.44	1158/m
Statutory Leave Dave				13		Maintanance Cost	anne ine (mm a)		23.69	IS\$/mhr	Total crew cost per machine m	24.44	033/11/
Sick Leave Days						Annual Maintenance C	oct		EE 145	IC te			
Productive Days	Mill Stope			0		2 3 PELOCATION CO	STS		00 140 0	0.990	A 1 WORK STUDY ANALYSIS		
Total Appual Production Dave	Will Otopa		1	300	Dave	Number of moves per	annum	[	4 #		Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	1580	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Cos			5 200	ISRe	travel emoty		km/hr
Machine Availability				100.0%	<b>T</b>	Relocation Cost per Ma	achine Hour		2 23	S\$/mhr	Load		min
Machine Utilisation				48.5%		5.1 Machine Requirer	nents		6.69	- Courtain	travel loaded		km/hr
Machine hours per Day				7.8	Hours	Annual Volume			217 500 0	13	OffLoad		min
Machine hours per Annum				2 328	Hours	Hourly Volume Require	d		93.43 0	3/mhr	Travel time empty	#DIV/0t	min
Machine Life Hours				15 000	Hours	Number Of Machines F	Required		2.00 #		Travel time loaded	#DIV/01	min
Machine Life Years				6.44	Years	Fleet Reserve			0%		Load	0.00	min
						Exact Number of Mach	ines Required		2.00 #		Off Load	0.00	min
1.4 OVERHEADS						Rounded number of ve	hicles Required		2 #		cycle time	#DIV/01	min
											cycle time	#DIV/01	hrs
Annual Licence Fees				19 740	US\$s						Machine Output per Hour	46.6	m3/mhr
											Machine Output per Day	363	m3/day
1.5 Overheads	_		10.00%	28529	US\$s					_	Machine Output per Annum	108 950	m3/yea
6.1 SUMMARY	-				-	6.2 FLEET SUMMARY							
	PE	R MACHINE	E	FLEET	%		_		-				
	US\$/hr U	S\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2,89	Inc. Profit	3.32			
OVERHEADS	12.25	2 377	28 529	57 058	9.09%	Number of Machines		2					
FIXED COSTS	68.64	13 316	159 794	319 589	50.9%	Number of Operators	2	4					
Hp's	35.72	6 930	83 166	166 331	26.5%		-						
Crew	24.44	4 741	56 889	113 778	18.1%	Machine Hours		4 656					
Licence	8.48	1 645	19 740	39 480	6,3%	Capital Employed		789 596					
Permit & Toll fees	0.0		0	0	D.0%	Residual Value		157 919					
VARIABLE COSTS	53.91	10 458	125 498	250 995	40.0%	Total Revenue		627 643					
Fuel	24.34	4 721	56 654	113 308	18.1%								
Lubrication	3.65	708	8 498	16 996	2.7%								
Tyres	0.00	4 505	55 145	110 201	0.0%								
Relocation	2 23	433	5 200	10 400	1.7%								
	ALC: NO.		the second se	14 M	10								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: I : I ARE ESTIMA	CFDD (Mo Delimb, De MSc McEwan TES,SITE SI	ebark 2455 ebark full t	5) trees SSUME FULLY 1	TRAINED	PERATORS					and the second second		
							NG COSTS				3 1 LABOUR COSTS		
Mashina Brias Evo VAT			1	714 271	11000	Eusl Consumption	10 00313	1	56.0	Inie	Driver Wage	0.80	USEDO
Machine Price, Exc. VAT	1.5			/14 3/1	0535	Fuel Consumption			50,9	UNF	Driver wage	9.00	03200
Less Cost of Tyres/Tracks/Rigg	ling			U	USAS	Fuel Cost			1.17	USAL	No.Drivers/Shift	1.1	IIC COL
Plus additional equipment	radio			0	USAS	Oll,% Fuel Cost			15%	lines	Labour wage	0.00	USAND
	combican			0	US\$s	Oll Cost				US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s	1	Qty	Cost	Life		Operating Days/Week	6.0	days
The second second second	other			0	US\$s	Chains	234	8	30		Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$s	Drum	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				714 371	US\$s	Tyres	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				150 485	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	142 874	US\$s	Fuel,Cost			66.57	US\$/hour	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			9,99	US\$/hour	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	ost		62.40	US\$/hour	Annual Time and a Half	225	US\$s
Monthly payment				12 540	US\$s	Annual Fuel Costs			207 708	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			31 156	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	ng Cost		194 688	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days			1	365		2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	52 269	USSS
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's)	_ [	100%		Total Crew Cost per Machine Hr	16.75	USS/mh
Statutory Leave Days				13		Maintenance Cost			47.62	US\$/mhr	factor and the second second		
Sick Leave Days				0	1.1	Annual Maintenance Co	st		148 589	US\$s			
Productive Days Lost to Weather	r/Mill Stops			0		2.3 RELOCATION COS	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	initial brops			300	Davs	Number of moves per a	num	Г	4	#	Average Tree Volume		m3
Shift length			1	8	Hours	Cost per Move			1 300	11580	Number of trees/grab		#
Number of Shifte ner day				2	#	Annual Relocation Cost			5 200	11580	other		
Machine Augilability				100.0%		Relocation Cost par Mar	hine Hour		1.67	11St/mhr	debranch debark	-	min
Machine I Hilication				65.0%	1.1	5 1 Machine Requirem	ante	-	1,01	000011111	other		min
Machine bours ser Dou				10.4	Hours	Annual Valuma	unus	ſ	217 500	m2	other		min
Machine hours per Day				7 120	Hours	Houdy Volume Dequired			217 000	m3/mhr	other		min
Machine hours per Annum				5 120	Hours	Hourry volume Required			09.71	m.svinni	other		inini atia
Machine Life Hours				15 000	Hours	Number Of Machines Ro	equired		1.00	"	other		min
Machine Life Years				4.81	Years	Fleet Reserve	and the second		0%	1	other		min
a second second second						Exact Number of Machin	nes Required		1.00	#	other	-	min
1.4 OVERHEADS						Rounded number of veh	icles Required	1	1	#	cycle time	0.00	min
an output and an output											cycle time	0.00	hrs
Annual Licence Fees & insurance	e		L	14 287	US\$s						Machine Output per Hour	69.8	m3/mhr
and the second second											Machine Output per Day	726	m3/day
1.5 Overheads			10.00%	80438	US\$s						Machine Output per Annum	217 776	m3/yea
6.1 SUMMARY	_					6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%	the second second	-	_	1.00				
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		4.07	Inc. Profit	4.68			
OVERHEADS	25.78	6 703	80 438	80 438	9.09%	Number of Machines		1					
FIXED COSTS	69.56	18 087	217 041	217 041	24.5%	Number of Operators	1	2					
Hp	48.23	12 540	150 485	150 485	17 0%		_						
Crew	16.75	4 356	52 269	52 269	5.9%	Machine Hours		3 120					
Licence	4.58	1 191	14 287	14 287	1.6%	Capital Employed		714 371					
Permit & Toll fees	0.0	1.11	0	0	0.0%	Residual Value		142 874					
VARIABLE COSTS	188.25	48 945	587 341	587 341	66.4%	Total Revenue	1	884 820					
Fuel	66.57	17 309	207 708	207 708	23.5%		-						
Lubrication	9.99	2 596	31 156	31 156	3.5%								
Tyres	62.40	16 224	194 688	194 688	22.0%								
Maintenance	47.62	12 382	148 589	148 589	16.8%								
Relocation	1.67	433	5 200	5 200	0.6%								
TOTAL COST / REVENUE	283.00	13 735	864 820	884 820	100,0%								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTEL	: : : : : : : :	Bell 220E Bundle tro MSc McEwan ATES, SITE S	Telelogger ee lengths : PECIFIC & AS	after debarki SUME FULLY 1	ing TRAINED C	OPERATORS					ARE ADDING TO A		
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATI	NG COSTS				3.1 LABOUR COSTS		
Machine Price, Exc. VAT				80 500	US\$s	Fuel Consumption		ſ	6.6	UHr	Driver Wage	9.80	USSING
Less Cost of Tyres/Tracks/Rig	aina			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	slasher			0	USSS	Oil % Fuel Cost			15%		Labour Wage	0.00	US\$/ho
i ito additorial equipment	Truck 2ne h	band		0	USSe	Oil Cost				1158/	No Labourers/Shift	0.0	#
	trailar	iana .		0	11000	Turae/Tracke/Digging				0041	Contributione	0.0%	
	other			0	10000	Tyrear Haukarkigging	Ohi	Cast	1.10		Operating Dave Mack	6.0	dave
	other				10000	Ture front	Q	0051	Life	r	Operating Daysweek	0.0	dave
	Lotner			0	10535	Tyre from	0	0	0		Paris Heursburgekidstuer	90.0	Lie
Sub total additional equipmen	t.				0535	Tyre rear	0	0	0		Basic Hours week driver	90.0	rirs
Total Capital Employed				80 500	US\$S	other	0	0	0		Total Overtime per week	0,0	HIS
Annual HP payment				10 958	US\$S	other	U	0	0	1.1.1	Time and a Hait per week	3.0	HIS
1.2 HP Calculation				- 30.000	1	other	0	0	0	Sec. 1	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	16 100	US\$s	Fuel,Cost			7.72	US\$/mhr	Shift or Other Allowance	0.00	US\$/da
Interest per annum				8.00%	1. 1.	Oil, Cost			1.16	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	ost		0.00	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				1 413	US\$s	Annual Fuel Costs			23 327	US\$s	Annual Double Time	300	US\$s
		_				Annual Lube Cost			3 499	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigg	ng Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365	10 C	2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's)	[	100%		Total Crew Cost per Machine Hr	17.30	US\$/ml
Statutory Leave Days				13		Maintenance Cost		1	5.37	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Co	st		16 212	US\$s			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COS	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Davs	Number of moves per a	num	ſ	4	#	Tree volume		m3
Shift length				8	Hours	Cost per Move			1 300	USSS	Number frees per cycle		#
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	USSS	pull trees		min
Machine Availability				100.0%		Relocation Cost ner Ma	thine Hour		1 72	US\$/mhr	other		min
Machina I Hilication				62 0%	1.1.1.1	51 Machine Requirem	ante		1.1 4	obarrinin	other		min
Machine bours per Day				10.1	Hours	Annual Volume	circs	F	217 500	m2	other		min
Machine hours per Day				10.1	Hours	Annual Volume			217 500	nis a 2 factor	other		man
Machine hours per Annum				5021	Hours	Houriy volume Required			12.00	m Sernin	other		(TIM)
Machine Life Hours			-	15 000	Hours	Number Of Machines R	equired		2.00	#	other		min
Machine Life Years				4.97	Years	Fleet Reserve	and the second s		0%		other		min
Contrate Content						Exact Number of Machin	nes Required		2.00	#	other		m3
1.4 OVERHEADS						Rounded number of veh	icles Required	L	2	#	cycle time	0.00	min
					Ú., .						cycle time	0.000	hrs
Annual Licence Fees & insuran	ce		L	1 610	US\$s						Machine Output per Hour	36.000	m3/mhi
					1.1						Machine Output per Day	363	m3/day
1.5 Overheads		_	10.00%	11908	US\$s						Machine Output per Annum	108 752	m3/yea
6.1 SUMMARY	_		-		_	6.2 FLEET SUMMARY							
	F	PER MACHIN	E	FLEET	%		-				1		
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1000	1.20	Inc. Profit	1.39			
OVERHEADS	3.94	992	11 908	23 815	9.09%	Number of Machines		2					
FIXED COSTS	23.45	5 903	70 837	141 673	54.1%	Number of Operators	1 mar	4					
Hp	5.61	1 413	16 958	33 915	12.9%								
Crew	17.30	4 356	52 289	104 538	39.9%	Machine Hours	1	6 0 4 2					
icence	0.53	124	1.610	3 220	1 204	Capital Employed		61 000					
Permit & Toll fees	0.00	194	10.0	0 220	0.0%	Residual Value	100	32 200					
VADIABLE COSTS	15.07	4.000	48 220	06 677	36.04	Total Devenue		161 065					
Cuel	15.97	4020	40 238	90 A(1	47.00	Total Revenue	4	1 302			1		
ruei	1.72	1 944	23 327	45 655	17.8%								
Lubrication	1 16	292	3 499	6.998	2.7%								
Maintenance	5 37	1 351	16 212	32 424	12 4%								
Relocation	172	433	5 200	10 400	4.0%								
TOTAL COST / REVENUE	43 36	10.015	120.002	264 065	100.08/								



MACHINE DESCRIPTION		Tracked loader with slasher deck (Tigercat T234)
OPERATION	:	Slash to 5.5m lengths
STUDY FOR	:	MSc
PREPARED BY	:	McEwan
NOTE: ALL FIGURES QUOTED AF	REEST	MATES, SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS



1.1 CAPITAL EMPLOYED					-	2 1 VEHICLE OPER	ATING COSTS				3 1 LABOUR COSTS		
Machine Price Evo VAT				381 224	11540	Euel Consumption	A11140 00010	Г	13.8	IAIr	Driver Wage	9.80	USEMOU
Lace Cost of Turge/Tracke/Pil	00.00			001224	11000	Fuel Cost			1 17	11000	No Driver (Shift	1.1	W
Disc additional equipment	discher			0	11000	Oil % Eval Cort			1.5%	0392	Labour Maga	0.00	USEDOUT
Plus additional equipment	Truck 2ne ha	had		0	11000	Oil Cort			13%	ileen.	No Labourare/Chiff	0.00	4
	trailer				11000	Turan/Tracke/Diamin		-		Juogr	Contributions	0.0%	<u> </u>
	other			0	11040	ryres/tracks/rogging	0.00	Cost	1 He		Operating Dave Week	6.0%	davie
	other			0	110535	Bar	City	714	250	1	Operating Days/week	0.0	days
Pub total additional aquinmor	Tomer			0	11580	Der		114	350		Denis Haumburgelidding	90.0	Udys
Sub total additional equipment	na -			204 004	0000	Spiocket		0	0		Basic Hours/week/driver	90.0	nis
Total Capital Employed				381 224	0535	Tracks		405			Total Overtime per week	0.0	HIS
Annual HP payment				80 300	0535	Chain	1	192	70		Time and a Hair per week	3.0	HIS
1.2 HP Calculation					luine	otner				una v	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	76 245	US\$s	Fuel,Cost			16.15	US\$/mhr	Shift of Other Allowance	0.00	US\$/day
Interest per annum				8.00%	-	Oil, Cost			2.42	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period			-	60	months	Tyres/Tracks/Rigging	g Cost		4.83	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment			L	6 692	US\$s	Annual Fuel Costs			46 838	US\$s	Annual Double Time	300	US\$s
Contraction of the second					-	Annual Lube Cost	and the second		7 026	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/R	ligging Cost		13 999	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINT	TENANCE COSTS			1	Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/m	hachine life (mhr's)		90%		Total Crew Cost per Machine Hr	18.02	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			22.87	US\$/mhr	and the second second second		
Sick Leave Days				0		Annual Maintenance	Cost		66 354	US\$s			
Productive Days Lost to Weath	her/Mill Stops			0		2.3 RELOCATION C	OSTS	-			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves pe	er annum		4	#	Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s			min
Number of Shifts per day				2	#	Annual Relocation C	ost		5 200	US\$s	Slash		min
Machine Availability				100.0%		Relocation Cost per	Machine Hour		1.79	US\$/mhr	other		min
Machine Utilisation				60.4%		5.1 Machine Requir	ements				other		min
Machine hours per Day				9.7	Hours	Annual Volume		ſ	217 500	m3	other		min
Machine hours per Annum				2 901	Hours	Hourly Volume Regu	lired		74.98	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machine	s Required		1.00	#	other		min
Machine Life Years				5.17	Years	Fleet Reserve	CALER WARES		0%		other		min
						Exact Number of Ma	chines Required		1.00	#	other		m3
1.4 OVERHEADS						Rounded number of	vehicles Required		1	#	cycle time	0.00	min
								-			cycle time	0.000	hrs
Annual Licence Fees & insurar	nce			5718	USSS						Machine Output per Hour	75.000	m3/mhr
	100		-	0110	10040						Machine Output per Hour	725	m3/day
1.5 Overheads			10.00%	27771	11550						Machine Output per Day	217 570	makinar
6.1 SUMMARY			10.00 %		0000	6.2 FLEET SUMMAR	RY		_		machine Output per Annum	211 510	moryear
	PF	RMACHI	NF	FLEET	%								
	USEDE II	St/month	USthear	lisshear	of Total	LISE nor m3		1.40	Inc Profit	1.62			
OVERHEADS	0.57	2 244	27 771	27 774	0,000	Alumber of Machiner			inc. From	1.04	1		
EIVED COSTS	47.67	44 524	120 202	128 202	45.70	Number of Operator							
Un	27.60	6 800	90 200	130 293	30.37	and the of operators		6					
Crow	10 00	4 350	52 200	50 300	17 40	Machine Hours		2 001					
Licence	10.02	4 300	52 209	52 269	1.19	Contal Employed		2 901					
Dormit & Tall face	1.97	4/1	5718	5718	1.9%	Capital Employed		78 045					
Permit & Toll fees	00	11.016	0	0	0.09	Residual Value		76 245					
VARIABLE COSTS	48.06	11 618	139 418	139 418	45.69	Total Revenue		305 482					
Fuel	16,15	3 903	46 838	46 838	15 39								
Lubrication	2.42	585	7 026	7 026	2.39								
Maintenance	22.87	5 530	66 354	66 354	21 79								
Relocation	1.79	433	5 200	5 200	1.79	5							
TOTAL COST / REVENUE	105.30	25 457	305 482	305 482	100.0%	5							



CFDD System – Tree volume 0.075m<sup>3</sup>



SYSTEM	:	CFDD
OPERATION	:	Stump to landing
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

FORESTRY

Activity	Stand	Extraction route	Roadside Landing	Forest Road	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)					\$4.46	124 500	2	2	7	300
Grapple Skidder (Tigercat 630D)		A			\$4.71	124 500	2	2	4	300
CFDD (Morbark 2455)					\$7.11	124 500	1	2	2	300
Bell 220E Telelogger			<b>*</b>		\$2.00	124 500	2	2	4	300
Tracked loader with slasher deck (Tigercat T234)			A		\$2.33	124 500	1	2	2	300
				Total	\$20.61 \$0.00 \$20.61		8 0 8		20 0 20	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	D ARE ESTIMA	Wheeled I Felling an MSc McEwan TES, SITE S	Feller Bunc d bunching PECIFIC & AS	her (Tigerca Euc full tre SUME FULLY	t 720E) es TRAINED (	DPERATORS					COLUMN ST ANY	
	-		_		_		ING COSTS		_		2 1 LABOUR COSTS	
Machine Price Evo VAT			T I	315 717	11500	Euel Consumption	1140 00313	L .	15.2	1 Aur	Driver Wage	0.80 1155/hou
Lass Cost of Tyres/Tracks/Bin	naina			010711	11500	Fuel Cost			1 17	LISEN	No Drivers/Shift	11 #
Plus additional equinment	radio			0	11580	Oil % Fuel Cost			15%	UGAL	Labour Wage	6.00 US\$/how
r iss sourcear equipment	combican			0	11580	Oil Cost			1070	115\$1	No I abourers/Shift	11#
and the second sec	other			0	11580	Tures/Tracks/Digging		-		USAL	Contributions	0.0%
	other			0	11000	Tyrear hackarrigging	Otv	Cost	Life		Operating Daug Maak	6.0 dava
	other			0	11000	Turan	diy	0.200	2 500		Operating Hours Meak	0.0 days
Sub total additional aquipment	+			0	11580	Cutting disk		9 300	2 300		Racio Hours Augok/driver	90.0 Uays
Total Capital Employed				245 747	11000	Cutting testh	0	0	0		Total Quartime assumate	90.0 Mrs
Acqual LD payment				515717	11000	Other	0	0	0		Time and a Half accuracy	D.O HIS
Annual HP payment				60 307	03\$8	Other	0	0	0		Time and a Hair per week	3.0 Hrs
Desidual Value @		1	20.000	62.442	1100-	Fuel Cert	0		17.70	Upplante	Double Time per Week	3.0 HIS
Residual value @		4	20.00%	03 143	0338	Puel, Cost			11.10	USAMIN	Shift of Other Allowance	0.00 055/day
Interest per annum				8.00%	and the second	Oil, Cost			2.67	USSymnr	Annual Normal Time	83 424 US\$5
Payment period				60	months	Tyres/Tracks/Rigging C	ost		3.12	USSymnr	Annual Time and a Hair	225 US\$8
Monthly payment			-	5 542	US\$s	Annual Fuel Costs			32 438	US\$s	Annual Double Time	300 US\$s
						Annual Lube Cost			4 866	US\$s	Annual Bonus	0 US\$8
1.3 OPERATING HOURS						Annual Tyre/Track/Rigg	ing Cost		6 785	US\$s	Annual Shift or Other Allowance	0 US\$8
Total Days			-	365		2.2 VEHICLE MAINTEN	NANCE COSTS				Annual Contributions	0 US\$s
Weekend Days				52		Maint,% Cap Cost/mac	hine life (mhrs)		100%	1. Sec. 1	Total Annual Crew Cost	83 949 US\$s
Statutory Leave Days				13		Maintenance Cost			21.05	US\$/mhr	Total Crew Cost per Machine Hr	46.02 US\$/mhr
Sick Leave Days				0		Annual Maintenance Co	ost		38 391	US\$s		
Productive Days Lost to Weathe	er/Mill Stops			0	1.1	2.3 RELOCATION COS	STS	-			4.1 WORK STUDY ANALYSIS	
Total Annual Production Days			-	300	Days	Number of moves per a	annum		4	#	Average Tree Volume	m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell	min
Number of Shifts per day				2	#	Annual Relocation Cost	t		5 200	US\$s	bunch	min
Machine Availability				100.0%		Relocation Cost per Ma	ichine Hour		2.85	US\$/mhr	place	min
Machine Utilisation				38.0%		5.1 Machine Requirem	nents	-			move	min
Machine hours per Day				6.1	Hours	Annual Volume			124 500	m3	other	min
Machine hours per Annum				1 824	Hours	Hourly Volume Require	d		68.26	m3/mhr	other	min
Machine Life Hours				15 000	Hours	Number Of Machines R	Required		2.00	#	other	min
Machine Life Years				8.22	Years	Fleet Reserve			0%		other	min
						Exact Number of Machi	ines Required		2.00	#	other	min
1.4 OVERHEADS						Rounded number of vel	hicles Required		2	#	cycle time	0.00 min
											cycle time	0.000 hrs
Annual Licence Fees & Insuran	ce			14 207	US\$s						Machine Output per Hour	34.2 m3/mhr
			_								Machine Output per Day	208 m3/day
1.5 Overheads		1	10.00%	25234	USSS	and the second sec					Machine Output per Annum	62 381 m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY			0			
	P	ER MACHIN	E	FLEET	%							
	US\$/hr L	IS\$/month	USSAvear	US\$/vear	of Total	US\$ per m3		4.46	Inc. Profit	5.13		
OVERHEADS	13.83	2 103	25 234	50 469	9.09%	Number of Machines		2				
EIXED COSTS	90.28	13 722	164 663	320 326	50 34	Number of Operators	-	7				
Hn	36.46	5.642	85 507	133 014	24.0%	internet of operators		-				
Crew	45 02	6 900	83 040	187 809	30.00/	Machina Hours	100	3 648				
Licence	7 70	1 184	14 207	28 415	5 104	Capital Employed		631 434				
Darmit & Tall fees	0.0	1104	14201	20415	0.00	Desidual Value		126 297				
VADIABLE COSTS	48.07	7 307	87 690	175 260	21 64	Total Pauranua						
Fuel	47.70	2 702	32 420	P4 970	15 74	Total Revenue		299 109				
Lubrigation	0.00	2103	A 000	04876	1.00							
Tyres	3.72	565	6 785	13 571	24%							
Maintenance	21.05	3 199	38 391	76 782	13.8%							
Relocation	2.85	433	5 200	10 400	1.9%							
TOTAL COST / REVENUE	152.18	23 131	277 578	555 155	100.0%							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY		Grapple S Full tree e MSc McEwan	kidder (Tige extraction	ercat 630D)		5947095					Constant Constant		
TOTE ALL FIGURES QUOTEL	ANE ESTIMA	123,3112 31	LUIFIC & ASS	UNE FULLY IN	NINED OF					-	-		_
1.1 CAPITAL EMPLOYED			-		1	2.1 VEHICLE OPERATI	NG COSTS				3.1 LABOUR COSTS		1
Machine Price, Exc. VAT				394 798	US\$s	Fuel Consumption			20.8	UHr	Driver Wage	9.80	US\$/hos
Less Cost of Tyres/Tracks/Rigg	ging			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hou
	other			0	US\$s	Oil Cost		l		US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	•
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
And a straight of the second	other			0	US\$s	front	0	0	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed			1	394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				83 166	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	78 960	US\$s	Fuel,Cost			24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			3.65	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	st		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 930	US\$s	Annual Fuel Costs			47 947	US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost			7 192	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	ng Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint % Cap Cost/mach	ine life (mhr's)	[	90%		Total Crew Cost per Machine Hr	28.87	US\$/mh
Statutory Leave Days				13		Maintenance Cost			23.69	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cos	st		46 670	USSS			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION COST	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per an	num	1	4		Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	USSS	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Cost		1	5 200	USSS	travel emoty		km/hr
Machine Availability				100.0%		Relocation Cost per Mac	hine Hour		2.64	US\$/mhr	Load		min
Machine Utilisation				41.0%	1.1	5.1 Machine Requireme	ents			o o p no n	travel loaded		km/hr
Machine hours per Day				6.6	Hours	Annual Volume		1	124 500	m3	Offload		min
Machine hours per boy				1 970	Hours	Hourty Volume Required			63 10	m3/mhr	Travel time empty	#011/01	min
Machine I de Hours				15 000	Hours	Number Of Machines Re	harmen		2.00	#	Travel time loaded	#011/01	min
Machine Life Years				7.61	Veare	Fleet Reserve	quireu		0%	-	Load	0.00	min
Machine Life reals				7,01	roars	Evact Number of Machin	as Dequired		2.00		Offload	0.00	min
14 OVERHEADS						Dounded number of macrini	olos Required		2.00		cuele time	#DIS//01	min
14 OVERHEADS						Rodinged inditioes of year	cles Redoiled				cycle time	+010/01	here
Annual Licenses Free				10 740	luce						Machine Ordert car blaur	#019701	nis m3/mbr
Annual Licence rees			-	18 140	10340						Machine Output per Plour	200	marinin marinin
1 E Ouerheads		ſ	10.00%	20000	11000						Machine Output per Day	62.250	morudy
A CLIMMADY			10.00%	20000	0345	6 2 EL EET SUMMARY					Machine Output per Annum	02 200	mayear
C.I SOMMARY		ED MACHIN	E I	CIEET	0/								
-	licens	CE MACHIN	LICEARA	FLEET	70	1100 000 002	1	4.74	Inc. Desta	E 40			
OVERHEADS	1254	2 april	os age	ES and	o non	Number of Machines		4./1	mc. Profit	3.42	4		
EIVED COSTS	13.04	12 223	150 704	240 560	5.03%	Number of Machines	1.00	2					
Hale COSTS	42.24	6.020	02 100	100 004	20.4%	of Operators		4					
Craw Craw	42.21	0 930	50 990	100 331	20.3%	Machine Maure		200					
Crew	20,67	4741	00 889	113 778	18.4%	Machine Hours		3 940					
Licence	10.02	1 845	18.740	39 480	0.7%	Capital Employed		789 596					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		157 919					
VARIABLE COSTS	54.31	8 917	107 009	214 017	36.5%	Total Révênue		586 967					
Fuel	24.34	3 996	47 947	95 894	16:3%								
Lubrication	3.65	599	7 192	14 384	2.5%								
Tyres Maintenance	23 60	3 880	46.870	0	15.0%								
Relocation	2.64	433	5 200	10 400	18%								
TOTAL COST / REVENUE	148,96	24 457	293 483	586 967	100.0%								



MACHINE DESCRIPTION	÷	CFDD (Morbark 2455)
OPERATION		Delimb, Debark full trees
STUDY FOR	1.0	MSc
PREPARED BY	3	McEwan
NOTE: ALL FIGURES QUOTED AF	E EST	MATES, SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS



1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	ING COSTS				3.1 LABOUR COSTS		
Machine Price Exc VAT			1	714 371	USSS	Fuel Consumption		Г	56.9	1 AHr	Driver Wage	9.80	USS/hour
Less Cost of Tyres/Tracks/Rigg	ina			0	11580	Fuel Cost			1 17	115\$1	No Drivers/Shift	11	#
Plus additional equipment	radio			0	110.00	Oil % Eup) Cost			1 60/	UDGL	Labour Wage	0.00	USEDour
Fius additional equipment	combiean			0	11000	Oil Cost			13%	11000	Na Labourere/Chiff	0.00	#
	other			0	11000	Tures Tracks Dissing		-		USAL	Contributions	0.0	-
	other			0	0345	i yrear nackarkigging	01	0	1.00		Contributions	0.0%	Sec. 1
	other			0	US\$S	Obeles	Qty	Cost	Life		Operating Days/Week	6.0	days
a state to the state of the state of the	other			0	US\$S	Chains	234	8	30		Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$S	Drum	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				714 371	US\$s	Tyres	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment	_			150 485	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation		T		11.000		other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	142 874	US\$s	Fuel Cost			66.57	US\$/hour	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			9.99	US\$/hour	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging C	lost		62.40	US\$/hour	Annual Time and a Half	225	US\$s
Monthly payment				12 540	US\$s	Annual Fuel Costs			207 708	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			31 156	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS				_		Annual Tyre/Track/Rigg	ing Cost		194 688	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTER	NANCE COSTS				Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/mac	hine life (mhr's)		100%		Total Crew Cost per Machine Hr	16.75	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			47.62	US\$/mhr			
Sick Leave Days				0		Annual Maintenance C	ost		148 589	US\$s			
Productive Days Lost to Weather	/Mill Stops			0		2.3 RELOCATION COS	STS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Davs	Number of moves per a	nnum	1	4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	USSs	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cos			5 200	11555	other		<i>"</i>
Machine Availability			1	100.0%		Relocation Cost per Ma	chine Hour		1.67	1/S\$/mhr	debranch debark		min
Machine I tilication				65 0%		5 1 Machine Requirem	ionine mour	-	1.07	03.000	other		min
Machine baue par Day				10.4	Hours	Annual Valuma	ients	Г	104 500		outier		min
Machine hours per Day				10.4	Hours	Annual volume.			124 500	ma	other		min
Machine hours per Annum			-	3 120	Hours	Houriy volume Require	a		39.90	msymnr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines R	required		1.00	#	other		min
Machine Life Years			L	4.81	Years	Fleet Reserve			0%		other		min
and the second second						Exact Number of Machi	ines Required		1.00	#	other	_	min
1.4 OVERHEADS						Rounded number of ve	hicles Required		1	#	cycle time	0.00	min
and the second											cycle time	0,00	hrs
Annual Licence Fees & insurance	e		L	14 287	US\$s						Machine Output per Hour	40.0	m3/mhr
						difference in the second secon					Machine Output per Day	416	m3/day
1.5 Overheads			10.00%	80438	US\$s			_		_	Machine Output per Annum	124 800	m3/year
6.1 SUMMARY	_					6.2 FLEET SUMMARY							
	1000	PER MACHIN	Æ	FLEET	%			_					
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		7.11	Inc. Profit	8.17			
OVERHEADS	25.78	6 703	80 438	80 438	9.09%	Number of Machines		1					
FIXED COSTS	69.56	18 087	217 041	217 041	24.5%	Number of Operators		2					
Hp	48 23	12 540	150 485	150 485	17.0%								
Crew	16.75	4 356	52 269	52 269	5.9%	Machine Hours		3 120					
Licence	4.58	1 191	14 287	14 287	1.6%	Capital Employed	7	14 371					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1	42 874					
VARIABLE COSTS	188.25	48 945	587 341	587 341	66.4%	Total Revenue		84 820					
Fuel	66 57	17.300	207 708	207 708	23 50/	- Star Fightering							
Lubrication	0.00	2 500	31 150	21 150	2 500								
Tyres	62.40	16 224	194 688	194 688	22.0%								
Maintenance	47.62	12 382	148 589	148 589	16.8%								
Relocation	1.67	433	5 200	5 200	0.6%								
TOTAL COST / REVENUE	283.60	73 735	884 820	884 820	100.0%								



NOTE ALL ROUNDES QUOTED ANE ESTIMATES SITE ENFORME FALLY TRANED OPERATIONS   In Contract Plants Pl	MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY		Bell 220E Bundle tre MSc McEwan	Telelogger e lengths a	after debarki	ng					TOLUNIONS			
11. CAPUAC DED     21. VARDUE D'ORERATING COSTS     11. LABOR COSTS	NOTE: ALL FIGURES QUOTE	DARE ESTIMA	TES, SITE SI	PECIFIC & AS	SUME FULLY	TRAINED C	PERATORS				Surger State			
Machine Processer: Variant Series General Series Series Gene	1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERAT	ING COSTS			3.1 LABOUR COSTS			
Lase Gord TynerTrade/Rigging     0     0     10     10     0 <td< td=""><td>Machine Price, Exc. VAT</td><td></td><td></td><td></td><td>80 500</td><td>US\$s</td><td>Fuel Consumption</td><td></td><td></td><td>6.6 L/Hr</td><td>Driver Wage</td><td>9.80</td><td>US\$/hou</td></td<>	Machine Price, Exc. VAT				80 500	US\$s	Fuel Consumption			6.6 L/Hr	Driver Wage	9.80	US\$/hou	
Pipe additional equipment     Same additional equipment     Same additional equipment     Column (Column	Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost			1.17 US\$/L	No.Drivers/Shift	1.1	#	
Took Strip and taker     OL Odi Oligits     OL Odi Tree frackRigging     USEL     No LobourseVisiti Contributions     O.0     6.0	Plus additional equipment	slasher			0	USSS	Oil % Fuel Cost			15%	Labour Wage	0.00	US\$/hou	
pale     0     USB     TyreIntackRggng     Contrustions     00%       Sub btal additional equipment     0     USB     Tyre front     0		Truck 2ns ha	and		0	US\$s	Oil Cost			USSA	No.Labourers/Shift	0.0	#	
piner     0     0/25p     The relation of the properties     0.0 </td <td></td> <td>trailer</td> <td></td> <td></td> <td>0</td> <td>USSS</td> <td>Tyres/Tracks/Rigging</td> <td></td> <td></td> <td></td> <td>Contributions</td> <td>0.0%</td> <td></td>		trailer			0	USSS	Tyres/Tracks/Rigging				Contributions	0.0%		
operating     operating     0 USA     Tyre Front     0 <th< td=""><td></td><td>other</td><td></td><td></td><td>0</td><td>11585</td><td>-1</td><td>Otv</td><td>Cost</td><td>Life</td><td>Operating Days/Week</td><td>6.0</td><td>days</td></th<>		other			0	11585	-1	Otv	Cost	Life	Operating Days/Week	6.0	days	
Bab Maddinul exponent     Image: Parmer     0    <		other			0	11555	Tyre front	0	0	0	Operating Hours/Week	96.0	days	
Table (Lights)     Open     O	Sub total additional equipment	t Control			0	liste	Tyre rear	0	0	0	Basic Hours/week/driver	90.0	Hrs	
Name of the set of t	Total Capital Employed				80 500	11000	other	0	0	0	Total Overtime per week	BI	Hre	
On the Production     Description     Description <thdescription< th=""></thdescription<>	Acquired HD pourment				16 058	11050	other	0	0	0	Time and a Half per week	30	Lire	
Lar Are Calculation     20.004     19.00     0     0     00000     100000     20.0000     100000     20.0000     100000     20.0000     100000     20.0000     100000     20.0000     100000     20.0000     100000     20.00000     20.0000     20.0000 </td <td>Annual HP payment</td> <td></td> <td>_</td> <td>-</td> <td>10 930</td> <td>0335</td> <td>other</td> <td>0</td> <td>0</td> <td>0</td> <td>Double Time out Meek</td> <td>3,0</td> <td>Ha</td>	Annual HP payment		_	-	10 930	0335	other	0	0	0	Double Time out Meek	3,0	Ha	
Interest part annum Payment period     20000 (0.0 Colt )     10000 (0.0	1.2 HP Calculation		1	20.000	40 400	U.C.C.	Curel Caret	0		7.72 1102/mbs	Chill as Other Allevinner	0.00	11C Cidau	
ummere partanum     E.VV%     On. Use     1.10 (Use mm     Annual Kent all Mortial June     5.11 44 (Use June       Morthy symmetric     1.30 PERATING HOURS     1.30 PERATING HOURS     3.06 (Use June     Annual Kent all Autor Annual Kent all Autor all Autor Annual Kent all Autor all Autor Annual Kent An	Residual Value @		L	20.00%	16 100	0535	Puer,Cost			1.12 USS/mhr	Annual Name Time	0.00	USDICAY	
unamet period     000 months     1 yrew TransAvrigging Cost     0.000 (U.S.min     Annual Tune and a Hail     22 (U.S.a.       1.3 OPERATING HOURS     1.3 OPERATING HOURS     0.01 (U.S.min     Annual Evol Cost     3.06 (U.S.a.     Annual Evol Cost     3.06 (U.S.a.     Annual Evol Cost     Cost St     Cost St     Annual Evol Cost     Cost St     Annual Evol Cost     Cost St     Cost St <td< td=""><td>interest per annum</td><td></td><td></td><td></td><td>8.00%</td><td></td><td>UII, COSt</td><td></td><td></td><td>1.10 US\$/mhr</td><td>Annual Normal Time</td><td>51744</td><td>0232</td></td<>	interest per annum				8.00%		UII, COSt			1.10 US\$/mhr	Annual Normal Time	51744	0232	
Monthy symmetric     Annual Live Costs     3 Odd 224     USSs     Annual Live Costs     3 Odd 225     Annual Live Costs     Annual Live	Payment period				60	months	Tyres/Tracks/Rigging C	ost		0.00 USS/mhr	Annual Time and a Hair	225	0535	
Annual Luce Cost 3 000 US8 Annual Sorta 0 US8 <td< td=""><td>Monthly payment</td><td></td><td></td><td></td><td>1 413</td><td>US\$\$</td><td>Annual Fuel Costs</td><td></td><td></td><td>20 029 US\$s</td><td>Annual Double Time</td><td>300</td><td>US\$s</td></td<>	Monthly payment				1 413	US\$\$	Annual Fuel Costs			20 029 US\$s	Annual Double Time	300	US\$s	
1.3 OPERATING HOURS     Annual TrueTrack/Egorg Cost     0 USS     Annual Shift Order Allowance Sot USS mithanual Singer Cost     0 USS sot USS mithanual Singer Cost							Annual Lube Cost			3 004 US\$s	Annual Bonus	0	US\$s	
Tatal Days     Tatal Anual Vesteina Days     Tatal Anual Xier Cost S     Tatal Xier Cost S     Tatal Anual Xier Cost S     Tatal Anual Xier Cost S     Tatal Xier Xier Cost S     Tatal Xier	1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigg	ging Cost		0 US\$s	Annual Shift or Other Allowance	0	US\$s	
Status     S2     Maint % Cap Confirmation life (rthrs)     100%     Tail Crew Cost per Machine Hof     20.15 (USSmhr       Sixtus Days     0     Annual Maintenance Cost     5.320 (USSmhr     1.3200 (USSs     1.32	Total Days			-	365		2.2 VEHICLE MAINTER	NANCE COSTS	5		Total Annual Crew Cost	52 269	US\$s	
Statutory Lawe Days     13     Maintenance Cost     5.37     USS hmr       Stot Lawe Days     0     Annual Mintenance Cost     15.320     USS hmr       Productor Days     0     2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Total Annual Reduction Days     0     2.4 Renuel Reduction Cost     53.00     USS hmr       Number of Shifts per day     2     4     Annual Reducation Cost     53.00     USS hmr       Number of Shifts per day     2     4     Annual Reducation Cost     53.00     USS hmr       Machine Ausing PD By     0.00     54.00%     54.00     USS hmr     700     0 min       Machine Nours per Annum     2.564     Annual Reducation Cost     124.500     min     min       Machine Life Years     15.000     Annual Wolume     124.500     min     other     min       Machine Life Years     5.77     Years     Fleet Reserve     0.05     #     other     min       Annual Wolume     10.00%     11290     USS     Fleet Reserve     0.05     #     other     min </td <td>Weekend Days</td> <td></td> <td></td> <td></td> <td>52</td> <td></td> <td>Maint,% Cap.Cost/mac</td> <td>thine life (mhr's)</td> <td>)</td> <td>100%</td> <td>Total Crew Cost per Machine Hr</td> <td>20.15</td> <td>US\$/mhr</td>	Weekend Days				52		Maint,% Cap.Cost/mac	thine life (mhr's)	)	100%	Total Crew Cost per Machine Hr	20.15	US\$/mhr	
Sink Leave Days     0     Annual Mantenance Cost     13920 USS     1     UNDER STUDY ANALYSIS       Productive Days Lost to Weather/Mill Stops     300     Days     Number of moves per annum     4     #     1     WORK STUDY ANALYSIS     m3       Number of Shifts per day     8     #     Annual Mantenance Cost     528/LCOATION COSTS     41 WORK STUDY ANALYSIS     m3       Number of Shifts per day     8     #     Annual Recotano Cost     5200     USS.     Number of see per cycle     #     m3       Machine Availability     50.00     #     Annual Notime     5.01 Machine Haur     2.00     USS.     Wolfree     min     min       Machine Itiliation     54.04     Number for Cost per Machine Haur     2.00     USS.     other     min     min       Machine Life Hours     5.0     Machine Required     4.00     m3     other     min     min       Machine Life Years     15.000     Hours     Number of Machine Required     2.00     #     other     min       1.4 OVERHEADS     1.500verhads     1.000%     115.000	Statutory Leave Days				13		Maintenance Cost			5.37 US\$/mhr				
Productive Days Lost to Weather/Mill Stops     0     2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Shift length     300 Days     Number of moves per annum     4 #     1300 //358     Number tess per cycle     #       Shift length     2 #     Annual Relocation Cost per Move     5200 //358     Number tess per cycle     #     #       Machine Ataliability     100 0/4     Relocation Cost per Move     5200 //358     pull trees     min       Machine Ataliability     100 0/4     Relocation Cost per Machine Hour     200 //358     pull trees     min       Machine Hours per Day     5.1 Machine Required     48.00     300 //358     other     min       Machine Life Years     5.78     Years     Fleet Reserve     0.05     other     min       1.4 OVERHEADS     5.78     Years     Fleet Reserve     0.00     min     min       1.4 OVERHEADS     5.1 SumMARY     6.2 FLEET SumMARY     2.00 #     other     min     min       1.4 OVERHEADS     10.00%     11290 //358     0.000 min     cycle time     0.000 min     cycle time     0.000 min	Sick Leave Days				0		Annual Maintenance C	ost		13 920 US\$s				
Tatal Annual Production Days     Number of moves per annum     4 #     The volume     m3       Number of Shifts per day     8 # Hours     0 ber Move     1300 USs     Number des per volume     #       Number of Shifts per day     2 #     Annual Relocation Cost     5 200 USs     Outret researcy cole     #       Number of Shifts per day     100.0%     Relocation Cost     5 200 USs     Outret researcy cole     #       Machine Availability     100.0%     Relocation Cost     200 USs     Outer     min       Machine Duris per Day     8.6 Hours     Annual Volume     124.500 m3     Other     min       Machine Life Years     5.78 Years     Fleet Reserve     0%     Other     min       Machine Life Years     5.78 Years     Fleet Reserve     0%     Other     min       1.4 OVERHEADS     10.00%     11299 USs     Annual Locace Res & insurance     1610 USs     Outer     0.000 min       1.5 Overheads     10.00%     11299 USs     Start Machines Required     2.0     Machine Output per Hour     24.000 min       Starer USSymm     USSymm	Productive Days Lost to Weath	er/Mill Stops			0	6	2.3 RELOCATION COS	STS			4.1 WORK STUDY ANALYSIS		-	
Shift length     Shift length     6 Hours     Cost per Move     1.300 U/S8     Number to spin (USS	Total Annual Production Days				300	Days	Number of moves per a	annum	1	4 #	Tree volume		m3	
Number of Shifts per day     2 #     Annual Relocation Cost per Machine Hour     2.00 U/S5     put trees     min       Machine Availine Availine Availine Hour     2.00 U/S5     put trees     min       Machine Hours per Day     54.05     S1 Machine Requirements     0.00 U/S5 m/n     other     min       Machine Hours per Day     2.664 //Arras     Houry Volume Required     140.00 //Arras     other     min       Machine Life Hours     15.000 //Arras     Years     5.78 Years     Years     other     min       1.4 OVERHEADS     5.78 Years     1610 U/Ss     Number of Machines Required     2.00 //S     other     min       1.4 OVERHEADS     10.00%     11289 U/Ss     Runded number of Vehicles Required     2.00 //S     other     0.000 //min       1.5 Overheads     10.00%     11289 U/Ss     S2 FLEET SUMMARY     S2 FLEE	Shift length				8	Hours	Cost per Move			1 300 US\$s	Number trees per cycle	-	#	
Machine Availability     100.0%     Relocation Cost per Machine Hour     2.00 US\$min     ohrer     min       Machine Outs per Day     54.0%     5.1 Machine Requirements     other     min       Machine hours per Anum     2.964 Hours     Anunal Volume Required     48.00 m3/min     other     min       Machine Hours per Anum     2.964 Hours     Houry Volume Required     2.00 #     other     min       Machine Hours per Anum     5.78     Years     16.00 // Mours     0.00 #     other     min       Machine Life Years     5.78     Years     Fleet Reserve     0%     other     min       Anual Lience Fees & insurance     1619     US\$s     Per Machine Required     2.00     #     other     min       1.5 Overheads     10.00%     11290     US\$s     Per Machine Sequired     2.00     min     min       1.5 Overheads     10.00%     11290     US\$year     US\$year     US\$year     US\$year     US\$year     US\$year     Machine Sequired     2.00     min       1.5 Overheads     10.00%     11290     2	Number of Shifts per day				2	#	Annual Relocation Cos	t		5 200 US\$s	pull trees		min	
Machine Lillisation     54.0%     54.0%     Annual Volume     124.500     Other     Imin     min       Machine hours per Annum     2.664     Hours     Annual Volume     145.000     #45.00     m3/min     other     min     min       Machine Life Hours     15.000     Hours     Number Of Machine Required     2.00     #     other     min     min       Machine Life Years     5.78     Years     Years     Pieter Reserve     00%     other     min     min       1.4 OVERHEADS     5.78     Years     Fieter Reserve     00%     other     0.000     min       1.4 OVERHEADS     5.78     Years     Rounded number of Vehicles Required     2.00     #     other     0.000     min       1.5 Overheads     10.00%     11299     USSs     FLEET SUMMARY     6.2     FLEET SUMMARY     Machine Output per Annum     6.2     FLEET SUMMARY     Machine Hours     1.8     Annuel Volue     4.36     942     11.299     22.588     9.095     Number of Machines     2     Annuel Volue     An	Machine Availability				100.0%	1.1	Relocation Cost per Ma	achine Hour		2.00 US\$/mhr	other		min	
Machine Indurs par Day   8.8. Hours   Annual/ Volume Required   124 500   m3/m1   other   min     Machine Ide Hours   1.5 000   Hours   Number Of Machines Required   2.00   #   other   min   min     Machine Life Years   5.78   Years   Fleet Reserve   0.5%   other   min   min     1.4 OVERHEADS   S.78   Years   Fleet Reserve   0.000   fleet Machines Required   2.00   #   other   min   min     Annual Licence Fees & insurance   1.610 US\$   VS\$   PER Machine Life Years   0.000   m3/m1   cycle time   0.000   min     1.5 Overheads   10.00%   11299 US\$   Server of Total   U\$\$ year of Total   VS\$ pr m3   2.00   #   Machine Clift Us Pr Hours   0.000   m3/m2     1.5 Overheads   10.00%   11299 US\$   Server of Total   VS\$ pr m3   2.00   #   Machine Clift Us Pr Hours   0.200   m3/m2   Machine Clift Us Pr Hours   0.200   m3/m2   Machine Clift Us Pr Hours   0.200   m3/m2   Machine Clift Us Pr Hours   0.000   Machine Clift Us Pr Hours   0.000	Machine Utilisation				54.0%		5.1 Machine Requirem	nents			other		min	
Machine hours per Annum 2 594 Hours Hours 48.00 m3mhr other min   Machine Life Hours 15 000 Hours Number Of Machines Required 2.00 # other min   Machine Life Years 5.78 Years Fileet Reserve 0.05 Other min   1.4 OVERHEADS 5.78 Years 1610 USS Statumber of Machines Required 2.00 # other min   Annual Licence Fees & insurance 1610 USS USS Fileet Reserve 2.00 # 0.000 min   1.5 Overheads 10.00% 11299 USS Vertex Machine Output per Hour 24.000 m3/day   6.1 SUMMARY 5.03 70.837 14.1673 57.704 Vertex Vertex Machine Output per Annum 62.261   0VERHEADS 10.00% 11299 USS for Total Vis S per m3 2.00 inc. Profit 2.30   0VERHEADS 2.33 5.903 70.837 141.673 57.704 Number of Machines 2   FixeD COSTS 27.31 5.903 70.837 141.673 57.704 Number of Machines 2   Grew 20.15 4.35 52.269 1	Machine hours per Day				8.6	Hours	Annual Volume			124 500 m3	other		min	
Machine Life Hours   15000 Hours   Number Of Machines Required   2.00 Hours   other   min     Machine Life Years   5.78 Years   FReserve   0.05   0.05   other   min     1.4 OVERHEADS   Statt Number of Machines Required   2.00 Hours   0.00 min   min     Annual Licence Fees & insurance   1610 US\$s   Rounded number of vehicles Required   2.00 Hours   0.00 min     1.5 Overheads   10.00%   11290 US\$s   PER MACHINE   6.2 FLEET SUMMARY   Machine Output per Day   28 m3/day     0VERHEADS   4.38   942   11 209   22 588   9.00%   Number of Machines   2     VERMEADS   4.38   942   11 209   22 588   9.00%   Number of Machines   2     VERMEADS   4.38   942   11 209   22 588   9.00%   Number of Machines   2   4     Hp   6.54   14 13   16 695   33 315   13.6%   Number of Machines   2   4     Hp   6.54   14 13   16 595   33 315   13.6%   Number of Machines   2   4     VERW   20.15	Machine hours per Annum				2 594	Hours	Hourly Volume Require	d		48.00 m3/mhr	other		min	
Machine Life Years 5.78 Years Fleet Reserve 0% other min   1.4 OVERHEADS 1.4 OVERHEADS Rounded number of Walchines Required 2,# 0% 0000 min   Annual Licence Fees & insurance 1.610 US\$s Status Number of Walchines Required 2,# 0% 0,000 min   1.5 Overheads 10.00% 11299 US\$s 6.2 FLEET SUMMARY Machine Output per Hour 2.4000 m3/mbrr   0VERHEADS 4.36 942 11299 22.598 9.09% Mumber of Machines 2   FIRED Costs 2.35 10.60% 113.6% Number of Operators 4   Hp 6.54 1.413 16.956 33.915 13.6%   Crew 20.15 4.386 52.299 104.558 42.1%   Hp 6.54 1.413 16.956 33.915 13.6%   Crew 20.15 4.386 52.299 104.558 42.1%   VARIABLE COSTS 16.25 3.513 42.164 84.307 33.945   Fuel 77.2 16.69 2.002 40.058 76.4%   Variable Ecosts 0.00 0 0.004 0.004   Yres 0.00	Machine Life Hours				15 000	Hours	Number Of Machines R	Required	1	2.00 #	other		min	
1.4 OVERHEADS 1.4 OVERHEADS Exact Number of Machines Required 2.00 # other m3   Annual Licence Fees & insurance 1610 US\$s Rounded number of vehicles Required 2.# other 0.000 min   1.5 Overheads 10.00% 11299 US\$s 0.55 Machine Output per Hour 84.000 m3/mbr   1.5 Overheads 10.00% 11299 US\$s 6.2 FLEET SUMMARY Machine Output per Hour 84.000 m3/mbr   0VERHEADS 4.35 942 11 259 US\$year 0.005 70.837 141.673 57.0% Number of Machines 2 10.00%   VESthr US\$month US\$year 0.205 11 1269 0.255 US\$ per m3 2.00 inc. Profit 2.30   VERHEADS 4.35 943 11 1269 0.259 0.005% Number of Machines 2 2 m3/mbr   FIXED COSTS 27.31 5.903 70.837 141.673 57.0% Number of Operators 4   Hp 6.54 1.413 16.968 33.915 13.6% Number of Operators 4   Hp 6.54 1.413 16.968 33.915 13.6% Residual Value 32.200 161.000   Crew 20.6 1.93 1.150 3.200 1.06% Residual Value 32.200 161.000   Variabele COSTS 16.25 3.913 42.154 84.307 3.3.9% Total Revenue 248.578	Machine Life Years			1	5.78	Years	Fleet Reserve			0%	other		min	
1.4 OVERHEADS Annual Licence Fees & insurance 1610 US\$s Outoed number of vehicles Required 2 # cycle time 0.000 min   Annual Licence Fees & insurance 100% 11299 US\$s 0.00% 11299 US\$s 0.000 min 0.000				_			Exact Number of Mach	ines Required		2.00 #	other		m3	
In ordinate of lands     Indication la	14 OVERHEADS						Rounded number of ve	hicles Required		2 #	cycle time	0.00	min	
Anual Licence Fees & insurance 1610 US\$s Anchine Output per Hour 40.000 m3/mbr   1.5 Overheads 10.00% 11299 US\$s 6.2 FLEET SUMMARY Machine Output per Hour 62 251 m3/mbr   0/VERHEADS 4.3 5 942 11299 US\$ year of Total US\$ year 0 US\$ per m3 2.00 inc. Profit 2.30   0/VERHEADS 4.3 5 943 11299 22 598 9.095% Number of Machines 2 2   FIXED COSTS 27.31 5 903 70.837 141 673 57.0% Number of Machines 2 2   Hp 6.54 1 413 16 958 33 943 13.6% Machine Hours 5 188   Crew 20 15 4 365 5 2269 104 538 42.1% Machine Hours 5 188   Licence 0.62 134 16 103 20.00 62 134 16 100   VARIABLE COSTS 16.25 3 513 42.154 84.307 3.3.9% Capital Employed 16 1000   Variable Loors 16.25 3 0.04 5 0.09 2.48.578 14 84.578 14 84.578   Variable Costs 16.25 3 0.04 5 0.09 2.48.578 14 84.578								inclus required			cycle time	0.000	hrs	
Minual Deline Fees & Initial allocity     I 000     I 0000     I 000     I 000	Appual Licence Fees & insuran	-			1.610	licee					Machine Output per Hour	24.000	m3/mhr	
15 Overheads     10,00%     11299     USS     Machine Output per Annum     62 251     machine Out	Annual Licence Fees & Insuran	ice.		-	1010	0000					Machine Output per Hour	205	an 2/dais	
PER MACHINE FLEET %   0VERHEADS 4.35 942   0VERHEADS 4.35 942   11200 11209 2258   0VERHEADS 4.35 942   11200 11209 2258   0VERHEADS 4.35 942   11200 11209 2258   902 11209 22598   902 11209 22598   903 70.837 141673   57.0% Number of Machines 2   11209 22598 9.09%   Number of Operators 4   Hp 6.54 1413   16 568 33 315 13.6%   Crew 2015 4.356   11209 2259   104 538 42.1%   Machine Hours 5188   11209 0   11209 0.00%   Permit & Toll fees 0.0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0   0.00 0 <t< td=""><td>A E Outerbands</td><td></td><td>F</td><td>10 000/</td><td>11200</td><td>11000</td><td></td><td></td><td></td><td></td><td>Machine Output per Day</td><td>62 264</td><td>maken</td></t<>	A E Outerbands		F	10 000/	11200	11000					Machine Output per Day	62 264	maken	
PER MACHINE     FLEET     %     US\$ per m3     2.00     Inc. Profit     2.30       OVERHEADS     4.36     942     11 299     22 598     9.09%     Number of Machines     2       FIXED COSTS     27.31     5 903     70 837     141 673     57.09%     Number of Machines     2       Hp     6.64     14 13     11 6958     33 915     13.6%     Number of Operators     4       Licence     0.62     134     16 103     32.20     13%     Capital Employed     161 000       Permit & Toll fees     0.0     0     0.0%     Residual Value     32 200       VARIABLE COSTS     1.62     3.513     42 15%     84 307     Total Revenue     248 578       Fuel     7.72     1.669     20.029     40 058     16.1%     Add Revenue     248 578       Fuel     7.72     1.669     20.029     40 058     16.1%     Add Revenue     248 578       Fuel     7.72     1.669     20.029     40 058     16.1%     Add Revenue     248 578	6 4 SUMMARY			10.00%	11299	0345	6 2 EL EET SUMMARY				Machine Output per Annum	02 201	msryear	
VEX.MUCHINE     VEX.Muchine     VEX.Vex.Muchine     VEX.Vex.Vex.Muchine     VEX.Vex.Vex.Muchine     VEX.Vex.Vex.Vex.Muchine     VEX.Vex.Vex.Vex.Vex.Vex.Vex.Vex.Vex.Vex.Vex	0.1 Sommart	-	D HACHIN	e	FIEET	6/								
OVERHEADS     4.36     942     11 299     22 99     Number of Machines     2       FIXED COSTS     27.31     5 903     70 837     141 673     57.0%     Number of Machines     2       FIXED COSTS     27.31     5 903     70 837     141 673     57.0%     Number of Operators.     4       Hp     6.54     1 413     16 958     33 915     13 5%		Lines I	ER MACHIN	LIDAL	FLECT	70			0.00					
OVERHEADS     4.36     942     11 299     22 298     9.0% Number of Machines     2       FIXED COSTS     27.31     5 903     70 837     141 673     57.0% Number of Operators.     4       Hp     6.54     1 413     16 956     33 915     13.5%		US\$/hr L	S\$/month	US\$/year	US\$/year	of Iotal	US\$ per m3		2.00	Inc. Protit	1			
FIXED COSTS     27.31     5903     70.837     141.673     57.0% Number of Operators.     4       Hp     6.54     1.413     16.958     33.815     13.6%	OVERHEADS	4.36	942	11 299	22 598	9.09%	Number of Machines		1					
Hp     0.54     1413     16 958     33 915     13 5%       Crew     20 15     4 356     52 269     104 558     42 1%     Machine Hours     5 188       Licence     0.62     134     1 610     3 220     1 3%     Capital Employed     151 000       Permit & Toll fees     0.0     0     0.0%     Residual Value     32 200       VARIABLE COSTS     16,25     3 513     42 154     84 307     33,9%     Total Revenue     248 578       Fuel     7.72     1 669     20 029     40 058     15 1%     16     16       Lubrication     1 16     250     3004     6 005     2.4%     15 1%       Maintenance     5.37     116,01     13 920     27 840     11 2%     12 200     12 248       Cost / REVENUE     433     5 200     10 400     4 2 %     12 200     12 248     10 207     10 207     10 207     10 207     10 207     10 207     10 207     10 207     10 207     10 207     10 207     10 207	FIXED COSTS	27.31	5 903	10 837	141 673	57.0%	number of Operators		4					
Crew     20 15     4 355     52 269     104 538     42 1% Machine Hours     5188       Licence     0.62     134     1610     3 220     1 3%     Capital Employed     161 000       Permit & Toll fees     0.0     0     0.00%     Residual Value     32 200       VARIABLE COSTS     16.25     3 513     42 154     84 307     33.9%     Total Revenue     248 578       Fuel     7.72     1 669     20 028     40 058     16 1%     248 578       Lubrication     1 16     250     3 004     5 009     2 4%     42%       Maintenance     5.37     11 160     13 3200     27 840     11 2%     42%       Relocation     2.00     433     5 200     10 400     42%     42%       ToTAL COST / REVENUE     47.92     10 357     124 289     248 578     100.0%     430	нр	6.54	1 413	16 958	33 915	13,6%		-	P 19-1					
Licence     0.62     134     1510     3.220     1.3% (2a)tal Employed     161000       Permit & Toll fees     0.0     0     0.0%     Residual Value     32 200       VARIABLE COSTS     16.25     3.513     42 154     84 307     33.9%     Total Revenue     248 578       Fuel     7.72     1.669     20.029     40.058     16.1%     700     700     0.00%       Fuel     7.72     1.669     20.029     40.058     16.1%     700     700     0.00%       Maintenance     5.37     1.160     13.920     27 940     11.2%     700 <th 70<="" td=""><td>Crew</td><td>20.15</td><td>4 356</td><td>52 269</td><td>104 538</td><td>42 1%</td><td>Machine Hours</td><td>100</td><td>5 188</td><td></td><td></td><td></td><td></td></th>	<td>Crew</td> <td>20.15</td> <td>4 356</td> <td>52 269</td> <td>104 538</td> <td>42 1%</td> <td>Machine Hours</td> <td>100</td> <td>5 188</td> <td></td> <td></td> <td></td> <td></td>	Crew	20.15	4 356	52 269	104 538	42 1%	Machine Hours	100	5 188				
Permit & Toil fees     0.0     0     0.0% Residual Value     32.200       VARIABLE COSTS     16.25     3.513     42.164     84.307     33.9%     Total Revenue     248.578       Fuel     7.72     1.669     20.029     40.058     16.1%     248.578       Lubrication     1.16     250     3.004     6.00%     2.4%     40.055     16.1%       Maintenance     5.37     11.60     13.920     27.840     11.2%     433     5200     10.400     4.2%       TOTAL COST / REVENUE     47.32     10.357     124.288     100.0%     4.2%     4.36     52.00     10.400     4.2%	Licence	0.62	134	1 610	3 220	1.3%	Capital Employed		161 000					
VARIABLE COSTS     16.25     3.513     42.154     64.307     33.8% Total Revenue     248.578       Fuel     7.72     1.699     20.029     40.058     16.1%     248.578       Lubrication     1.16     250     3.004     5.009     2.4%       Tyres     0.00     0     0     0.00%       Maintenance     5.37     1.160     13.3920     27.840     11.2%       Relocation     2.00     433     5.200     10.400     4.2%       TOTAL COST / REVENUE     47.92     10.357     124.269     248.578     100.0%	Permit & Toll fees	0.0		0	0	0.0%	Residual Value		32 200					
Fuel     7.72     1.869     20.022     40.058     16.1%       Lubrication     1.16     250     3.004     5.009     2.4%       Tyres     0.00     0     0     0.00%       Maintenance     5.37     1.160     13.320     27.840     1.12%       Relocation     2.00     433     5.200     10.400     4.2%       TOTAL COST / REVENUE     47.92     10.357     124.289     248.678     100.0%	VARIABLE COSTS	16.25	3 513	42 154	84 307	33.9%	Total Revenue		248 578					
Lubrication     1 16     2 50     3 904     5 005     2 4%       Tyres     0.00     0     0     0.00%       Maintenance     5 37     1 160     13 920     27 840     11 2%       Relocation     2.00     433     5 200     10 400     4 2%       TOTAL COST / REVENUE     47.92     10 357     124 288     100.0%	Fuel	7,72	1 669	20 029	40 058	16.1%								
Tyres     0.00     0     0     0.00%       Maintenance     5.37     1.160     13.920     27.840     11.2%       Relocation     2.00     43.35     2.00     10.400     4.2%       TOTAL COST / REVENUE     47.92     10.357     124.269     248.578     100.0%	Lubrication	1 16	250	3 004	6 009	2.4%								
Maintenine     0.01     13 200     27 340     14 78       Relocation     2 00     43 35     2 00     10 400     4 2%       TOTAL COST / REVENUE     47.92     10 357     124 289     248 578     100.0%	Tyres	0,00	1 160	12 020	77 640	0.0%								
TOTAL COST / REVENUE 47.92 10.357 124 289 248 578 100.0%	Relocation	2 00	433	5 200	10 400	4 2%								
	TOTAL COST / REVENUE	47.92	10 357	124 289	248 578	100.0%								



MACHINE DESCRIPTION	3	Tracked loader with slasher deck (Tigercat T234)
OPERATION		Slash to 5.5m lengths
STUDY FOR	:	MSc
PREPARED BY		McEwan



1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERATIN	G COSTS				3.1 LABOUR COSTS		
Machine Price, Exc. VAT			L	381 224	US\$s	Fuel Consumption			13.8	L/Hr	Driver Wage	9.80	US\$/ho
Less Cost of Tyres/Tracks/Rigg/	ing			0	USSS	Fuel Cost			1.17	US\$/L	No Drivers/Shift	1.1	#
Plus additional equipment	slasher			0	US\$s	Oil % Fuel Cost			15%		Labour Wage	0.00	US\$/ho
	Truck 2ns h	and		0	USSS	Oil Cost				US\$/L	No Labourers/Shift	0.0	#
	trailer	Sector .		0	11580	Turee/Tracke/Rigging		_			Contributions	0.0%	
	other			0	110.20	The a manual subling	054	Cost	Life		Operation Dave/Meek	6.0	dave
	other			0	100-	Det	Caty	744	250	1	Operating Dayarveek	06.0	dave
	other			0	0535	Dar	1	114	330		Operating Hours/Week	00.0	Uays
Sub total additional equipment				0	US\$s	Sprocket	0	0	0		Basic Hours/week/driver	90.0	HITS
Total Capital Employed				381 224	US\$s	Tracks	0	0	0		Total Overtime per week	6.0	HIS
Annual HP payment				80 306	US\$s	Chain	1	195	70		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other		_	-	in the second	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	76 245	US\$s	Fuel,Cost			16.15	US\$/mhr	Shift or Other Allowance	0.00	US\$/daj
Interest per annum				8.00%		Oil, Cost			2.42	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cos	t		4.83	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				6 692	US\$s	Annual Fuel Costs			41 918	US\$s	Annual Double Time	300	US\$s
					_	Annual Lube Cost			6 288	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging	Cost		12 529	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENA	NCE COSTS	-			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machin	e life (mhr's)		90%	1	Total Crew Cost per Machine Hr	20.13	US\$/mh
Statutory Leave Days				13		Maintenance Cost			22.87	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost			59 384	US\$s			
Productive Days Lost to Weather	Mill Stops			0		2.3 RELOCATION COSTS	\$	-			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	runn otopo			300	Davs	Number of moves per ann	um		4	#	Tree Volume		1m3
Shift length				8	Hours	Cost per Move			1 300	115 Ce	ince relative		min
Number of Chiltra por day				2	#	Acquial Relacation Cost			5 200	11000	Clash		min
Number of Shifts per day				100.00		Palaestian Cost and Mark	in Here		200	UCEImbe	olabit		man
Machine Availability				100.0%		Relocation Cost per Mach	ine Hour	_	2.00	USSMIN	other		min
Machine Utilisation			-	54.1%	h	5.1 Machine Requiremen	Its				other		min
Machine hours per Day				8.7	Hours	Annual Volume			124 500	m3	other		min
Machine hours per Annum			-	2 596	Hours	Hourly Volume Required			47.95	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Reg	uired		1.00	#	other		min
Machine Life Years				5.78	Years	Fleet Reserve			0%		other		min
						Exact Number of Machine	s Required		1.00	#	other		m3
1.4 OVERHEADS						Rounded number of vehic	les Required		1	#	cycle time	0.00	min
											cycle time	0.000	hrs
Annual Licence Fees & insurance	в			5718	US\$s						Machine Output per Hour	48.000	m3/mhr
			-								Machine Output per Day	415	m3/day
1.5 Overheads			10.00%	26361	US\$s						Machine Output per Annum	124 618	m3/vear
6.1 SUMMARY						6.2 FLEET SUMMARY			-	_			
	P	ER MACHIN	NE	FLEET	%	and an and the second							
	USS/hr I	IS\$/month	USSWear	USSWear	of Total	US\$ per m3		2.33	Inc. Profit	2.68			
OVERHEADS	10.15	2 197	26 361	26 361	9 00%	Number of Machines		1	and a control	2.00	1		
EIXED COSTS	53.27	11 524	138 203	138 203	47 79/	Number of Operators		2					
Lis 00010	20.02	6 600	90 200	80 202	27 70	interior of operators	-	-					
Circle Control	30,93	0.092	50 306	E0 300	19.000	Machine Maure		2 506					
Crew	20,13	4 356	52 269	52 269	18.0%	Machine Hours		2 090					
Licence	2 20	4/7	5798	5/18	2.0%	Capital Employed	3	101 224					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1.000	76 245					
VARIABLE COSTS	48.27	10 443	125 319	125 319	43.2%	Total Revenue	2	89 974					
Fuel	16.15	3 493	41 918	41.918	14.5%								
Lubrication	2.42	524	6 288	6 288	2.2%								
Tyres	1 0 2	1044	12 529	12 529	4.3%								
	4,00	10000	50.001	ED CO.	DO COL	V							
Relocation	22.87	4 949	59 384	59 384	20 5%								



CFDD System – Tree volume 0.25m<sup>3</sup>



:	CFDD
:	Stump to landing
:	MSc
:	McEwan
	:

FORESTRY

Activity	Stand	Extraction route	Roadside Landing	Forest Road	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)					\$2.04	269 500	2	2	7	300
Grapple Skidder (Tigercat 630D)		A			\$2.37	269 500	2	2	4	300
CFDD (Morbark 2455)					\$3.28	269 500	1	2	2	300
Bell 220E Telelogger			*		\$0.93	269 500	2	2	4	300
Tracked loader with slasher deck (Tigercat T234)			A		\$1.13	269 500	1	2	2	300
				Total	\$9.76		8		20	
				1955	\$0.00		0		0	
				TOTAL	\$9.76		8		20	



MACHINE DESCRIPTION OPERATION		Wheeled Feller Buncher (Tigercat 720E) Felling and bunching Euc full trees	
PREPARED BY	:	McEwan	
NOTE: ALL FIGURES QUOTED AN	REEST	IMATES, SITE SPECIFIC & ASSUME FULLY TRAINED	OPERATORS
1.1 CAPITAL EMPLOYED			2.1 VEHICL
Machine Price, Exc. VAT		315 717 US\$s	Fuel Consul
Loss Cost of Turne/Tracks/Dinging		B 11000	Eugl Cont



1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERA	TING COSTS		_		3.1 LABOUR COSTS		
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging		-	-0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%	1000	Labour Wage	6.00	US\$/hour
	combican			0	US\$s	Oll Cost				US\$/L	No.Labourers/Shift	1.1	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
1. A. S. S. S. S. S. S. S.	other			0	US\$s	Tyres	1	9 300	2 500		Operating Hours/Week	96.0	days
Sub total additional equipment	1			0	US\$s	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	US\$s	Other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						Other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		1.1	20.00%	63 143	US\$s	Fuel,Cost			17.78	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%	1.0	Oil, Cost			2.67	US\$/mhr	Annual Normal Time	83 424	US\$s
Payment period				60	months	Tyres/Tracks/Rigging	Cost	- 1	3.72	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs			31 584	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			4 738	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS					-	Annual Tyre/Track/Rid	ging Cost		6 607	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365	1	2.2 VEHICLE MAINTI	ENANCE COST	S			Annual Contributions	0	US\$s
Weekend Days			1	52		Maint,% Cap Cost/ma	chine life (mhr's	.)	100%		Total Annual Crew Cost	83 949	US\$s
Statutory Leave Days				13		Maintenance Cost			21.05	US\$/mhr	Total Crew Cost per Machine Hr	47.27	US\$/mhr
Sick Leave Days				0		Annual Maintenance	Cost	_	37 381	US\$s			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION CO	OSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	annum	1	4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Co	st		5 200	US\$s	bunch		min
Machine Availability				100.0%		Relocation Cost per M	achine Hour		2.93	US\$/mhr	place		min
Machine Utilisation				37.0%	-	5.1 Machine Require	ments	-			move		min
Machine hours per Day				5.9	Hours	Annual Volume		1	269 500	m3	other		min
Machine hours per Annum				1 776	Hours	Hourly Volume Requir	red		151.75	m3/mhr	other		min
Machine Life Hours			[	15 000	Hours	Number Of Machines	Required		1.99	#	other		min
Machine Life Years			1	8.45	Years	Fleet Reserve			0%		other		min
						Exact Number of Mac	hines Required		1.99	#	other		min
1.4 OVERHEADS						Rounded number of v	ehicles Require	d l	2	#	cycle time	0.00	min
										÷	cycle time	0.000	hrs
Annual Licence Fees & insurand	ce		F	14 207	USSS						Machine Output per Hour	76.1	m3/mhr
											Machine Output per Day	451	m3/day
1.5 Overheads			10.00%	25017	USSS						Machine Output per Annum	135 154	m3/vear
6.1 SUMMARY	G				-	6.2 FLEET SUMMAR	Y			-			
	1 I	PER MACHIN	NE	FLEET	%								
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.04	Inc. Profit	2.35			
OVERHEADS	14.09	2 085	25 017	50 035	9.09%	Number of Machines		2		-			
FIXED COSTS	92.72	13 722	164 663	329 326	59.8%	Number of Operators		7					
Нр	37 45	5 542	66 507	133 014	24.2%								
Crew	47.27	6 996	83 949	167 898	30.5%	Machine Hours		3 552					
Licence	8.00	1 184	14 207	28 415	5.2%	Capital Employed	5.0	631 434					
Permit & Toll fees	0.0		0	D	0.0%	Residual Value	1	126 287					
VARIABLE COSTS	48.15	7 126	85 510	171 019	31.1%	Total Revenue		550 380					
Fuel	17 78	2 6 3 2	31 584	63 169	11.5%								
Lubrication	2.67	395	4 738	9 475	1.7%								
Tyres	3.72	551	6 607	13 213	2.4%	2							
Maintenance	21.05	3 1 1 5	37 381	74 762	13.6%	2							
TOTAL COST / REVENUE	2.93	433	5 200	10 400	1.9%								
I STAL OUDT THE FEITURE	10-100	BE 000	A10 100	200 000	100.0%								



MACHINE DESCRIPTION OPERATION STUDY FOR	4 1 1	Grapple S Full tree e MSc	kidder (Tig xtraction	ercat 630D)							Constant		
NOTE ALL FIGURES QUOTE	D ARE ESTIMA	TES, SITE SI	PECIFIC & AS	SUME FULLY TR	AINED OF	ERATORS							
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	TING COSTS		_	-	3.1 LABOUR COSTS		
Machine Price Exc. VAT			Г	394 798	US\$s	Fuel Consumption		-	20.8	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	aina		1	0	USSS	Fuel Cost			1.17	US\$/L	No. Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil.% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	other			0	USSS	Oil Cost				USSIL	No Labourers/Shift	0.0	#
	other			0	USSS	Tyres/Tracks/Ridging					Contributions	0.0%	-
	other			0	USSS	.,	Qtv	Cost	Life		Operating Days/Week	6.0	davs
	other			0	USSS	front	0	0	0	1	Operating Hours/Week	96.0	Hrs
Sub total additional equipment	t			0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				83 166	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation		-				other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	78 960	US\$s	Fuel,Cost			24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			3.65	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging C	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 930	US\$s	Annual Fuel Costs			58 994	US\$s	Annual Double Time	2 940	US\$s
			_			Annual Lube Cost			8 849	US\$s	Annual Bonus	0	USSS
1.3 OPERATING HOURS						Annual Tyre/Track/Rig	ging Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS				Total Annual Crew Cost	56 889	USSS
Weekend Davs				52		Maint % Cap Cost/mac	thine life (mhr's)		90%	1	Total Crew Cost per Machine Hr	23.47	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69	US\$/mhr	tion of the state of the state of the		
Sick Leave Days				0		Annual Maintenance C	ost	_	57 422	US\$s			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION CO	STS	-			4.1 WORK STUDY ANALYSIS	_	
Total Annual Production Days	and a second sec			300	Davs	Number of moves per a	annum	1	4	#	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	USSS	Volume per Load		m3
Number of Shifts per day				2		Annual Relocation Cos			5 200	USSS	travel emoty		km/hr
Machine Availability				100.0%		Relocation Cost per Ma	achine Hour		2.15	US\$/mhr	Load		min
Machine Utilisation				50.5%	1	5.1 Machine Requirem	nents				travel loaded		km/hr
Machine hours per Day				8.1	Hours	Annual Volume	206	F	269 500	m3	Offload		min
Machine hours per Annum				2 424	Hours	Houriy Volume Require	d		111.17	m3/mhr	Travel time empty	#DIV/01	min
Machine Life Hours				15 000	Hours	Number Of Machines R	Required		2.00	#	Travel time loaded	#DIV/01	min
Machine Life Years				6.19	Years	Fleet Reserve	and the second s		0%		Load	0.00	min
						Exact Number of Mach	ines Required		2.00	#	OffLoad	0.00	min
1 4 OVERHEADS						Rounded number of ve	hicles Required		2		cycle time	#DIV/01	min
							and a stade of	-			cycle time	#DIV/01	hrs
Annual Licence Fees				19 740	US\$s						Machine Output per Hour	55.6	m3/mhr
			-								Machine Output per Day	449	m3/day
1.5 Overheads		-	10.00%	29026	US\$s						Machine Output per Annum	134 781	m3/vear
6.1 SUMMARY						6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%	1 Contraction of the second							
	US\$/hr L	/S\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.37	Inc. Profit	2,72			
OVERHEADS	11.97	2 419	29 026	58 052	9.09%	Number of Machines		2			1		
FIXED COSTS	65.92	13 316	159 794	319 589	50.0%	Number of Operators							
Hp's	34 31	6 930	83 165	166 331	28.0%		-						
Crew	23.47	4741	56 889	113 778	17.8%	Machine Hours		4 848					
Licence	8 14	1 645	19 740	39 480	8.2%	Capital Employed		789 596					
Permit & Toll fees	0.0		n	0	0.0%	Residual Value		157 919					
VARIABLE COSTS	53.82	10 872	130 485	260 930	40.9%	Total Revenue		638 571					
Fuel	24.34	4.916	58 994	117 987	18 5%		-						
Lubrication	3.65	737	8 849	17 699	2 8%								
Tyres	0.00	0	D	0	0.0%								
Maintenance	23,69	4 785	57 422	114 845	18.0%								
Relocation	2.15	433	340 285	10 400	1.6%								
I THE COOL TREVENUE	101.11	20.00/	219 100	000 0/1	100.078								



MACHINE DESCRIPTION	:	CFDD (Morbark 2455)
OPERATION	:	Delimb, Debark full trees
STUDY FOR	1.	MSc
PREPARED BY	:	McEwan
NOTE ALL FIGURES QUOTED AF	REEST	MATES, SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS



1.1 CAPITAL EMPLOYED				_		2.1 VEHICLE OPERATI	NG COSTS	-			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				714 371	USSS	Fuel Consumption		1	56.9	L/Hr	Driver Wage	9.80	US\$/ho
Less Cost of Tyres/Tracks/Rig	aina			Ó	USSS	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil.% Fuel Cost			15%		Labour Wage	0.00	USSMO
Second States of the second	combican			0	USSS	Oil Cost				USSAL	No.Labourers/Shift	0.0	#
	other			0	USSS	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	USSS	00.0	Otv	Cost	Life		Operating Days/Week	6.0	days
	other		_	0	11550	Chains	234	8	30	1	Operating Hours/Week	96.0	days
Sub total additional equipmen	- Tourist			0	11550	Doum	0	0			Basic Hourstweak/driver	00.0	Hre
Total Capital Employed				744 374	11080	Turne	0	0	0	-	Total Quedime per week	80.0	Hee
Total Capital Employed				114 311	10000	Tyles	0	0	0		Tital overtime per week	0.0	His
Annual HP payment				150 465	0535	other	0	0	0		Time and a Hair per week	3.0	HIS
1.2 HP Calculation			20.000		luce	other	0			UCRA	Double Time per week	3.0	HIS
Residual value @		6	20.00%	142 574	0535	Fuel, Cost			00.07	USSMOUR	Shift of Other Allowance	0.00	USSOa
Interest per annum				8.00%		Oil, Cost			9.99	US\$/nour	Annual Normal Time	51 744	US\$S
Payment period				60	months	Tyres/Tracks/Rigging Co	ost		62.40	US\$/hour	Annual Time and a Half	225	US\$s
Monthly payment				12 540	US\$s	Annual Fuel Costs			207 708	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			31 156	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	ng Cost		194 688	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap Cost/mach	ine life (mhr's)		100%		Total Crew Cost per Machine Hr	16.75	US\$/mi
Statutory Leave Days				13		Maintenance Cost			47.62	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Co	st		148 589	US\$s			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COS	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per an	ากมศา	1	4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	USSS	other		
Machine Availability				100.0%	<u> </u>	Relocation Cost per Mar	thine Hour	_	1.67	US\$/mhr	debranch debark		min
Machine Litilisation				65.0%		5.1 Machine Requirem	ants		1.07	COpinin	other		min
Machine hours per Day				10.4	Hours	Annual Volume		F	260 500	1	other		min
Machine hours per bay				3 120	Hours	Hourty Volume Dequired			205 000	m2/mbr	other		min
Machine Life Hours				15 000	Hours	Houriy volume Required			00.30	in Serie	other		rinei
Machine Life Hours				15 000	Hours	Number Of Machines Re	aquirea		1,00	-	other		min
Machine Life Years				4.61	rears	Fleet Reserve			0%		other		min
						Exact Number of Machin	ies Required		1,00	#	other	-	min
1.4 OVERHEADS						Rounded number of veh	icles Required		1	#	cycle time	0.00	min
A CONTRACT OF A CONTRACT OF					Control 1						cycle time	0.00	hrs
Annual Licence Fees & insuran	ice		L	14 287	US\$s						Machine Output per Hour	86.4	m3/mhr
											Machine Output per Day	899	m3/day
1.5 Overheads			10.00%	80438	US\$s						Machine Output per Annum	269 568	m3/yea
6.1 SUMMARY	_					6.2 FLEET SUMMARY							
	1	PER MACHI	NE	FLEET	%		_						
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1	3.28	Inc. Profit	3.78			
OVERHEADS	25.78	6 703	80 438	80 438	9.09%	Number of Machines		1					
FIXED COSTS	69.56	18 087	217 041	217 041	24.5%	Number of Operators		2					
Hp	48.23	12 540	150 485	150 485	17 0%								
Crew	16.75	4 356	52 269	52 269	5.9%	Machine Hours		3 120					
Licence	4 58	1 191	14 287	14 287	1.6%	Capital Employed	12.000	714 371					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		142 874					
VARIABLE COSTS	188.25	48 0.45	597 344	597 241	66 49/	Total Revenue		884 820					
Fuel	100.23	40 940	207 700	207 341	22 50	Total Revenue		004 020					
Librication	0.00	2 500	201 100	201 108	20.0%								
Tyrac	9.99	16 224	104 699	31 156	3.5%								
Maintenance	47.62	12 382	148 589	148 589	16.8%								
Relocation	1.67	433	5 200	5 200	0.6%								
TOTAL COST / REVENUE	283.60	73 735	884 820	884 820	100.0%								



MACHINE DESCRIPTION		Bell 220E Telelogger		
OPERATION	:	Bundle tree lengths after debar	king	
STUDY FOR		MSc		
PREPARED BY	:	McEwan		
NOTE: ALL FIGURES QUOTED	ARE EST	MATES, SITE SPECIFIC & ASSUME FULL	TRAINED	OPERATORS
1.1 CAPITAL EMPLOYED			_	2.1 VEHICL
Machine Price, Exc. VAT		80 50	US\$s	Fuel Consu
Less Cost of Tyres/Tracks/Rigg	ing		O US\$s	Fuel Cost
Plus additional equipment	slasher		0 US\$s	Oil,% Fuel
	Truck 2n	is hand	0 US\$s	Oil Cost
	trailer		0 USSS	Tyres/Track



1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATING	G COSTS		3.1 LABOUR COSTS	-	
Machine Price, Exc. VAT				80 500	US\$s	Fuel Consumption		6.6 L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost		1.17 US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	slasher			0	US\$s	Oil,% Fuel Cost		15%	Labour Wage	0.00	US\$/hou
	Truck 2ns	hand		0	USSS	Oil Cost		USS/L	No.Labourers/Shift	0.0	#
	trailer	(mile		0	USSS	Tyres/Tracks/Rigging			Contributions	0.0%	
	other			0	11584	i free machainingging	Oty Cost	1 de	Operating Days/Week	6.0	days
	other		_	0	11000	Type front	0 0	0	Operating Hours Week	06.0	dave
Cub total additional aquipment	Tomer			0	11050	Tyre non	0 0	0	Rasis Hours husek/driver	90.0	Udys.
Sub total additional equipmen	R.				0535	Tyre rear	0 0		Basic Hours/week/driver	90.0	HIS
Total Capital Employed				80 500	US\$S	other	0 0	0	Total Overtime per week	6.0	HIS
Annual HP payment				16 958	US\$S	other	0 0	0	Time and a Half per week	3.0	HIS
1.2 HP Calculation				100 - 100		other	0 0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	16 100	US\$s	Fuel,Cost		7.72 US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		1.16 US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		0.00 US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				1 413	US\$s	Annual Fuel Costs		20 814 US\$s	Annual Double Time	300	US\$s
					_	Annual Lube Cost		3 122 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging	Cost	0 US\$s	Annual Shift or Other Allowance	0	US\$s
Total Davs			1	365		2.2 VEHICLE MAINTENAM	ICE COSTS		Total Annual Crew Cost	52 269	USSS
Weekend Days				52		Maint % Cap.Cost/machine	e life (mhr's)	100%	Total Crew Cost per Machine Hr	19.39	USS/mhr
Statutory Leave Dave				13		Maintenance Cost	e me trinn ev	5 37 US\$/mhr	Teles eles eserper lossimiera L		
Sick Lasva Dave						Annual Maintenance Cost		14 485 11555			
Broductive Days	arittill Stone					2 3 PELOCATION COSTS		14 400 0 0000	A 1 WORK STUDY ANALVER		
Productive Days Lost to weath	enmin Stops			200	-	2.5 RELUCATION COSTS			4.1 WORK STUDT ANALTSIS		La
Total Annual Production Days			-	300	Days	Number of moves per anni	um	4 #	Tree volume		ma
Shift length				8	Hours	Cost per Move		1 300 US\$s	Number trees per cycle		#
Number of Shifts per day				2	#	Annual Relocation Cost	2 C	5 200 US\$s	pull trees		min
Machine Availability				100.0%		Relocation Cost per Machi	ne Hour	1.93 US\$/mhr	other		min
Machine Utilisation				56.2%		5.1 Machine Requiremen	ts		other		min
Machine hours per Day				9.0	Hours	Annual Volume		269 500 m3	other		min
Machine hours per Annum				2 695	Hours	Hourly Volume Required		99.99 m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Requ	uired	2.00 #	other		min
Machine Life Years				5,57	Years	Fleet Reserve		0%	other		min
						Exact Number of Machines	Required	2.00 #	other		m3
1 4 OVERHEADS						Rounded number of vehicl	es Required	2 #	cucle time	0.00	min
							op residence		cycle time	0.000	hre
Annual Licence Fees & insuran	0.0			1 610	11000				Machine Output per Hour	50,000	m 2/mhr
Annual Licence rees a insuran	ve.		L	1.610	0.322				Machine Output per Hour	50.000	m Sinni
		1	10.00						Machine Output per Day	449	m3/day
1.5 Overheads			10.00%	11444	US\$s				Machine Output per Annum	134 768	m3/year
D.1 SUMMARY	-					0.2 FLEET SUMMARY					
	1000	PER MACHIN	IE .	FLEET	%	Service -					
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	0.93	Inc. Profit 1.07			
OVERHEADS	4.25	954	11 444	22 887	9.09%	Number of Machines	2				
FIXED COSTS	26.28	5 903	70 837	141 673	56.3%	Number of Operators	4				
Hp	6.29	1 413	16 958	33 915	13.5%						
Crew	19.39	4 356	52 269	104 538	41.5%	Machine Hours	5 391				
Licence	0.60	194	1610	3 220	1 39	Capital Employed	161.000				
Permit & Toll fees	0.00	04	1010	0.220	0.000	Pacidual Value	32 200				
ADIADI E COSTE	10.00	2022	12.000	0	0.0%	Tetal Daveaue	52 200				
VARIABLE COSTS	16.18	3 633	43 601	87 201	34.6%	Total Revenue	251 762				
Fuel	7.72	1734	20 814	41 627	16.5%						
Lubrication	1 16	260	3 122	6 244	2.5%	1 C C C C C C C C C C C C C C C C C C C					
Tyres	0.00	1 200	14.455	29 020	0.0%						
Relocation	5.37	1205	5 200	28 930	11 6%						
TOTAL COST / REVENUE	46 70	10 490	125 881	251 762	100.0%						



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTE	I : Trac : Slasi : MSc : McE D ARE ESTIMATES.	ked loader with si h to 5.5m lengths wan SITE SPECIFIC & ASS	asher decl	k (Tigero	operators				And the second second	
1.1 CAPITAL EMPLOYED					2.1 VEHICLE OPER	ATING COSTS			3.1 LABOUR COSTS	
Machine Price, Exc. VAT			381 224	US\$s	Fuel Consumption			13.8 L/Hr	Driver Wage	9.80 US\$/hou
Less Cost of Tyres/Tracks/Rig	ging		Ď	US\$s	Fuel Cost			1.17 US\$/L	No.Drivers/Shift	1.1 #
Plus additional equipment	slasher		0	US\$s	Oil,% Fuel Cost			15%	Labour Wage	0.00 US\$/hou
	Truck 2ns hand	-	0	US\$s	Oil Cost			US\$1	No.Labourers/Shift	0.0 #
	trailer		0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%
	other		0	US\$s		Qty	Cost	Life	Operating Days/Week	6.0 days
the second s	other		0	US\$s	Bar	1	714	350	Operating Hours/Week	96.0 days
Sub total additional equipment	nt		0	US\$s	Sprocket	0	0	0	Basic Hours/week/driver	90.0 Hrs
Total Capital Employed			381 224	US\$s	Tracks	0	0	0	Total Overtime per week	6.0 Hrs
Annual HP payment			80 306	US\$s	Chain	1	195	70	Time and a Half per week	3.0 Hrs
1.2 HP Calculation					other				Double Time per Week	3.0 Hrs
Residual Value @		20.00%	76 245	US\$s	Fuel,Cost			16.15 US\$/mhr	Shift or Other Allowance	0.00 US\$/day
Interest per annum			8.00%		Oil, Cost			2.42 US\$/mhr	Annual Normal Time	51 744 US\$s
Payment period			60	months	Tyres/Tracks/Rigging	Cost		4.83 US\$/mhr	Annual Time and a Half	225 US\$s
Monthly payment			6 692	US\$s	Annual Fuel Costs			46 412 US\$s	Annual Double Time	300 US\$s
				_	Annual Lube Cost			6 962 US\$s	Annual Bonus	0 US\$s
1.3 OPERATING HOURS		_			Annual Tyre/Track/R	gging Cost		13 872 US\$s	Annual Shift or Other Allowance	0 US\$s
Total Days		-	365		2.2 VEHICLE MAINT	ENANCE COSTS			Total Annual Crew Cost	52 269 US\$s
Weekend Days			52		Maint,% Cap.Cost/m	achine life (mhr's)	).	90%	Total Crew Cost per Machine Hr	18.18 US\$/mhr
Statutory Leave Days			13		Maintenance Cost			22.87 US\$/mhr		
Sick Leave Days	a desire and the		0		Annual Maintenance	Cost		65 750 US\$s		
Productive Days Lost to Weath	er/Mill Stops		0	-	2.3 RELOCATION C	OSTS			4.1 WORK STUDY ANALYSIS	
Total Americal Planet - advant			300	T THE AVE	The second second shall shall shall be set of the second sec	T ITS IS IS IN THE T			The second state of the second s	12 444

Productive Days Lost to Weather	r/Mill Stops			0		2.3 RELOCATION COSTS			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per annum		4 #	Tree Volume		m3
Shift length				8	Hours	Cost per Move	13	00 US\$s	a second s	1	min
Number of Shifts per day				2	#	Annual Relocation Cost	52	US\$s	Slash		min
Machine Availability				100.0%		Relocation Cost per Machine Hour	1	81 US\$/mhr	other		min
Machine Utilisation				59.9%		5.1 Machine Requirements		_	other		min
Machine hours per Day				9.6	Hours	Annual Volume	269 5	00 m3	other		min
Machine hours per Annum				2 875	Hours	Hourly Volume Required	93	75 m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Required	1	00 #	other		min
Machine Life Years				5.22	Years	Fleet Reserve		0%	other		min
						Exact Number of Machines Required	1.	00 #	other		m3
1.4 OVERHEADS						Rounded number of vehicles Required		1 #	cycle time	0.00	min
			1.1						cycle time	0.000	hrs
Annual Licence Fees & insurance	e			5 718	US\$s				Machine Output per Hour	93.800	m3/mhr
		1.1							Machine Output per Day	899	m3/day
1.5 Overheads			10.00%	27649	US\$s				Machine Output per Annum	269 630	m3/year
6.1 SUMMARY	-					6.2 FLEET SUMMARY					
	P	ER MACHIN	Æ	FLEET	%			-			
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1.13 Inc. Pro	fit 1.30			
OVERHEADS	9.62	2 304	27 649	27 649	9.09%	Number of Machines	1				
FIXED COSTS	48.11	11 524	138 293	138 293	45.5%	Number of Operators	2				
Нр	27.94	6 692	80 306	80 306	26.4%						
Crew	18.18	4 356	52 269	52 269	17,2%	Machine Hours	2 875				
Licence	1.99	477	5718	5718	1.9%	Capital Employed 38	1 224				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value 7	6 245				
VARIABLE COSTS	48.08	11 516	138 196	138 196	45.4%	Total Revenue 30	4 138				
Fuel	16.15	3 868	46 412	46 412	15.3%						
Lubrication	2.42	580	6 962	6 962	2.3%						
Tyres	4.83	1 156	13 872	13 872	4.6%						
Relocation	22.87	5.479	5 200	5 750	1 794						
TOTAL COST / REVENUE	105.80	25 345	304 138	304 138	100.0%						



CFDD System – Tree volume 0.40m<sup>3</sup>



SYSTEM OPERATION STUDY FOR PREPARED BY		:	CFDD Stump to landing MSc McEwan						Ground Life	FORESTRY
Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working day / annum
Wheeled Feller Buncher (Tigercat 720E)					\$1.14	296 500	1	2	3	300
Grapple Skidder (Tigercat 630D)					\$2.05	296 500	2	2	4	300
CFDD (Morbark 2455)					\$2.98	296 500	1	2	2	300
Bell 220E Telelogger			<b>**</b>		\$0.81	296 500	2	2	4	300
Tracked loader with slasher deck (Tigercat T234)					\$0.96	296 500	1	2	2	300
				Total	\$7.93		7		17	
				TOTAL	\$0.00		0		0	
				TOTAL	\$7.93		7		17	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTE	N : : : : : : : : : : : : : : : : : : :	Wheeled F Felling an MSc McEwan TES, SITE SI	Feller Buncl d bunching PECIFIC & AS	her (Tigerca Euc full tre SUME FULLY 1	t 720E) es	OPERATORS					Convinces		
1.1 CAPITAL EMPLOYED	_				-	2.1 VEHICLE OPERA	TING COSTS			-	3.1 LABOUR COSTS		
Machine Price Exc VAT			Г	315 717	USSS	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Ri	aaina			0	USSS	Fuel Cost			1.17	US\$/L	No Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil % Fuel Cost			15%		Labour Wage	6.00	US\$/hour
r ius additional equipment	combican			0	11580	Oil Cost				11581	No Labourers/Shift	11	#
	other			0	11585	Tures/Tracks/Ringing				COPL	Contributions	0.0%	
	other			0	11580	The art a creating ging	Otv	Cost	Life		Operating Days/Week	6.0	davs
	other			0	11586	Tures	1	9 300	2 500		Operating Hours/Week	95.0	days
Sub total additional equipment	ot			0	11580	Cutting diek		0			Basic Hours/week/driver	90.0	Hrs
Sub total additional equipment	rin,			245 747	11000	Cutting tests		0			Total Quartime per week	6.0	Hre
Total Capital Employed				313717	0035	Others			0		Time and a Half per week	2.0	Line
Annual HP payment				00.007	0535	Other		0	0		Time and a Hair per week	3.0	His
1.2 HP Galculation		1	20.000	62 4 40	11000	Evol Cent	U	0	17.70	11CE Insta	Chiff or Other Allowance	3.0	11CE/den
Residual Value @		L	20.00%	63 143	0535	Puel, Gost			17.78	USSIMA	Shift of Other Allowance	0.00	USSUday
interest per annum				8.00%	and the second	Cil, Cost			2.67	USSymnr	Annual Normal Time	83 424	0535
Payment period				60	months	Tyres/Tracks/Rigging	Cost		3.72	USS/mhr	Annual time and a Hait	225	USAS
Monthly payment				5 542	US\$s	Annual Fuel Costs			53 779	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			8 067	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rig	ging Cost	_	11 249	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS				Annual Contributions	D	US\$s
Weekend Days				52		Maint,% Cap.Cost/mai	chine life (mhr's)		100%		Total Annual Crew Cost	83 949	US\$s
Statutory Leave Days				13		Maintenance Cost			21.05	US\$/mhr	Total Crew Cost per Machine Hr	27.76	US\$/mhr
Sick Leave Days				0		Annual Maintenance C	Cost	_	63 649	US\$s			_
Productive Days Lost to Weath	her/Mill Stops			0		2.3 RELOCATION CO	STS				4.1 WORK STUDY ANALYSIS		1
Total Annual Production Days			2	300	Days	Number of moves per	annum		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cos	st		5 200	US\$s	bunch		min
Machine Availability				100.0%		Relocation Cost per M	lachine Hour		1.72	US\$/mhr	place		min
Machine Utilisation				63.0%		5.1 Machine Require	ments		_		move		min
Machine hours per Day				10.1	Hours	Annual Volume		-	296 500	m3	other		min
Machine hours per Annum				3 024	Hours	Hourly Volume Requir	ed		98.05	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		1.00	#	other		min
Machine Life Years				4.96	Years	Fleet Reserve			0%		other		min
						Exact Number of Mach	hines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of w	ehicles Required		1	#	cycle time	0.00	min
											cycle time	0.000	hrs
Annual Licence Fees & insural	nce			14 207	US\$s						Machine Output per Hour	98.1	m3/mhr
											Machine Output per Day	989	m3/day
1.5 Overheads			10.00%	30661	US\$s						Machine Output per Annum	296 654	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY	(						
	P	ER MACHIN	E	FLEET	%								
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		1.14	Inc. Profit	1.31			
OVERHEADS	10.14	2 555	30 661	30 661	9.09%	Number of Machines		4					
FIXED COSTS	54.45	13 722	164 663	164 663	48.8%	Number of Operators		3					
Hp	21.99	5.542	66 507	66 507	19.7%								
Crew	27.76	6 995	83 949	83 949	24 9%	Machine Hours	1 Contraction	3 024					
Licence	4.70	1 184	14 207	14 207	4,2%	Capital Employed		315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		63 143					
VARIABLE COSTS	46.94	11 829	141 943	141 943	42.1%	Total Revenue		337 267					
Fuel	17.78	4 482	53 779	53 779	15.9%		_						
Lubrication	2.67	672	8 067	8 067	2.4%								
Tyres	3.72	937	11 249	11 249	3.3%	2							
Maintenance	21.05	5 304	63 649	63 649	18.9%	2							
Relocation	1.72	433	5 200	5 200	1.5%	2							
IUTAL COST / REVENUE	111.53	28 106	337 267	337 267	100.0%	1							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTEL	D ARE ESTIMA	Grapple S Full tree e MSc McEwan TES, SITE SI	kidder (Tig xtraction PECIFIC & ASS	ercat 630D) SUME FULLY TR	RAINED OF	PERATORS					Constant Con		
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERA	TING COSTS		-	_	3.1 LABOUR COSTS	_	
Machine Price, Exc. VAT			L	394 798	US\$s	Fuel Consumption		[	20.8	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	6
	other			0	US\$s	2	Qty	Cost	Life		Operating Days/Week	6.0	days
And the second s	other			0	US\$s	front	0	0	0		Operating Hours/Week	96,0	Hrs
Sub total additional equipment	t			0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's		_		83 166	US\$s	other	0	0	0	1.1.1	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		L	20.00%	78 960	US\$s	Fuel,Cost			24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			3,65	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 930	US\$s	Annual Fuel Costs			52 138	US\$s	Annual Double Time	2 940	US\$s
					_	Annual Lube Cost			7 820	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rig	iging Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	ENANCE COSTS				Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/ma	chine life (mhr's)		90%	in the second	Total Crew Cost per Machine Hr	26.55	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69	US\$/mhr			
Sick Leave Days	A Charles			0		Annual Maintenance C	JOST		50 748	05\$\$			
Total Annual Braduction David	er/Mill Stops			200	Dave	2.3 RELOCATION CO	515	1			4.1 WORK STUDY ANALYSIS		7
Shit leasth			-	300	Hours	Cost per Moves per	annum		4 200	11000	Lead Distance		Km
Number of Shifts per day				2	H	Annual Relocation Con			5 200	11000	travel empty		Ins los
Machine Availability				100.0%		Relocation Cost per M	achine Hour		2 43	11St/mhr	Load		min
Machine Litilisation				44.6%		5 1 Machine Require	ments			004/1111	travel loaded		km/hr
Machine hours per Day				7.1	Hours	Annual Volume		[	296 500	m3	Offload		min
Machine hours per Annum				2 142	Hours	Hourly Volume Require	ed		138.40	m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines I	Required		2.00	#	Travel time loaded	#DIV/01	min
Machine Life Years				7.00	Years	Fleet Reserve	1.000		0%		Load	0.00	min
and a state of the second second						Exact Number of Mach	nines Required		2.00	#	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of ve	chicles Required		2	#	cycle time	#DIV/0!	min
											cycle time	#DIV/0!	hrs
Annual Licence Fees				19 740	US\$s						Machine Output per Hour	69.2	m3/mhr
and the second											Machine Output per Day	494	m3/day
1.5 Overheads			10.00%	27570	US\$s						Machine Output per Annum	148 251	m3/year
6.1 SUMMARY	-	_				6.2 FLEET SUMMARY	r						
	P	ER MACHIN	E	FLEET	%								
and and a second se	US\$/hr U	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.05	Inc. Profit	2.35			
OVERHEADS	12.87	2 297	27 570	55 140	9.09%	Number of Machines	18	2					
FIXED COSTS	74.59	13 316	159 794	319 589	52.7%	Number of Operators	N	4					
Hp's	38.82	6 930	83 166	166 331	27.4%	-	-						
Crew	26.55	4 741	56 889	113 778	18.8%	Machine Hours	1.00	4 285					
Licence	9.21	1 645	19 740	39 480	6,5%	Capital Employed		789 596					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		157 919					
VARIABLE COSTS	54.10	9 659	115 905	231 809	38.2%	Total Revenue		606 538					
Fuel	24.34	4 345	52 138	104 273	17.2%								
Lubrication	3.65	652	7 820	15 641	2.6%								
Maintenance	23.69	4 229	50 748	101 496	16.7%								
Relocation	2.43	433	5 200	10 400	1.7%								
TOTAL COST / REVENUE	141.56	25 272	303 269	606 538	100.0%								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	I : : : : : : : : : : : : : : : : : : :	CFDD (Mo Delimb, D MSc McEwan	ebark 2455 ebark full tr	) rees SUME FULLY 1	RAINED C	DPERATORS				a transferrer		
						24 VEHICLE OPERATING COSTS		_		2 1 LABOUR COSTS		
1.1 CAPITAL EMPLOTED				744 974	11000	2.1 VERICLE OPERATING COSTS	L	EE O	TRIC	S.T LABOUR COSTS	0.90	USEMOU
Machine Price, Exc. VAT	alaa			/14 3/1	11080	Fuel Cest		1 47	LICEA	No Driver (Chiff	9.00	#
Eless Cost of Tyres/Tracks/Rig	ging			0	11000	Oil % Eval Cost		1.07	USAL	Labour Wage	0.00	# US\$/hour
Plus additional equipment	radio			0	0535	Oil Cast		13%	110.04	Labour wage	0.00	4
	othor			0	11050	Turas (Tracker/Disping			USPL	Contributions	0.0%	
	other			0	11000	Tyresi nacksirkigging	Cost	Life		Operating DaugMeek	6.0	daue
	other		_	0	11050	Chaine 234	CUSI 9	20		Operating Daysweek	0.0	dave
Cub total additional aquipmant	Lottier			0	11050	Drum 0	0	30		Pasis Haurahusakidriusr	90.0	Lice
Sub total additional equipment				744 274	11080	Turan	0	0		Total Quartime par week	50.0	Hee
Total Capital Employed				114 3/1	0535	Tyres 0	0	0		Tiotal Overtime per week	0.0	Mrs
Annual HP payment				150 485	05\$\$	lother 0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation		r	00.000	100 100	une	Cure O	0	0	UCRA	Double Time per Week	3.0	HIS
Residual Value @		ļ	20.00%	142 874	US\$S	Fuel, Cost		66.57	USS/hour	Snitt or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		9,99	USSMour	Annual Normal Time	51 744	USSS
Payment period			· · ·	60	months	Tyres/Tracks/Rigging Cost		62.40	US\$/hour	Annual Time and a Half	225	US\$s
Monthly payment				12 540	US\$s	Annual Fuel Costs		207 708	US\$s	Annual Double Time	300	US\$s
		_				Annual Lube Cost		31 156	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS					1	Annual Tyre/Track/Rigging Cost		194 688	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days			-	365		2.2 VEHICLE MAINTENANCE COSTS	S T			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine life (mhr's)	)	100%		Total Crew Cost per Machine Hr	16.75	US\$/mhr
Statutory Leave Days				13		Maintenance Cost		47.62	US\$/mhr			
Sick Leave Days				0	1 6	Annual Maintenance Cost	-	148 589	US\$s			
Productive Days Lost to Weather	er/Mill Stops		-	0	1.1	2.3 RELOCATION COSTS	-			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days			-	300	Days	Number of moves per annum		4	#	Average Tree Volume		<i>m</i> 3
Shift length				8	Hours	Cost per Move		1 300	US\$s	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cost		5 200	US\$s	other		1
Machine Availability				100.0%		Relocation Cost per Machine Hour		1.67	US\$/mhr	debranch, debark		min
Machine Utilisation				65.0%		5.1 Machine Requirements	_			other		min
Machine hours per Day				10.4	Hours	Annual Volume		296 500	m3	other		min
Machine hours per Annum				3 120	Hours	Hourly Volume Required		95.03	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Required		1.00	#	other		min
Machine Life Years				4.81	Years	Fleet Reserve		0%		other		min
						Exact Number of Machines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of vehicles Required	5	1	#	cycle time	0.00	min
						Contraction of the second second second				cycle time	0.00	hrs
Annual Licence Fees & insuran	ce			14 287	US\$s					Machine Output per Hour	95.1	m3/mhr
			-							Machine Output per Day	989	m3/day
1.5 Overheads			10.00%	80438	US\$s					Machine Output per Annum	296 712	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY						
	F	PER MACHIN	IE I	FLEET	%							
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	2.98	Inc. Profit	3.43			
OVERHEADS	25.78	6 703	80 438	80 438	9.09%	Number of Machines	1					
FIXED COSTS	69.56	18 087	217 041	217 041	24.5%	Number of Operators	2					
Нр	48,23	12 540	150 485	150 485	17,0%							
Crew	16,75	4 356	52 269	52 269	5,9%	Machine Hours	3 120					
Licence	4.58	1 191	14 287	14 287	1.6%	Capital Employed	714 371					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	142 874					
VARIABLE COSTS	188.25	48 945	587 341	587 341	66 4%	Total Revenue	884 820					
Fuel	66.57	17 300	207 708	207 708	23 5%		Cor ond					
Lubrication	9.00	2 506	31 150	31 156	3 500							
Tyres	62.40	16 224	194 688	194 688	22.0%							
Maintenance	47.62	12 382	148 589	148 589	16.8%							
Relocation	1.67	433	5 200	5 200	0.6%							
TOTAL COST / REVENUE	283.60	73 735	884 820	884 820	100.0%							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	ARE ESTIMA	Bell 220E 1 Bundle tree MSc McEwan TES,SITE SP	elelogger e lengths a ECIFIC & AS	fter debarki SUME FULLY	ing TRAINED (	OPERATORS				A COLUMN AND A COLUMN A		
1.1 CAPITAL EMPLOYED					_	2.1 VEHICLE OPERATING	COSTS			3.1 LABOUR COSTS		_
Machine Price Exc. VAT				80 500	USSS	Fuel Consumption		6.6	UHr	Driver Wage	9.80	USS/h
Less Cost of Tyres/Tracks/Rig	ning			0	USSS	Fuel Cost		1.17	US\$A	No Drivers/Shift	11	#
Plus additional equipment	slasher	-		0	11555	Oil % Fuel Cost		15%	o o o o c	Labour Wage	0.00	USSA
t the section of all the section	Truck 2ns h	and		0	11555	Oil Cost			115\$1	No Labourers/Shift	0.0	#
	trailer	ung .		0	11580	Tyres/Tracks/Rigging			00gr	Contributions	0.0%	
	other			0	11580	i yrear naekarkigging	Oty Cost	Life		Operating DaveM/eek	6.0	dave
	other			0	liste	Ture front	0 0	0		Operating Days Week	96.0	dave
Sub total additional equipment	ourier			0	liste	Tyre rear	0 0	0		Basic Hourstweek/driver	90.0	Hre
Total Canital Employed				80 500	11580	other	0 0	0		Total Overtime per week	8.0	Hre
Annual HP payment				16 058	11000	other	0 0	0		Time and a Half per week	3.0	Hre
1.2 HP Calculation				10 000	00.05	other	0 0	0		Double Time per Week	3.0	Him
T.2 HP Calculation		Г	20.000	10 100	11000	Suel Cast	0 0	7 70	1D.C.m.h.c	Chiff of Other Alloweek	3.0	HIS
Residual value @			20.00%	10 100	0338	Fuel, Cost		1.12	USSMIN	Shint of Other Allowance	0.00	1053/04
Interest per annum				8.00%		Oil, Cost		1.10	USSMIN	Annual Normal Time	51 /44	USSS
Payment period				60	months	Tyres/Tracks/Rigging Cost		0.00	USymnr	Annual Time and a Hair	225	USSS
Monthly payment				1413	0535	Annual Fuel Costs		1/ /1/	USAS	Annual Double Time	300	USSS
			_		_	Annual Lube Gost		2 0 58	0535	Annual Bonus	0	USSS
1.3 OPERATING HOURS			-		1	Annual Tyre/Track/Rigging	Cost	0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days			-	365		2.2 VEHICLE MAINTENAN	ICE COSTS			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine	e life (mhr's)	100%		Total Crew Cost per Machine Hr	22.78	US\$/m
Statutory Leave Days				13		Maintenance Cost		5.37	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost	-	12 313	US\$s			_
Productive Days Lost to Weathe	r/Mill Stops			0		2.3 RELOCATION COSTS	1			4.1 WORK STUDY ANALYSIS	_	1
Total Annual Production Days			-	300	Days	Number of moves per annu	um	4	#	Tree volume		m3
Shift length				8	Hours	Cost per Move		1 300	US\$s	Number trees per cycle		#
Number of Shifts per day				2	#	Annual Relocation Cost	100 C	5 200	US\$s	pull trees		min
Machine Availability				100.0%	1	Relocation Cost per Machin	ne Hour	2.27	US\$/mhr	other		min
Machine Utilisation				47.8%		5.1 Machine Requirement	ts			other		min
Machine hours per Day				7.6	Hours	Annual Volume		296 500	m3	other		min
Machine hours per Annum				2 294	Hours	Hourly Volume Required		129.23	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Requ	uired	1.99	ŧ	other		min
Machine Life Years				6.54	Years	Fleet Reserve		0%		other		min
						Exact Number of Machines	Required	1.99	¥	other		<i>m</i> 3
1.4 OVERHEADS						Rounded number of vehicle	es Required	2	¥	cycle time	0.00	min
			-		1.0					cycle time	0.000	hrs
Annual Licence Fees & insurance	e			1 610	US\$s					Machine Output per Hour	64.800	m3/mhi
		-			6					Machine Output per Day	496	m3/day
1.5 Overheads			10.00%	10872	US\$s				_	Machine Output per Annum	148 677	m3/yea
5.1 SUMMARY	_		_			6.2 FLEET SUMMARY						
	P	ER MACHINE		FLEET	%							
	US\$/hr U	/S\$/month	US\$/year	US\$/year	of Total	US\$ per m3	0.81	Inc. Profit	0.93			
OVERHEADS	4.74	906	10 872	21 745	9.09%	Number of Machines	2					
FIXED COSTS	30.87	5 903	70 837	141 673	59.2%	Number of Operators	4					
Hp	7.39	1 413	16 958	33 915	14.2%							
Crew	22.78	4 356	52 269	104 538	43.7%	Machine Hours	4 589					
Licence	0.70	134	1 610	3 220	1.3%	Capital Employed	161 000					
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value	32 200					
VARIABLE COSTS	16.51	3 157	37 888	75 776	31.7%	Total Revenue	239 195					
Fuel	7.72	1 476	17 717	35 435	14.8%							
Lubrication	1.16	221	2 658	5 315	2.2%							
lyres	0.00	0	0	0	0.0%							
Relocation	5.37	1 026	12 313	24 627	10.3%							
TOTAL COST ( DEVENUE	E2 421	0.068	440 507	020 400	4.5%							



OPERATION		
		Slash to 5.5m lengths
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

1.1 CAPITAL EMPLOYED					1.1.1	2.1 VEHICLE OPERATI	NG COSTS			100	3.1 LABOUR COSTS		
Machine Price, Exc. VAT				381 224	US\$s	Fuel Consumption		1	13.8	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Riggin	ng			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	slasher			0	US\$s	Oil,% Fuel Cost			15%	100	Labour Wage	0.00	US\$/hour
	Truck 2ns h	and		0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0	#
	trailer			0	US\$s	Tyres/Tracks/Rigging			_		Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	714	350		Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$s	Sprocket	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				381 224	US\$s	Tracks	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment			_	80 306	US\$s	Chain	1	195	70		Time and a Half per week	3.0	Hrs
1.2 HP Calculation		_				other					Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	76 245	US\$s	Fuel,Cost			16.15	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			2.42	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	vst		4.83	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				6 692	US\$s	Annual Fuel Costs			39 899	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			5 985	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riddi	ng Cost		11 925	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days			1	365		2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	52 269	USSS
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's)	T	90%		Total Crew Cost per Machine Hr	21.15	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			22.87	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Co	st		56 523	US\$s			
Productive Days Lost to Weather/	Mill Stops			0		2.3 RELOCATION COST	rs			0000	4 1 WORK STUDY ANALYSIS		
Total Annual Production Days	inin otopo			300	Davs	Number of moves per an	num	ſ	4	#	Tree Volume		m3
Shift length			1	8	Hours	Cost per Move			1 300	115\$5	The Fording		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	USSS	Slash		min
Machine Availability				100.0%		Relocation Cost per Mac	hine Hour		2.10	US\$/mhr	other		min
Machine Litilisation				51.5%		5.1 Machine Requireme	ents	-		0 Oprinin	other		min
Machine bours per Day				82	Hours	Annual Volume	inte .	Г	296 500	ma	other		min
Machine hours per Day				2 471	Hours	Hourly Volume Required			110.00	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Re	duired		1.00	t	other		min
Machine Life Years				6.07	Vears	Fleet Reserve	dauga		0%		other		min
Machina che reala				0.01	10010	Evact Number of Machin	es Required		1.00	#	other		ma
14 OVERHEADS						Rounded number of vehi	icles Required		1.00	#	cycle time	0.00	min
I OVERHEADS						Nounded number of ven	cies required				cycle time	0.000	hre
Annual Licence Fees & insurance			1	5 718	11550						Machine Output per Hour	120.000	m2/mbr
Chinda Licence r ees a maurance				5710	10043						Machine Output per Flour	000	m3/day
1.5 Overheade		1	10.00%	25702	11000						Machine Output per Day	205 525	mahaar
6 1 SUMMARY	_		10.00 %	60100	0023	6.2 FI FFT SUMMARY					machine Output per Annum	100 000	maryour
o.r oommert	P	ER MACHIN	E	FIFET	04								
-	USS/hr I	IS\$/month	USSWear	USSWear	of Total	US\$ ner m3		0.96	Inc Profit	1.10			
OVERHEADS	10.43	2 1 40	25 793	25 783	0.00%	Number of Machines		0.00	me. From	1.10	1		
FIXED COSTS	55.06	11 524	138 203	138 203	49.95	Number of Operators		2					
Ha	32.50	8.600	80 306	80 205	28 34	interior of operators		-					
Crew	21.15	4 350	52 260	52 060	18,494	Machine Hours		2 474					
Licence	221	4 500	5 7 1 9	5 749	2.00	Capital Employed		181 224					
Darmit & Toll faas	2.01	an	0110	5/10	0.0%	Residual Value		76 245					
VAPIABLE COSTS	48.27	DOF	110 522	110 533	42 40	Total Revenue	1.000	283 609					
Eusi	40.37	3 301	20.900	20 002	44.170	I otal Revenue		103 008					
Lubication	2.10	0 020	5 0 0 5 0 0 5	5000	2 401								
Tyres	4.83	994	11 975	11 925	4.7%								
Maintenance	22.87	4710	56 523	56 523	19.9%								
Relocation	2.10	433	5 200	5 200	1.8%								
TOTAL COST / REVENUE	114.77	23 634	283 608	283 608	100.0%					_			_



CFDDC System – Tree volume 0.075m<sup>3</sup>



:	CFDDC
:	Stump to Mill
	MSc
:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)						\$3.96	121 500	2	2	4	300
Grapple Skidder (Tigercat 630D)						\$4.79	121 500	2	2	4	300
CFDDC (Morbark 2355)						\$10.68	121 500	1	2	2	300
				Total		R 19.43 R 0.00		5		11 0	
				TOTAL		R 19.43		5		11	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	: V : F : N	Wheeled F Felling and MSc McEwan	eller Bunch I bunching	er (Tigercat	720E)							ONFETRY
NOTE: ALL FIGURES QUOTED A	ARE ESTIMA	TES, SITE S	PECIFIC & A	SSUME FULLY	TRAINED	OPERATORS					1	
1.1 CAPITAL EMPLOYED					-	2.1 VEHICLE OPERATI	NG COSTS			3.1 LABOUR COSTS		-
Machine Price, Exc, VAT			L	315 717	US\$s	Fuel Consumption		1	15.2 L/Hr	Driver Wage	9.80	USS
Less Cost of Tyres/Tracks/Riggin	na			0	USSS	Fuel Cost			1.17 US\$A	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil % Fuel Cost			15%	Labour Wage	0.00	USS
	combican			0	USSS	Oil Cost			US\$A	No Labourers/Shift	0.0	#
	other			0	11585	Tyres/Tracks/Ringing				Contributions	0.0%	
	other			0	11980	Tyrear Tuokan ugging	ON	Cost	Life	Operating Days/Meek	6.0	dav
	othor			0	11050	Turne	0	0	0	Operating Hours Meak	96.0	dava
Cub total additional aquiament	omen			0	11080	Cutting diek				Rasic Hours week driver	00.0	Lie
Sub total additional equipment				245 747	11000	Cutting disk		0 200	2 500	Tatal Quadima pasunak	50.0	Hro
Total Capital Employed				310 /1/	0535	Other		9 300	2 500	Time and a Welf assurable	0.0	nis Un
Annual HP payment				66 507	0535	Other	0	0	0	Time and a Hair per week	3.0	HIS
1.2 HP Calculation		Г			Line	Other	U			Double Time per week	3.0	HIS
Residual Value @		L	20.00%	63 143	0535	Puel,Cost			17.78 US\$/mhr	Shift of Other Allowance	0.00	USS
Interest per annum				8.00%	Sec. 1	Oil, Cost			2.67 US\$/mhr	Annual Normal Time	51 744	USS
Payment period				60	months	Tyres/Tracks/Rigging Co	st		3.72 US\$/mhr	Annual Time and a Half	225	USS
Monthly payment				5 542	US\$s	Annual Fuel Costs			31 670 US\$s	Annual Double Time	300	USS
						Annual Lube Cost			4 750 US\$s	Annual Bonus	0	US\$
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	ng Cost		6 625 US\$s	Annual Shift or Other Allowance	0	US\$
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COST	S		Annual Contributions	0	US\$
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's	)	100%	Total Annual Crew Cost	52 269	US\$
Statutory Leave Days				13		Maintenance Cost			21.05 US\$/mhr	Total Crew Cost per Machine Hr	29.35	USS
Sick Leave Days				0		Annual Maintenance Cos	st		37 482 US\$s		_	
Productive Days Lost to Weather/	Mill Stops			0		2.3 RELOCATION COST	rs	-		4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	and sold for		5	300	Davs	Number of moves per an	num	[	4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300 //555	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost		1	5 200 //585	bunch		min
Machine Availability				100.0%		Relocation Cost ner Mar	hine Hour		2 92 //SS/mbr	place		min
Machine Utilization				37 1%		5 1 Machine Requireme	inte		alle Copinin	move		min
Machine bours per Day				57.1%	Hours	Annual Volume	ints	Г	121 500 m2	other		min
Machine hours per Day				1 704	Hours	Hauda Volume Desuited			121 500 m3/mbs	other		min
Machine hours per Annum				1 /81	Hours	Houriy Volume Required			68.23 m3/mnr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Re	quired		1/99 #	other		min
Machine Life Years				8.42	Years	Fleet Reserve	1.611.715		0%	other		min
						Exact Number of Machin	es Required		1.99 #	other		min
1.4 OVERHEADS						Rounded number of vehi	cles Required	d	2 #	cycle time	0.00	min
			-							cycle time	0.000	hrs
Annual Licence Fees & insurance			L	14 207	US\$s					Machine Output per Hour	34.2	m3/r
		-								Machine Output per Day	203	m3/0
1.5 Overheads			10.00%	21871	US\$s					Machine Output per Annum	60 903	m3/
6.1 SUMMARY	-					6.2 FLEET SUMMARY						
	PE	R MACHIN	E	FLEET	%		_					
	US\$/hr U	S\$/month	US\$/year	US\$/year	of Total	US\$ per m3	100	3.96	Inc. Profit 4.55			
OVERHEADS	12.28	1 823	21 871	43 742	9.09%	Number of Machines	6	2				
FIXED COSTS	74.68	11 082	132 983	265 966	55.3%	Number of Operators		<4				
Hp	37.35	5 542	66 507	133 014	27.6%							
Crew	29.35	4 356	52 269	104 538	21.7%	Machine Hours		3 562				
Licence	7.98	1 184	14 207	28 4 15	5,9%	Capital Employed		631 434				
Permit & Toll fees	0.0		p	D	0.0%	Residual Value		126 287				
VARIABLE COSTS	48.14	7 144	85 727	171 453	35.6%	Total Revenue		481 162				
Fuel	17.78	2 639	31.670	63 330	13 2%							
ubrication	267	306	4 750	9 501	2 000							
Tyres	3.72	552	6 625	13 249	2.8%							
Maintenance	21.05	3 123	37 482	74 964	15.6%							
Relocation	2.92	433	5 200	10 400	2.2%							
TOTAL COST / REVENUE	135.10	20 048	240 581	481 162	100.0%					1		



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTE	D ARE ESTIMA	Tree lengt MSc McEwan	specific & A	n ASSUME FULLY	TRAINED	OPERATORS							and a state
11 CAPITAL EMPLOYED							TING COSTS	_		_	311 ABOUR COSTS	_	_
Machine Price Exc VAT			Г	394 798	11585	Euel Consumption	11140 00313	1	20.8	Inter	Driver Wage	9.80	USShour
Less Cost of Tyres/Tracks/Rid	naina			004700	USSS	Fuel Cost			1.17	USSA	No Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil % Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	other			0	USSS	Oil Cost				USSA	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qtv	Cost	Life		Operating Days/Week	6.0	davs
	other			0	US\$s	front	0	0	0	1	Operating Hours/Week	96.0	Hrs
Sub total additional equipment	it			0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				83 166	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	78 960	US\$s	Fuel,Cost			24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum		2		8.00%		Oil, Cost			3.65	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 930	US\$s	Annual Fuel Costs			46 801	US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost			7 020	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rig	gging Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	ENANCE COSTS				Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/ma	chine life (mhr's)		90%		Total Crew Cost per Machine Hr	29.58	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69	US\$/mhr	Contraction and interests		
Sick Leave Days				0		Annual Maintenance C	Cost		45 555	US\$s	A CONTRACTOR OF		
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION CO	OSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	annum		4	#	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	US\$s	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Co	st		5 200	US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per M	lachine Hour		2.70	US\$/mhr	Load		min
Machine Utilisation				40.1%		5.1 Machine Require	ments				travel loaded		km/hr
Machine hours per Day				6,4	Hours	Annual Volume			121 500	m3	Off Load		min
Machine hours per Annum			-	1 923	Hours	Houriy Volume Requir	ea		63.18	m3/mhr	Travel time empty	#DIV/01	min
Machine Life Hours				15 000	Mours	Number Of Machines	Required	ł	2.00	#	Travel time loaded	#DIV/01	min
Machine Life reals				1.00	rears	Event Number of Mari	hines Desuised		0%	1	Citil and	0.00	min
1 4 OVERHEADS						Exact Number of Mach	chicles Required		2.00		on Load	0.00	min
1.4 OVERHEADS						Rounded number of vi	enicies Required		6	*	cycle time	#DIV/01	min
Annual Licence Fees				19 740	lusse						Machina Output par Hour	#111/01	m2/mhr
Annual Licence rees				19 /40	10335						Machine Output per Hour	31.0	m3/mnr
1.5 Overheads		1	10.00%	26437	11580						Machine Output per Day	60 771	m3Alear
6.1 SUMMARY	1		1010070		0000	6.2 FLEET SUMMAR	Y				and only output por stantant	00111	marjour
	PI	ER MACHIN	E	FLEET	%								
	USS/hr L	IS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	2	4.79	Inc. Profit	5.50			
OVERHEADS	13.75	2 203	26 437	52 874	9.09%	Number of Machines	0.7	2	ALL LA				
FIXED COSTS	83.09	13 316	159 794	319 589	54.9%	Number of Operators		4					
Hp's	43.25	6 930	83 166	166 331	28.6%		0						
Crew	29.58	4.741	56 889	113 778	19.6%	Machine Hours		3 846					
Licence	10.26	1 645	19 740	39 480	6.8%	Capital Employed		789 596					
Permit & Toll fees	0.0		0	D	0.0%	Residual Value		157 919					
VARIABLE COSTS	54.38	8 715	104 576	209 152	36.0%	Total Revenue	h	581 615					
Fuel	24.34	3 900	46 801	93 602	16.1%								
Lubrication	3.65	585	7 020	14 040	2.4%	í.							
Tyres	0.00	0	0	0	0.0%								
Relocation	23.69	3 796	45 555	91 109	15.7%								
TOTAL COST / REVENUE	151.22	24 234	290 807	581 615	100.0%								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: : : : : : : : : : : : : : : : : : :	CFDDC (I Delimb, D MSc McEwan	Morbark 235 Debark, Chip SPECIFIC & A	5) , Load SSUME FULL	Y TRAINEI	DOPERATORS							OREATRY
11 CAPITAL EMPLOYED					_		TING COSTS		-	_	3 1 LABOUR COSTS		
Machine Price Eve VAT				1 059 368	Is	Euel Consumption	1110 00010	Г	104.9	Intr	Driver Wage	9.80	She
Lass Cost of Turas/Tracks/Ring	nina		_	1 053 508	5	Fuel Cost			1 17	51	No Drivers/Shiff	1.1	#
Plus additional equipment	radio			0	e	Oil % Fuel Cost			15%	DIL	Labour Wage	0.00	Shr
r ius autoriai squipinerit	combican			0	s	Oil Cost			1070	\$1	No Labourers/Shift	0.0	#
	other		9	0	s	Tyres/Tracks/Rigging		-		Jar	Contributions	0.0%	
	other			0	8	i ji contraction agging	Otv	Cost	Life		Operating Days/Week	6.0	days
	other			0	s	Chains	234	8	30	1	Operating Hours/Week	96.0	days
Sub total additional equipment	Contract.			0	s	Disc Knives	12	24	50		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				1 059 368	S	Drum	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				223 159	s	Tyres	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	211 874	5	Fuel.Cost		-	122.73	s/mhr	Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%	1	Oil. Cost			18.41	s/mhr	Annual Normal Time	51 744	s
Payment period				60	months	Tyres/Tracks/Rigging (	Cost		68.26	\$/mhr	Annual Time and a Half	225	s
Monthly payment				18 597	\$	Annual Fuel Costs			382 927	s	Annual Double Time	300	\$
,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,						Annual Lube Cost			57 439	s	Annual Bonus	4 312	s
1.3 OPERATING HOURS						Annual Tyre/Track/Rig	ging Cost		212 959	5	Annual Shift or Other Allowance	0	5
Total Days			1	365		2.2 VEHICLE MAINTE	NANCE COSTS				Total Annual Crew Cost	56 581	\$
Weekend Days				52	1	Maint,% Cap.Cost/mad	chine life (mhr's)	Г	100%		Total Crew Cost per Machine Hr	18,13	\$/mhr
Statutory Leave Days				13		Maintenance Cost			70.62	s/mhr			C. C
Sick Leave Days				0		Annual Maintenance C	ost		220 349	\$			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION CO	STS				4.1 WORK STUDY ANALYSIS		-
Total Annual Production Days				300	Days	Number of moves per	annum	1	4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	5	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cos	st		5 200	5	other		1.1
Machine Availability				100.0%		Relocation Cost per Ma	achine Hour		1.67	\$/mhr	debranch, debark, chip, Load		min
Machine Utilisation				65.0%		5.1 Machine Requirer	nents			1	other		min
Machine hours per Day				10.4	Hours	Annual Volume			121 500	m3	other		min
Machine hours per Annum				3 120	Hours	Hourly Volume Require	ed		38.94	m3/mhr	other		min
Machine Life Hours			L	15 000	Hours	Number Of Machines F	Required		1.00	#	other		min
Machine Life Years				4.81	Years	Fleet Reserve			0%		other 1		min
						Exact Number of Mach	ines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of ve	hicles Required		1	#	cycle time	0.00	min
					100	1					cycle time	0.00	hrs
Annual Licence Fees & insurance	e			21 187	\$						Machine Output per Hour	39.1	m3/mhr
											Machine Output per Day	407	m3/day
1.5 Overheads			10.00%	117980	\$					_	Machine Output per Annum	121 992	m3/year
6.1 SUMMARY	-					6.2 FLEET SUMMARY	1						
	P	PER MACHI	NE	FLEET	%				1. 2. 20				
	\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3		10.68	Inc. Profit	12.28	3		
OVERHEADS	37.81	9 832	117 980	117 980	9.09%	Number of Machines		1					
FIXED COSTS	96.45	25 077	300 928	300 928	23.2%	Number of Operators		2					
Нр	71.53	18 597	223 159	223 159	17.2%	2							
Crew	18.13	4 715	56 581	56 581	4.4%	Machine Hours	1000	3 120					
Licence	6.79	1 766	21 187	21 187	1.6%	Capital Employed	11	059 368			1		
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		211 874					
VARIABLE COSTS	281.69	73 239	878 873	878 873	67.7%	Total Revenue	13	297 781					
Fuel	122.73	31 911	382 927	382 927	29.5%	2							
Lubrication	18.41	4 787	57 439	57 439	4.4%	2							
Tyres	68.26	17 747	212 959	212 959	16.4%								
Relocation	1.67	433	5 200	5 200	0.4%								
TOTAL COST / REVENUE	415.96	108 148	1 297 781	1 297 781	100.0%								



CFDDC System – Tree volume 0.15m<sup>3</sup>



:	CFDDC
:	Stump to Mill
:	MSc
:	McEwan

FORESTRY

Locality											
Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)						\$1.91	147 500	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$3.68	147 500	2	2	4	300
CFDDC (Morbark 2355)						\$8.80	147 500	1	2	2	300
				Total		R 14.39		4		9	
				TOTAL		R 0.00 R 14.39				0 8.8	



MACHINE DESCRIPTION	:	Wheeled Feller Buncher (Tigercat	720E)	
OPERATION	:	Felling and bunching		
STUDY FOR	:	MSc		
PREPARED BY	:	McEwan		
NOTE: ALL FIGURES QUOTED	ARE EST	IMATES, SITE SPECIFIC & ASSUME FULLY	TRAINE	ED OPERATORS
				1
1.1 CAPITAL EMPLOYED	_			2.1 VEHICLE
1.1 CAPITAL EMPLOYED Machine Price, Exc. VAT		315 717	US\$s	2.1 VEHICLE C
1.1 CAPITAL EMPLOYED Machine Price, Exc.VAT Less Cost of Tyres/Tracks/Riggi	ing	315 717 0	US\$s US\$s	2.1 VEHICLE C Fuel Consump Fuel Cost
1.1 CAPITAL EMPLOYED Machine Price, Exc. VAT Less Cost of Tyres/Tracks/Riggi Plus additional equipment	radio	315 717 0 0	US\$s US\$s US\$s	2.1 VEHICLE C Fuel Consump Fuel Cost Oil,% Fuel Cost

1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERA	TING COSTS	-			3 1 LABOUR COSTS		
Machine Price Exc VAT				315 717	USSS	Fuel Consumption		[	15.2	IAr	Driver Wage	9.80	USSMOUR
Less Cost of Tyres/Tracks/Rigg	ina			0	11585	Fuel Cost			1 17	11581	No Drivers/Shift	11	#
Plus additional equipment	radio			0	11550	Oil % Fuel Cost			15%	COPIL	Labour Wage	0.00	11se hour
r las additional equipment	combican			0	11580	Oil Cost			1070	11091	No Labourare/Shift	0.00	4
	other			0	11980	Turas/Tracks/Ringing				OUAL	Contributions	0.0%	
	other			0	11000	i yidar nackar tigging	Obr	Cost	Life		Operating Dave Meak	6.0	dave
	other			0	11000	Turne	City	CUSI	Life		Operating Days/Week	0.0	days
Cub total additional aquiamont	other			0	USAS	Tyres Cutting diele	0	0	0		Operating Hours/week	96.0	days
Sub total additional equipment					0535	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	HIS
Total Capital Employed				315 /1/	USAS	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	0535	Other	0	0	0		Time and a Hair per week	3.0	HIS
1.2 HP Calculation			00 000/	00.440	Luca	Other	0	0	17 70		Double Time per vveek	3.0	HIS
Residual Value @			20.00%	63 143	0535	Fuel,Cost			17.78	US\$/mnr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			2.67	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period			1.0	60	months	Tyres/Tracks/Rigging	Cost		3.72	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs			46 622	US\$s	Annual Double Time	300	US\$s
<b>1</b>						Annual Lube Cost			6 993	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS					1	Annual Tyre/Track/Rig	ging Cost		9 752	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	ENANCE COSTS	5			Annual Contributions	0	US\$s
Weekend Days				52		Maint,% Cap.Cost/ma	chine life (mhr's)		100%		Total Annual Crew Cost	52 269	US\$s
Statutory Leave Days				13		Maintenance Cost			21.05	US\$/mhr	Total Crew Cost per Machine Hr	19.94	US\$/mhr
Sick Leave Days				0	1.1.1.1	Annual Maintenance C	Cost		55 178	US\$s			-
Productive Days Lost to Weather	/Mill Stops			0	1.00	2.3 RELOCATION CO	STS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	annum		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cos	st		5 200	US\$s	bunch		min
Machine Availability				100.0%		Relocation Cost per M	achine Hour		1.98	US\$/mhr	place		min
Machine Utilisation				54.6%		5.1 Machine Require	ments				move		min
Machine hours per Day				8.7	Hours	Annual Volume			147 500	m3	other		min
Machine hours per Annum				2 622	Hours	Hourly Volume Require	ed		56.26	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		1.00	#	other		min
Machine Life Years				5.72	Years	Fleet Reserve			0%		other		min
					1000	Exact Number of Mach	nines Required		1.00	#	other		min
14 OVERHEADS						Rounded number of ve	hicles Required		1	#	cycle time	0.00	min
1							stricter required				cycle time	0.000	bre
Annual Licence Fees & insurance			I	14 207	USSS						Machine Output per Hour	56.3	m3/mhr
				14 201	0000						Machine Output per Day	492	m3/day
1.5 Overheads			10.00%	25673	11580	1					Machine Output per Day	147 505	makeer
6.1 SUMMARY			10.00 /0	20073	0000	6.2 ELEET SUMMARY	(				Machine Output per Annum	14/ 050	maryear
		ER MACHI	NE	FIEET	0/								
	1100/44	1100/month	LICEMARK	LICEARAN	of Total	1100	1.5	4.04	Ine Broffe	0.00			
OVERHEADS	0.34/11	2 4 20	25 672	055/year	0 000	Number of Machines		1.01	inc. Pront	2.20			
EIVED COSTS	5.79	44 000	422 002	20 0/3	9.097	Number of Machines	S. 1						
FIXED COSTS	50.73	11 002	132 903	132 903	47.17	Number of Operators		2					
rip O	25.37	5 542	66 507	66 507	23.6%								
Crew	19.94	4 356	52 269	52 269	18.5%	Machine Hours		2 622					
Licence	5.42	1 184	14 207	14.207	5,0%	Capital Employed		315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		63 143					
VARIABLE COSTS	47.20	10 312	123 746	123 746	43.8%	Total Revenue	10 million (100 million)	282 402					
Fuel	17.78	3 885	46 622	46 622	16.5%	2							
Lubrication	2.67	583	6 993	6 993	2.5%	2							
Maintenance	3.72	4 509	9 /52	9 752	3.5%								
Relocation	1,98	433	5 200	5 200	1.8%								
TOTAL COST / REVENUE	107.72	23 534	282 402	282 402	100.0%	2					1		



1.1 CarVitz, Barti, VAT   31.1 Versite   21.1 Versite   20.1 Versite   20.0 Versite   1.1 Labours Costs   0.0 S at the costs   0.0 S at	MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	DARE ESTIMA	Grapple S Free lengt MSc McEwan	kidder (Tig th extractio	ercat 630D) n	TRAINED	OPERATORS							DECUTIONS	
1) Low Line Surv Or UV     24 198 (USS in the UV Color in															
Machine Inclusion     247.00	1.1 CAPITAL EMPLOYED			Г		Lunes	2.1 VEHICLE OPERA	TING COSTS		00.0	1.44	3.1 LABOUR COSTS	0.90	Licebau	
Lab 3. def of year (index input a manual horizon of year (index input a definite experiment in a	Machine Price, Exc. VA1				394 /98	USAS	Fuel Consumption			20.8	Unr	Driver wage	9.80	US\$/nour	
Park additional equiprintin	Less Cost of Tyres/Tracks/Rig	gging			0	0535	Fuel Cost			1.1/	USAL	No.Drivers/Shift	1.1	H LICE Annue	
min     0     0.532     01.533     01.533     02.532     02.532     02.532     03.532	Plus additional equipment	radio			0	0535	Oil,% Fuel Cost			10%	1000	Labour wage	0.00	US\$/nour	
Inter     O     O.33     Output TackInngging     Output TackInnging     Output TackInngging <th< td=""><td></td><td>other</td><td></td><td></td><td>0</td><td>USSS</td><td>Oll Cost</td><td></td><td>1</td><td>-</td><td>USAL</td><td>No.Labourers/Shim</td><td>0.0</td><td>#</td></th<>		other			0	USSS	Oll Cost		1	-	USAL	No.Labourers/Shim	0.0	#	
joiner     joiner<		other			0	US\$S	Tyres/Tracks/Rigging	200	1.00			Contributions	0.0%	1	
But botal additional equipmit     But Park     But Park     Port I     0     0     0     Operating hours/Week     BBB     Park       Sub total additional equipmit     BU CSS     Ferr     0     <		other			0	US\$s		Qty	Cost	Life	1	Operating Days/Week	6.0	days	
Sub bit additional equipment     00     0 C/SS     rate / EO     0	and the second states of	other			0	US\$s	front	0	0	0	1	Operating Hours/Week	96.0	Hrs	
Table Lape Englisher     394 F788 USS     tack Eco     0	Sub total additional equipment	nt			0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs	
Annual Hogins     61 Stelle (LSS: Presidual Value @ Residual Value @ Shift of Der Allewance Shift shift Shift of Der Allewance Shift shift Shift of Der Allewance Shift shift Shift of Der Allewance Shift shift Shift shift Marine Analia Shift of Der Allewance Shift shift Marine Marine Marine Marine Marine Marine Marine Marine Ma	Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs	
12.HP Gatualision     other     0     Double Time per Veeks     32.0 Voet	Annual Hp's				83 166	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs	
Realization     20.00%     278 850     USS     Fuel Cost     24.44     USS/hm/     All or Other Allowance     0.00     USS/stay       Payment period     6.00     (Cost     6.00     USS/stay     Annual Time and a Half     2.280     USS       Annual Fuel Costs     8.05     Annual Time and a Half     2.280     USS     Annual Evel Costs     8.05     USS     S.55     USS     S.55     USS     S.55     USS     Annual Evel Costs     7.05     USS     Annual Evel Costs     7.05     USS     Maintenance Cost     7.05     USS     Annual Evel Costs     7.05     USS     S.55     USS     S.56     USS     S.56     USS     S.56     USS     S.56     USS     S.56     USS     Annual Evel Costs     Total Annual Annual Annual Annual Annual An	1.2 HP Calculation				-		other	0	0	0		Double Time per Week	3.0	Hrs	
Linterest premert period     0.00%     0.1. Cost     3.86     USS/m/     Anual Normal Time     51.74     USS       Monthy payment     6.530     0.530     0.1. Cost     3.86     USS/m     Anual Normal Time     2.260     USS       1.3 OPERATIVE HOURS	Residual Value @			20.00%	78 960	US\$s	Fuel,Cost			24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day	
Payment genod     60 morbit     Tyreu/Track/Rigong Coat     0.00 USS/m     Annual Tureu and a Yarif     2 200 USS     Annual Tureu Coats     Annual Tureu Toreu and a Yarif     2 200 USS     Annual Tureu Toreu and a Yarif     2 200 USS     Annual Tureu Toreu and a Yarif     2 200 USS     Annual Tureu Toreu Annual Tureu Toreu KRigging Coat     0 0.05     Annual Tureu Toreu Annual Tureu Toreu KRigging Coat     0 0.05     Annual Tureu Toreu KRigging Coat     Toreu KRigging Coat     Annual Tureu Toreu KRigging Coat     Tor	Interest per annum				8.00%		Oil, Cost			3.65	US\$/mhr	Annual Normal Time	51 744	US\$s	
Machab pisyment     6 380     USas     Annual Luce Costs     98 333     USas     Annual Luce Costs     98 333     USas     Annual Luce Cost     0     USas     Annual Luce Cost     20 88 035     USas     Annual Kone Cost     20 88 035     USas     Annual Luce Cost     20 805     USas     Annual Luce Cost     Annual Luce Cost     Annual Luce Cost     Annual Luce Cost <th< td=""><td>Payment period</td><td></td><td></td><td></td><td>60</td><td>months</td><td>Tyres/Tracks/Rigging</td><td>Cost</td><td></td><td>0.00</td><td>US\$/mhr</td><td>Annual Time and a Half</td><td>2 205</td><td>US\$s</td></th<>	Payment period				60	months	Tyres/Tracks/Rigging	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s	
Annual Luce Cost     575     USS     Annual Luce Cost     575     USS     Annual Bonus     0     USS       Total Days     365     365     Annual Vortice CoSTS     0     USS     Annual Bonus     0     USS       Statudory Laws     365     362     Marn Mo Cap, Costmachne Ille (min's)     905,     23.66 USS     36.01 USS     Total Annual Crew Cost per Machine H     25.58 8.66 USS     36.01 USS     41 WORK STUDY ANALYSIS     Mark Monte Cost     36.01 USS     41 WORK STUDY ANALYSIS     Mark Monte Cost     36.01 USS     41 WORK STUDY ANALYSIS     Mark Monte Cost     36.01 USS     41 WORK STUDY ANALYSIS     Mark Monte Monte Cost     36.01 USS     41 WORK STUDY ANALYSIS     Mark Monte	Monthly payment				6 930	USSS	Annual Fuel Costs			38 353	USSS	Annual Double Time	2 940	USSS	
1.3 OPERATING HOURS Total Days	,						Annual Lube Cost			5 753	US\$s	Annual Bonus	0	US\$s	
Total Days     355     22 VH/LE MAINTENANCE COSTS     Total Annual Crew Cost     58 88     USS:       Weekend Days     53     Maint, %i Cap, Costimachine ife (mir/s)     20%     Total Annual Crew Cost     Total Annual Crew	1 3 OPERATING HOURS					-	Annual Tyre/Track/Rig	aina Cost		0	USSS	Annual Shift or Other Allowance	0	USSS	
1001L Ug93     1002	Total Dave				365		2 2 VEHICLE MAINTE	NANCE COSTS			10000	Total Appual Crew Cost	56 880	11550	
Vietner     0.05 <th0.05< th="">     0.05     0.05     &lt;</th0.05<>	Mankand Dave			F	500		Maint % Can Cost/ma	china life (mhr/e)		00%	1	Total Crew Cost per Machine Hr	26 10	1/CC/mhr	
Statulary Leave Days     13     mainterface Cost     23 82 USS interv       Productive Days Lost for Wesher/Mill Stops     0     0     23 RELCOCATION COSTS     4.1 WORK STUDY ANALYSIS       Cala Annual Production Days     300 Days     300 Days     1.30 USS interv     4.1 WORK STUDY ANALYSIS       Shift length     8     Hours     Cost per Move     1.30 USS interv     4.1 WORK STUDY ANALYSIS       Machine Availability     0.04     8     Hours     Cost per Move     1.30 USS interv     4.1 WORK STUDY ANALYSIS       Machine Availability     0.05     8     Annual Mechanine Hours     5.100 USS interv     5.00 USS interv     interv     mod       Machine Availability     10.06 Mill Stops     5.1 Machine Requirements     miniture Cost     3.30 USS interv     interve time paded     9.05 Mill Stops       Machine Ide Years     9.52 (Yaar     16.50 (Machine Required     2.00 git     17 avel time enpty     #0/W0 min       1.4 OVERHEADS     9.52 (Vaar     9.52 (Vaar     0.00 min     0.00 min     0.00 min       1.5 Oreneads     10.00%     2.62 (FLET SUMMARY     6.2 (FLET SUMMARY     0.00 min     0.00 mi	Weekend Days				12	1	Maint, 70 Cap.Costinat	come me (mm s)		00 00	USEmbe	Total Crew Cost per Machine Fi	30.10	035/11/1	
Sinc Larve Days 0 <td>Statutory Leave Days</td> <td></td> <td></td> <td></td> <td>13</td> <td></td> <td>Maintenance Cost</td> <td></td> <td></td> <td>23.09</td> <td>USSAmnr</td> <td></td> <td></td> <td></td>	Statutory Leave Days				13		Maintenance Cost			23.09	USSAmnr				
Production Days   2.3 RELOCATION COSTS   4.1 WORK STUDP ANALTYSIS     Dial Annual Production Days   300 Days   Number of Shifts par day   4.1 WORK STUDP ANALTYSIS     Shift length   300 Days   Number of Shifts par day   1.300 USS   1.300 USS     Shift length   2.8 #   Annual Relocation Cost   5.300 USS   1.300 USS from the more sper annum   4.1 WORK STUDP ANALTYSIS     Machine Availability   100.0%   2.8 #   Annual Relocation Cost   5.300 USS from the weil empty   min     Machine burs per Day   5.3 Hours   5.1 Machine Requirements   147.500 m3   Travel time loaded   min     Machine Life Years   9.52 Years   9.52 Years   9.52 Years   2.00 #   Cycle time   2.00 #     1.4 OVERHEADS   1.4 OVERHEADS   1.4 OVERHEADS   1.000%   2.6643 USS   0.00 min   min     1.5 Overheads   10.00%   2.6643 USS   6.2 FLEET SUMMARY   2.8 #   Output per Annum   7.3 7.56 m3/year     1.5 Overheads   10.13 # 13.11 # 157 # 13 158 #   1.02 #   0.00 min   min   7.3 7.56 m3/year     1.5 Overheads   0.0 0   1.3 # 13.11 # 157 # 13 158 #   1.00 #   1.02 #   1	Sick Leave Days				0		Annual Maintenance C	ost		31 332	0535			-	
Total Annual Production Days 300 Cays Number of Movies 1300 USS International Production Days International Productin Production Days International Productional P	Productive Days Lost to Weath	ner/Mill Stops			0		2.3 RELOCATION CO	1515		-	1.	4.1 WORK STUDY ANALYSIS		1.	
Shift length 1 300 USs 1 300 USs Volume per Load m3   Machine Availability 100.0% 2 # Annual Relocation Cost 5 30 USS 3.00 USS Volume per Load m3   Machine Availability 100.0% Relocation Cost 5 30 USS 3.00 USS Volume per Load m3   Machine Life Varia 100.0% Relocation Cost 5 30 USS 3.00 USS Load min   Machine Life Varia 15 000 / fours Machine Requirements 147 500 m3 m3 min min   Machine Life Varia 15 000 / fours Machines Required 20.5% # Usad 0.00 min   Machine Life Varia 9.52 Year Fleet Reserve 0% Load 0.00 min   1.4 OVERHEADS 19740 USS S S E E E   Annual Licence Fees 19740 USS S S S S 0.00 min   1.5 Overheads 10.00% 24648 USS S S S S   5.1 SUMMARY S 5.2 FLEET SUMMARY S S S S   VShr USShr USShr USShr USShr S S   S 00 0 0.00 0	Total Annual Production Days			-	300	Days	Number of moves per	annum		4	#	Lead Distance		km	
Number of Shifts per day     2 #     Annual Relocation Cost     5 200 USSs     travel empty     Am/r       Machine Availability     32.8%     100.0%     Relocation Cost     5 200 USSs     travel empty     Am/r       Machine hours per Annum     52.8%     5.1     Annual Volume     147 500 m3     travel ime empty     #M/r       Machine hours per Annum     15 000 Hours     15 000 Hours     Number of Machines Required     9.53     #A     117 avel time empty     #D/V00 min       Machine Life Hours     15 000 Hours     15 000 Hours     Number of Machines Required     9.53     #A     000 min       Machine Life Years     9.52     Years     19.740     USSs     14 OVERHEADS     000 min     000 min     000 min       Annual Licence Fees     19.740     USSs     5.2 FLEET SUMMARY     6.2 FLEET SUMMARY     48.8 m3/m3/machines     00/machines     00/min     00/min     73.758 m3/year       1.5 Overheads     10.00%     24643     49.288     9.05%     Number of Machines     2.4     4.7     73.758 m3/year       FRKED COSTS     10.38 10 37.16     10	Shift length				8	Hours	Cost per Move			1 300	US\$s	Volume per Load		m3	
Machine Availability     100.0%     Relocation Cost per Machine Hour     3.30 (USS/m/r)     Coad     min       Machine Haurs per Day     5.3     Hours     5.1     Machine Required     3.33     0/0.0%     Gft Load     min       Machine Hours per Day     5.3     Hours     Annual Volume     147 500     m3     Off Load     min       Machine Life Years     1576     Hours     Number Of Machines Required     2.00 #     Travel time empty     #DIV/01     min       Machine Life Years     9.52     Years     Fleet Reserve     0.9%     Load     0.00     min       14 OVERHEADS     Machine Educated     2.00 #     2.00 #     Cold     0.00     min       Annual Licence Fees     19 740     USSs     Fleet Reserve     0.00     #     0.00     min       1.5 Overheads     10.0%     24643     USSs     S.2 FLEET SUMMARY     Machine Output per Annum     73 758     m3/day       0VERHEADS     15.64     2.054     2.4643     49 236     9.0%     Machine Hours     3.165     Inc. Profit	Number of Shifts per day				2	#	Annual Relocation Cos	st		5 200	US\$s	travel empty		km/hr	
Machine Iuliiiaation     32.8%     5.1 Machine Requirements     147.500     700     7147.500     701     7147.500     7147.500     701     7147.500     7147.500     7147.500     7147.500     7147.500     7147.500     7147.500     7147.500     7147.500 <th 7147.500<="" t<="" td=""><td>Machine Availability</td><td></td><td></td><td></td><td>100.0%</td><td></td><td>Relocation Cost per M</td><td>achine Hour</td><td></td><td>3.30</td><td>US\$/mhr</td><td>Load</td><td></td><td>min</td></th>	<td>Machine Availability</td> <td></td> <td></td> <td></td> <td>100.0%</td> <td></td> <td>Relocation Cost per M</td> <td>achine Hour</td> <td></td> <td>3.30</td> <td>US\$/mhr</td> <td>Load</td> <td></td> <td>min</td>	Machine Availability				100.0%		Relocation Cost per M	achine Hour		3.30	US\$/mhr	Load		min
Machine hours per Day   5.3, Hours   Anual Volume   147 500 m3   Off Laad   min     Machine hours per Annum   1506 Hours   Hourly Volume Required   93.58 m3/mt   Travel time loaded   #DIVIO   min     Machine Life Years   9.52 Years   9.52 Years   Size Years   0%   Load   0.00 min     1.4 OVERHEADS   9.52 Years   19 740 US\$s   Per Machine Sequired   2.00 #   Off Laad   0.00 min     Annual Licence Fees   19 740 US\$s   Per Machine Sequired   2.00 #   Off Laad   0.00 min     1.5 Overheads   10.00%   24643 US\$s   FLEET SUMMARY   Sz FLEET SUMMARY   Machine Cutput per Hour,   #43. m3/min     OVERHEADS   15.64 2054 24 643 49 285 9.09%   Number of Machines   2   Machine Cutput per Annum   73 788 m3/year     OVERHEADS   15.64 2054 24 643 49 285 9.09%   Number of Operators   4   Machine Hours   3   16.78 9.586     OVERHEADS   15.64 19 740   19 549 07.78   21.0% Machine Hours   3 152   17.98 9.586   10.0% 9.6861441   10.79 9.586   10.88 9.113 778 21.0% Machine Hours   3 152   10.59 9.686   10 9.0.0% 9.6861441   10 9.096	Machine Utilisation				32.8%		5.1 Machine Requirer	ments				travel loaded		km/hr	
Machine hours per Annum     1576     Hours     1076     Hours     93.55     m3/mbr     Travel time empty     PDI/Viol     min       Machine Life Hours     15 000     Hours     9.52     Years     0.00     #DI/Viol     min       Machine Life Years     9.52     Years     0.52     Years     0.00     min       Annual Licence Fees     19740     USSs     19740     USSs     0.00     min       1.5 Overheads     10.00%     24643     USSs     0.00     min     Machine Culput per Hour, Machine Output per Day     248     m3/day       1.5 Overheads     10.00%     24643     USSyer     of Total     USS per m3     3.58     inc. Profit     4.23       VERHEADS     15.54     2.064     24.643     49.286     9.09%     Number of Machines     2     machine Output per Annum     73.756     m3/day       1.5 Overheads     15.54     2.064     24.643     49.286     9.09%     Number of Machines     2     machine Output per Annum     73.756     m3/day       1.5 Overhead	Machine hours per Day				5.3	Hours	Annual Volume			147 500	m3	Off Load		min	
Machine Life Hours     15 000 Machine Life Years     15 000 State Reserve     2.00 O%     # Code     Travel time loaded     #DIVIOL om om     min       1.4 OVERHEADS     1.4 OVERHEADS     1.4 OVERHEADS     2.00 Machine Liber of Machines Required     2.00 O%     #     Travel time loaded     0.00 min     min       1.4 OVERHEADS     1.9 740     USS     VSS     0.00     #     0.00     min       1.5 Overheads     10.00%     24643     USS     0.00     min     3.35     min       1.5 Overheads     10.00%     24643     USS     0.00     min     min       0.5 Styme     15.04     2.643     4.928     9.09%     Number of Machines     2     Machine Output per Annum     73.758     m3/3year       0.5 PER MACHINE     FLEET     %     USS per m3     3.85     Inc. Profit     4.23     Machine Output per Annum     73.758     m3/3year       0.00 0     0     0     0     0.00%     Machine Hours     3.152     4     VSS     VSS     VSS     VSS     VSS     VSS	Machine hours per Annum				1 576	Hours	Hourly Volume Require	ed		93.59	m3/mhr	Travel time empty	#DIV/0!	min	
Machine Life Years   9.52   Years   Fleet Reserve   0%   Load   0.00   min     1.4 OVERHEADS   Rounded number of Vahicles Required   2.00   #   Off_Load   0.00   min     Annual Licence Fees   19.740   USSs   VSs   Permit S   10.00%   24643   USSs   VISS   Machine Cutput per Hour   465.8   min     1.5 Overheads   10.00%   24643   USSs   September 10   VISS perm 3   3.65   Inc. Profit   4.23   maximum   73 756   m3/mer     OVERHEADS   15.64   2054   24 643   49 286   9.09%   Number of Machines   2   Machine Output per Annum   73 756   m3/mer     OVERHEADS   16.54   2054   24 643   49 286   9.09%   Number of Operators   1   Machine Output per Annum   73 756   m3/mer     Hp's   52.77   6 930   83 166   166 331   30.79   Number of Operators   1   Machine Hours   3 162   736   Capital Uvalue   15 59 594   1   1   1   1   1   1   1   1   1 <td>Machine Life Hours</td> <td></td> <td></td> <td></td> <td>15 000</td> <td>Hours</td> <td>Number Of Machines I</td> <td>Required</td> <td></td> <td>2.00</td> <td>#</td> <td>Travel time loaded</td> <td>#DIV/0!</td> <td>min</td>	Machine Life Hours				15 000	Hours	Number Of Machines I	Required		2.00	#	Travel time loaded	#DIV/0!	min	
1.4 OVERHEADS   Annual Licence Fees   19740) USSs   Exact Number of Machines Required   2.00 #   Off Load   0.00 min     Annual Licence Fees   19740) USSs   Sss   Machine Output per Hour   48.8 m3/mbr     1.5 Overheads   10.00%   24643 USSs   Sss   Machine Output per Hour   48.8 m3/mbr     6.1 SUMMARY   5.2 FLEET SUMMARY   6.2 FLEET SUMMARY   Machine Output per Annum   73 756 m3/gear     OVERHEADS   15.64 2.064 2.046 4.055   44.64 3.9258   Ss.958   Number of Machines   2     FIXED COSTS   101.39 13 316 159 794 319 569 58.9%   Number of Operators   4   4   4     Hp's   52.77 6.930 83 166   166 331 30.7%   Number of Operators   4   4     Hp's   0.00 0   0   0.09%   Residual Value   157 919   54.97 7.05 9.076 14.1%     Userical   0.00 0   0   0.09%   Residual Value   157 919   54.97 7.97 5.075 11.506 2.1%   7.3% Capital Employed   789 596 14.1%   54.97 7.97 5.075 11.506 2.1%   7.98 596 17.97 5.075 11.506 2.1%   7.98 596 1.08 1.07 5.075 11.506 2.1%   54.97 7.97 5.075 11.506 2.1%   7.98 596 1.07 5.075 11.506 2.1%   7.98 506 1.1 1%   54.97 7.95 5.75	Machine Life Years				9.52	Years	Fleet Reserve			0%		Load	0.00	min	
1.4 OVERHEADS   Rounded number of vehicles Required   2 #   cycle time   #DVV/00   min     Annual Licence Fees   19 740   US3:   Machine Output per Nour   468   m3/dby     1.5 Overheads   10.00%   24843   US3:   6.2 FLEET SUMMARY   Machine Output per Day   Machine Output per Annum   73 756   m3/dby     0VERHEADS   15.64   2.054   24.643   49 286   9.09%   Number of Machines   2   Number of Operators   4   1.5							Exact Number of Mach	nines Required		2.00	#	Off Load	0.00	min	
Annual Licence Fees     19 740     USS:       1.5 Overheads     10.00%     24643     USS:     Machine Output per Day     246     m3/day       1.5 Overheads     10.00%     24643     USS:     Set FLEET     Machine Output per Day     246     m3/day       6.1 SUMMARY     FLEET     %     USS/hr     USS/hr     USS/hr     USS/hr     USS/hr     USS/hr     VSS/hr     VSS/hr     73 756     m3/day       OVERHEADS     16.54     2.054     2.4 643     49 286     9.09%     Number of Machines     2       Number of Operators     4     Number of Operators     4     Number of Operators     4     4     4     2.0%     Residual Value     157 919     5     54.97     7.220     86.638     173.276     3.0%     Residual Value     157 919     54     7.220     86.638     173.276     3.0%     Fold Revenue     542.161     10.0%     7.464     18.8%     Revenue     542.161     10.0%     10.0%     10.0%     10.0%     10.0%     10.0%     10.0%     10.0%	1.4 OVERHEADS						Rounded number of ve	hicles Required		2	#	cycle time	#DIV/01	min	
Annual Licence Fees   19740 USSs   Machine Output per Hour Machine Output per Day Machine Output per Day Machine Output per Annum   48.8 m3/mhr Machine Output per Day Machine Output per Annum   48.8 m3/mhr Machine Output per Day Machine Output per Annum   48.8 m3/mhr Machine Output per Annum     0.1 SUMMARY   6.2 FLEET SUMMARY   6.2 FLEET SUMMARY   6.1 SUMMARY   6.2 FLEET SUMMARY     0VERHEADS   15.64   2.054   2.4 643   49.286   9.09%   Number of Machines   2     FIXED COSTS   101.39   13.316   159.794   319.589   9.09%   Number of Operators   4     Hy's   5.2.77   6 930   83.166   166 331   30.7%   Machine Hours   3 152     Crew   36.10   4 741   56.889   113.778   21.0%   Machine Hours   3 152     Fuel   12.53   1.645   19 740   39.480   7.3%   Capital Employed   789.596     Fuel   24.34   3.196   38.353   76.706   14.1%   Total Revenue   542.151   10.4   4.3     VARIABLE COSTS   54.93   7.1076   542.151   10.00%   542.151   10.4   4.4.3   4.4.3   4.4.	The reduction of the re									-		cycle time	#DIV/01	brs	
1.5 Overheads     10.00%     24643 /USS     Machine Output per Annum     73 756 m3/year       6.1 SUMMARY     FLEET     %     USS/year     of Total     USS per m3     3.68     Inc. Profit     4.23       OVERHEADS     15.64     2064     24.643     492.86     9.09%     Number of Machines     2     4       FIXED COSTS     101.39     13.316     156.794     319.58     58.9%     Number of Machines     2     4       Hp's     52.77     6.930     83.166     166.331     30.7%     Machine Hours     3.152       Crew     36.10     4.741     56.889     113.778     21.0%     Machine Hours     3.152       Permit & Toll fees     0.0     0     0.0%     Residual Value     157.791       VARIABLE COSTS     54.97     7.220     86.638     173.276     32.0%     Total Revenue     542.151       Variable COSTS     54.97     7.20     86.638     173.276     32.0%     Total Revenue     542.151       Variable COSTS     54.97     7.20	Annual Licence Fees			E	19 740	]US\$s						Machine Output per Hour Machine Output per Day	46.8	m3/mhr m3/day	
B.1 SUMMARY PER MACHINE FLEET %   US\$/nr US\$/year 0f Total US\$/year 0f Total   OVERHEADS 15.64 2.054 24.643 49.286 9.09%   Number of Machines 2 2 4 4.23   Hp's 52.77 6.930 83.166 166.331 30.7%   Crew 36.10 4 741 56.889 113.778 21.0%   Machine Hours 3.152 789.596 789.596   Dermit & Toll Fees 0 0 0.0% Total Revenue   VARIABLE COSTS 54.97 7.220 86.638 173.276 32.0%   Fuel 24.34 3.196 38.353 76.706 14.1%   Lubrication 3.65 479 5.753 11.506 2.1%   Maintenance 23.69 3.111 37.332 74.664 13.8%   Relocation 3.30 433 5.200 10.400%	1.5 Overheads		[	10.00%	24643	USSS	· · · · · · · · · · · · · · · · · · ·					Machine Output per Annum	73 756	m3/year	
PER MACHINE     FLEET     %       US\$/hr     US\$/year     of Total     US\$ per m3     3.68     Inc. Profit     4.23       OVERHEADS     15.64     2 054     24 643     49 286     9.09%     Number of Machines     2       FIXED COSTS     101.39     13 316     159 794     319 589     58.9%     Number of Operators     4       Hp's     52.77     6 930     63 166     166 531     30.7%     4       Crew     36.10     4 741     56 889     113 778     21.0%     Machine Hours     3 152       Licence     12.53     1 645     19 740     39 430     7.3%     Capital Employed     789 596       Permit & Toll fees     0.0     0     0.0%     Residual Value     157 919       VARIABLE COSTS     54.97     7 220     86 638     173 276     32.0%     Total Revenue     542 151       Lubrication     3.65     479     5 753     11 506     2.1%     542 151       Maintenance     23.69     3 111     37 332     7	6.1 SUMMARY	(				10000	6.2 FLEET SUMMARY	1							
US\$/hr     US\$/year     US\$/year     of Total     US\$ per m3     3.68     Inc. Profit     4.23       OVERHEADS     15.64     2.054     24.643     49.286     9.09%     Number of Machines     2       FIXED COSTS     101.39     13.316     159.794     319.589     58.9%     Number of Operators     4       Hp's     52.77     6.930     83.166     166.331     30.7%     Number of Operators     4       Locance     12.53     1.645     19.740     39.480     7.3%     Capital Employed     789.596       Dermit & Toil fees     0.0     0     0.0%     Residual Value     157.919       VARIABLE COSTS     54.97     7.220     86.638     173.278     32.0%     Total Revenue     542.151       Variation     3.65     479     5.753     11.506     2.1%     Total Revenue     542.151       Variation     3.65     479     5.753     1.506     2.1%     Total Revenue     542.151       Maintenance     23.09     31.11     37.352 <td< td=""><td>Constant and</td><td>PI</td><td>ER MACHIN</td><td>E</td><td>FLEET</td><td>%</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>	Constant and	PI	ER MACHIN	E	FLEET	%	1								
OVERHEADS     15.64     2009 / 61     Coupleting     Coupleting <td></td> <td>US\$/hr I</td> <td>IS\$/month</td> <td>11SS/vear</td> <td>US\$/vear</td> <td>of Total</td> <td>USS per m3</td> <td></td> <td>3.68</td> <td>Inc. Profit</td> <td>4.25</td> <td></td> <td></td> <td></td>		US\$/hr I	IS\$/month	11SS/vear	US\$/vear	of Total	USS per m3		3.68	Inc. Profit	4.25				
Contraction     10.01     12.03	OVERHEADS	15.54	2 054	24 642	40 200	0.00%	Number of Machiner		0.00		4.64	1			
Frace Cost of a     101.53     103.15 <t< td=""><td>EIVED COSTS</td><td>101 20</td><td>12 240</td><td>150 704</td><td>99 200</td><td>50 000</td><td>Number of Operators</td><td>1.00</td><td>1</td><td></td><td></td><td></td><td></td><td></td></t<>	EIVED COSTS	101 20	12 240	150 704	99 200	50 000	Number of Operators	1.00	1						
Strips     S2(7)     S300     S3100     S307 Mode     S307 Mode       Crew     36:10     4 741     56 889     113 778     21.0%     Machine Hours.     3152       Licence     12:53     1645     19 740     39 480     7 3% Capital Employed     789 596       Permit & Toll fees     0.0     0     0.0%     Residual Value     157 919       VARIABLE COSTS     54:97     7 220     86 638     173 276     32.0%     Total Revenue     542 151       Fuel     24:34     3 196     38 353     76 706     14.1%     542 151       Lubrication     3.65     479     5 753     11 506     2.1%     542 151       Maintenance     23:69     31 11     37 332     74 664     13.8%     5200     10 4000     1.9%       ToTAL COST / REVENUE     172.00     22 580     21 1076     542 151     100.0%     540     540	Hole	60.77	6 000	02 400	100 001	20.3%	inditiber of Operators		4						
Crew     38:10     4 / 41     50:69     113 / 10     21:076 (Machine Hours)     3152       Licence     12:53     1 645     19 740     39 480     7.3%     Capital Employed     789 596       Permit & Toil fees     0.0     0     0.0%     Residual Value     187 919       VARIABLE COSTS     54:97     7 220     86 638     173 276     32.0%     Total Revenue     542 151       Fuel     24:34     3 196     38 353     76 706     14.1%     542 151       Lubrication     3.65     479     5 753     11 506     2.1%     542 151       Variantemance     23:69     31 11     37 332     74 664     13.8%       Relocation     3.30     433     5 200     10 400     1.9%       TOTAL COST / REVENUE     172.00     22 590     271 1076     542 151     100.0%	Crow Crow	52,11	0 930	60 000	100 331	30.7%	Machina Haura		2450						
Licence 12.53 1 545 19 740 39 450 7 3% (Capital Employed 78 93%) Permit & Toll Fees 0 0 0 0 0.0% Residual Value 157 919 VARIABLE COSTS 54.97 7 220 86 538 173 276 32.0% Total Revenue 542 151 Fuel 24.34 3 196 38 353 76 706 14.1% Lubrication 3.65 479 5 753 11 506 2.1% Tyres 0.00 0 0 0 0.0% Maintenance 23.69 3 111 37 332 74 664 13.8% Relocation 3.30 433 5 200 10.400 1.9%	CIEW	36.10	4 /41	00 889	113 778	21.0%	Resident Frederic		3 152			1			
Permit & Toll Tees     0.0     0     0.0%     Residual Value     157 919       VARIABLE COSTS     54.97     7 220     86 638     173 276     32.0%     Total Revenue     542 151       Fuel     24.34     3 196     38 353     76 706     14.1%     542 151       Lubrication     3.65     479     5 753     11 506     2.1%       Tyres     0.00     0     0.0%     0.0%       Maintenance     23.69     3111     37 332     74 664     13.8%       Relocation     3.30     433     5 200     10 400     1.9%       TOTAL COST / REVENUE     172.00     22 590     271 1076     542 151     100.0%	Licence	12.53	1 645	19 740	39 480	7.3%	Capital Employed	1.0	789 596						
VARIABLE COSTS     54.97     7 220     86 638     173 276     32.0% [Total Revenue]     542 151       Fuel     24.34     3 196     38 353     76 706     14.1%     542 151       Lubrication     3.65     479     5 753     11 506     2.1%       Tyres     0.00     0     0     0.0%     542 151       Maintenance     23.69     3 111     37 332     74 664     13.8%       Relocation     3.0     433     5 200     10 400     1.9%       TOTAL COST / REVENUE     172.00     22 590     271 076     542 151     100.0%	Permit & Toll fees	0.0		0	0	0.0%	Residual Value		157 919						
Fuel     24.34     3 196     38 353     76 706     14.1%       Lubrication     3.65     479     5 753     11 506     2.1%       Tyres     0.00     0     0     0.0%       Maintenance     23.69     3 111     37 332     74 664     13.8%       Relocation     3.0     433     5 200     10 400     1.9%       TOTAL COST / REVENUE     172.00     22 590     271 1076     542 151     100.0%	VARIABLE COSTS	54.97	7 220	86 638	173 276	32.0%	Total Revenue	-	542 151						
Lubrication     3.65     479     5.753     11.506     2.1%       Tyres     0.00     0     0     0.0%5       Maintenance     23.69     3.111     37.332     74.664     13.8%       Relocation     3.30     433     5.200     10.400     1.9%       TOTAL COST / REVENUE     172.00     22.590     271.076     542.151     100.0%	Fuel	24.34	3 196	38 353	76 706	14.1%	5								
Tyres     0.00     0     0     0.0%       Maintenance     23.69     3.11     37.332     74.664     13.8%       Relocation     3.30     433     5.200     10.400     1.9%       TOTAL COST / REVENUE     172.00     22.590     271.076     542.151     100.0%	Lubrication	3.65	479	5 753	11 506	2.1%	5								
Waimmenance     23 091     3 111     37 332     74 6564     13.8%       Relocation     3.30     433     5 200     10 400     1.9%       TOTAL COST / REVENUE     172.00     22 590     271 076     542 151     100.0%	Tyres	0.00	0	0	0	0.0%									
TOTAL COST / REVENUE 172.00 22 590 271 076 542 151 100.0%	Relocation	23.69	3111	5 200	14 664	10.8%									
	TOTAL COST / REVENUE	172.00	22 590	271 075	542 151	100.0%									


MACHINE DESCRIPTION	:	CFDDC (Morbark	2355)			
OPERATION	:	Delimb, Debark, C	chip, Load			
STUDY FOR	:	MSc				
PREPARED BY	:	McEwan				
NOTE: ALL FIGURES QUOTEL	ARE EST	TIMATES, SITE SPECIFIC	& ASSUME FULLY	TRAI	NED OPERATORS	
1.1 CAPITAL EMPLOYED				_	2.1 VEHICLE OPER	RATING COSTS
Machine Price, Exc. VAT			1 059 368	\$	Fuel Consumption	
Less Cost of Tyres/Tracks/Rig	ging		Ō	\$	Fuel Cost	
Plus additional equipment	radio		0	\$	Oil,% Fuel Cost	
and the second second second second	combica	in	0	\$	Oil Cost	
	other		0	\$	Tyres/Tracks/Riggin	g
	other		0	\$		Qty
	other		0	\$	Chains	234
Sub total additional equipment			0	\$	Disc Knives	12
Total Capital Employed			1 059 368	\$	Drum	0
Annual HP payment			223 159	\$	Tyres	0

Total Capital Employed				1 059 500	\$
Annual HP payment				223 159	\$
1.2 HP Calculation					
Residual Value @			20.00%	211 874	\$
Interest per annum				8.00%	
Payment period				60	months
Monthly payment				18 597	\$
1.3 OPERATING HOURS	_		_		
Total Days				365	
Weekend Days				52	
Statutory Leave Days				13	
Sick Leave Days				0	
Productive Days Lost to Wea	ther/Mill Stops			0	
Total Annual Production Days	S			300	Days
Shift length				8	Hours
Number of Shifts per day				2	#
Machine Availability				100.0%	
Machine Utilisation				65.0%	
Machine hours per Day				10.4	Hours
Machine hours per Annum				3 120	Hours
Machine Life Hours				15 000	Hours
Machine Life Years				4.81	Years
1.4 OVERHEADS					
Annual Licence Fees & insura	ance			21 187	\$
1.5 Overheads			10.00%	117980	\$
6.1 SUMMARY	-				
	F	ER MACHIN	E	FLEET	%
	\$/hr	\$/month	\$/year	\$/year	of Tota
OVERHEADS	37.81	9 832	117 980	117 980	9.09
FIXED COSTS	96.45	25 077	300 928	300 928	23.2
Hp	71.53	18 597	223 159	223 159	17.2
Crew	18.13	4 715	56 581	56 581	4.4
Licence	6.79	1 766	21 187	21 187	1.6

433 108 148

0.0

281.69

122.73 18.41 68.26 70.62

1.67

878 873

5 200 1 297 781

Fuel

Permit & Toll fees

VARIABLE COSTS

Fuel Lubrication Tyres Maintenance Relocation TOTAL COST / REVENUE

878 873

0

		Qty	Cost	Life		Operating Days/Week	6.0	days
	Chains	234	8	30		Operating Hours/Week	96.0	days
	Disc Knives	12	24	50		Basic Hours/week/driver	90.0	Hrs
	Drum	0	0	0		Total Overtime per week	6.0	Hrs
	Tyres	0	0	0		Time and a Half per week	3.0	Hrs
	other	0	0	0		Double Time per Week	3.0	Hrs
	Fuel,Cost		1	122.73	\$/mhr	Shift or Other Allowance	0.00	\$/day
	Oil, Cost			18.41	\$/mhr	Annual Normal Time	51 744	\$
onths	Tyres/Tracks/Rigging	Cost	13	68.26	\$/mhr	Annual Time and a Half	225	\$
	Annual Fuel Costs			382 927	\$	Annual Double Time	300	\$
	Annual Lube Cost			57 439	\$	Annual Bonus	4 312	\$
-	Annual Tyre/Track/Rig	ging Cost		212 959	\$	Annual Shift or Other Allowance	0	\$
	2.2 VEHICLE MAINT	ENANCE COST	S			Total Annual Crew Cost	56 581	\$
	Maint,% Cap.Cost/ma	chine life (mhr's		100%		Total Crew Cost per Machine Hr	18.13	\$/mhr
	Maintenance Cost			70.62	s/mhr			
	Annual Maintenance	Cost	0	220 349	\$			
	2.3 RELOCATION CO	OSTS				4.1 WORK STUDY ANALYSIS		
ays	Number of moves per	annum		4	#	Average Tree Volume		m3
ours	Cost per Move			1 300	\$	Number of trees/grab		#
	Annual Relocation Co	st		5 200	\$	other		
	Relocation Cost per N	achine Hour		1.67	\$/mhr	debranch, debark, chip, Load		min
	5.1 Machine Require	ments				other		min
ours	Annual Volume			147 500	m3	other		min
ours	Hourly Volume Requir	ed		47.28	m3/mhr	other		min
ours	Number Of Machines	Required		1.00	#	other		min
ears	Fleet Reserve			0%		other 1		min
	Exact Number of Mac	hines Required		1.00	#	other		min
	Rounded number of v	ehicles Required		1	#	cycle time	0.00	min
			_			cycle time	0.00	hrs
						Machine Output per Hour	47.4	m3/mhr
						Machine Output per Day	493	m3/day
	the second s					Machine Output per Annum	147 888	m3/vear
	6.2 FLEET SUMMAR	Y						
%								
of Total	\$ per m3		8.80	Inc. Profit	10.13	2		
9.09%	Number of Machines		1			1		
23.2%	Number of Operators	lane -	2					
17.2%		-						
4.4%	Machine Hours		3 120					
1 6%	Capital Employed		059 368					
0.0%	Residual Value		211 874					
67.7%	Total Revenue		297 781					
29.5%								
4.4%								
16.4%								
17.0%								
0.4%								
100.0%					_			

104.9 L/Hr

1.17 S/L

15% \$AL



9.80 \$/hr

1.1 # 0.00 \$/hr

0.0 #

0.0%

3.1 LABOUR COSTS

Driver Wage

Contributions

No.Drivers/Shift

Labour Wage No.Labourers/Shift



CFDDC System – Tree volume 0.25m<sup>3</sup>



SYSTEM DESCRIPTION	:	CFDDC
OPERATION	:	Stump to Mil
STUDY FOR		MSc
PREPARED BY	:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)						\$1.47	186 000	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$2.97	186 000	2	2	4	300
CFDDC (Morbark 2355)						\$6.98	186 000	1	2	2	300
L				Total		R 11.42		4		9	
				TOTAL		R 0.00		0		0	



1.1 CAPITAL EMPLOYED			2.1 VEHICLE
NOTE: ALL FIGURES QUOTED A	RE EST	IMATES, SITE SPECIFIC & ASSUME FULLY TRAINE	D OPERATORS
PREPARED BY	1	McEwan	
STUDY FOR	:	MSc	
OPERATION	:	Felling and bunching	
MACHINE DESCRIPTION	1	Wheeled Feller Buncher (Tigercat 720E)	



1 1 CAPITAL EMPLOYED						2 1 VEHICLE OPER	ATING COSTS	-	_	_	31LABOUR COSTS		
Machine Price Eve VAT				315 717	11580	Fuel Consumption		1	15.2	Inter	Driver Wage	9.80	USShou
Less Cost of Tyras/Tracks/Pi	aging			010711	11580	Fuel Cost			1 17	LISSA	No Drivers/Shift	11	#
Dive additional equipment	gging			0	11080	Oil % Eval Cost			150/	UGAL	Labour Wage	0.00	USEhou
Pida additional equipment	combican			0	11000	Oil Cost			1076	LISSA	No Labourare/Shift	0.00	#
	other			0	11000	Turse Tracks/Disain				JOSAL	Contributions	0.0	-
	outer			0	0335	Tyles/Tracks/Riggin	9	Cast	1740		Contributions	0.0%	dave
	other			0	USSS		Qty	Cost	Lite	1	Operating Days/week	6.0	days
a construction of the second	other			0	US\$S	Tyres	0	0	0		Operating Hours/Week	96.0	days
Sub total additional equipment	nt			0	US\$s	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	US\$s	Other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						Other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		L	20.00%	63 143	US\$s	Fuel,Cost			17.78	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			2.67	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Riggin	g Cost		3.72	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs			43 474	US\$s	Annual Double Time	300	US\$s
					_	Annual Lube Cost			6 521	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/R	tigging Cost	_	9 094	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAIN	TENANCE COST	TS			Annual Contributions	0	US\$s
Weekend Days				52		Maint % Cap.Cost/m	achine life (mhr	s)	100%	1	Total Annual Crew Cost	52 269	US\$s
Statutory Leave Days				13		Maintenance Cost		·	21.05	US\$/mhr	Total Crew Cost per Machine Hr	21.38	US\$/mhr
Sick Leave Days				0		Annual Maintenance	Cost		51 453	USSS			
Productive Days Lost to Weath	er/Mill Stons			0		2 3 RELOCATION C	OSTS	-		0000	4 1 WORK STUDY ANALYSIS		
Total Annual Production Days	icinini otopa			300	Dave	Number of moves of	er annum	1	4	1#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move	or annum		1 300	11580	fall		min
Number of Chiffe par day				2	#	Annual Relocation C	ort		5 200	11080	hunch		min
Machine Availability				100 0%	-	Relocation Cost par	Machina Haur		242	1100 mbr	place		min
Machine Availability				E0.0%		E 1 Machine Dequi	Machine Hour		2.10	033/11/1	place		min
Machine Otilisation				50.9%	Laura	5.1 machine Reguin	ements	ſ	400.000	1	move		min
Machine hours per Day				8.1	Hours	Annual Volume			186 000	ma	other		min
Machine hours per Annum			-	2 445	Hours	Hourly Volume Requ	lired		76.09	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machine	s Required		1.00	#	other		min
Machine Life Years				6.14	Years	Fleet Reserve			0%		other		min
and the second second						Exact Number of Ma	ichines Required		1.00	#	other	-	min
1.4 OVERHEADS						Rounded number of	vehicles Require	ed L	1	#	cycle time	0.00	min
the second second second			_								cycle time	0,000	hrs
Annual Licence Fees & insurar	nce			14 207	US\$s						Machine Output per Hour	76.1	m3/mhr
											Machine Output per Day	620	m3/day
1.5 Overheads			10.00%	24873	US\$s						Machine Output per Annum	186 033	m3/year
6.1 SUMMARY						6.2 FLEET SUMMA	RY				the second se		
	PI	ER MACHIN	E	FLEET	%		6			_			
	US\$/hr L	IS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	11	1.47	Inc. Profit	1.69	9		
OVERHEADS	10.17	2 073	24 873	24 873	9.09%	Number of Machines	5	1					
FIXED COSTS	54.40	11 082	132 983	132 983	48.6%	Number of Operator	s	2					
Hp	27.21	5 542	66 507	66 507	24.3%		-	-			E		
Crew	21.38	4 356	52 269	52 269	19.1%	Machine Hours		2 445					
Licence	5.81	1 184	14 207	14 207	5,2%	Capital Employed		315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		63 143					
VARIABLE COSTS	47 35	9 645	115 742	115 742	42 30	Total Revenue	6	273 598			1		
Fiel	17.79	3 622	43 474	43 474	15.00	I GIAI I TOYOTIGO	-	210 000					
Lubrication	2.67	540	6 521	0.504	0.8%								
Tyres	3.72	758	9 094	9.094	3 30								
Maintenance	21.05	4 288	51 453	51 453	18.8%	6							
Relocation	2.13	433	5 200	5 200	1.9%								
TOTAL COST / REVENUE	111.92	22 800	273 598	273 598	100.0%								



1 1 CAPITAL EMPLOYED				2 1 VEHICI E OPER	ATING COSTS				3 1 LABOUR COSTS
Machine Price Eve VAT		394 798 115	222	Evel Consumption	A1110 00313		20.8	Ar	Driver Wage
Lass Cost of Tures/Tracks/Pi	aging	334 130 03	000	Fuel Cost			1 17	USEA	No Drivers (Shift
Dive additional equinment	radio	0 1/5	250	Oil % Eval Cost			15%	USAL	Labour Maga
r las additional oquipment	other	0 1/5	222	Oil Cost			1070	N2211	No Labourers/Shift
	other	0 1/5	222	Tyres/Tracks/Ringing		_		ODAL	Contributions
	other	0 1/5	222	i yrear ruckar (igging	Otv	Cost	Life		Operating Days/Week
	other	0 1/5	222	front	0	0	0		Operating Hours/Week
Sub total additional equipment	t t	0 1/5	222	rear	0	0	0		Basic Hours/week/driver
Total Canital Employed		394 798 1/5	222	tracks Eco	0	0	0		Total Overtime per week
Annual Hn's		83 166 1/5	222	other	0	0	0		Time and a Half ner week
1.2 HP Calculation				other	0	0	0		Double Time per Week
Residual Value @	20.0	78 960 US	SSS	Fuel.Cost	-		24.34	US\$/mhr	Shift or Other Allowance
Interest per annum		8.00%		Oil. Cost			3.65	US\$/mhr	Annual Normal Time
Payment period		60 mg	onths	Tyres/Tracks/Rigging	Cost		0.00	US\$/mhr	Annual Time and a Half
Monthly payment		6 930 US	SSS	Annual Fuel Costs			40 706	US\$s	Annual Double Time
(menned) bedrauen				Annual Lube Cost			6 106	US\$s	Annual Bonus
1.3 OPERATING HOURS				Annual Tyre/Track/R	igging Cost		0	US\$s	Annual Shift or Other Allowance
Total Days		365		2.2 VEHICLE MAINT	ENANCE COSTS				Total Annual Crew Cost
Weekend Days		52		Maint,% Cap.Cost/m	achine life (mhr's)		90%		Total Crew Cost per Machine Hr
Statutory Leave Days		13		Maintenance Cost			23.69	US\$/mhr	
Sick Leave Days		0		Annual Maintenance	Cost		39 622	US\$s	
Productive Days Lost to Weath	er/Mill Stops	0		2.3 RELOCATION C	OSTS			-	4.1 WORK STUDY ANALYSIS
Total Annual Production Days		300 Da	iys	Number of moves pe	er annum		4	#	Lead Distance
Shift length		8 Ho	ours	Cost per Move			1 300	US\$s	Volume per Load
Number of Shifts per day		2 #		Annual Relocation C	ost		5 200	US\$s	travel empty
Machine Availability		100.0%		Relocation Cost per I	Machine Hour	in the	3.11	US\$/mhr	Load
Machine Utilisation		34.8%		5.1 Machine Require	ements				travel loaded
Machine hours per Day		5.6 Ho	ours	Annual Volume			186 000 /	m3	Off Load
Machine hours per Annum		1 673 Ho	ours	Hourly Volume Requ	ired		111.20	m3/mhr	Travel time empty
Machine Life Hours		15 000 Ho	ours	Number Of Machines	Required		2.00	#	Travel time loaded
Machine Life Years		8.97 Ye	ars	Fleet Reserve			0%		Load
				Exact Number of Mar	chines Required		2.00	*	Off Load
A CONTRACTOR OF				Rounded number of	vehicles Required	-	2 :	#	cycle time
1.4 OVERHEADS							and the second se		
1.4 OVERHEADS				1					cycle time

Grapple Skidder (Tigercat 630D)

MACHINE DESCRIPTION

:

Machine hours per Day				5.6	Hours	Annual Volume	186 000 m3	Off Load		min
Machine hours per Annum				1 673	Hours	Hourly Volume Required	111.20 m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines Required	2.00 #	Travel time loaded	#DIV/0!	min
Machine Life Years				8.97	Years	Fleet Reserve	0%	Load	0.00	min
						Exact Number of Machines Required	2.00 #	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of vehicles Required	2 #	cycle time	#DIV/01	min
								cycle time	#DIV/0!	hrs
Annual Licence Fees				19 740	US\$s			Machine Output per Hour	55.6	m3/mhr
								Machine Output per Day	310	m3/day
1.5 Overheads			10.00%	25143	US\$s			Machine Output per Annum	93 001	m3/vea
6.1 SUMMARY	15					6.2 FLEET SUMMARY				
		PER MACHI	NE	FLEET	%					
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3 2	97 Inc. Profit 3.4	2		
OVERHEADS	15.03	2 095	25 143	50 286	9.09%	Number of Machines	2	1		
FIXED COSTS	95.53	13 316	159 794	319 589	57.8%	Number of Operators	4			
Hp's	49.72	6 930	83 166	166 331	30.1%					
Crew	34.01	4 741	56 889	113 778	20.6%	Machine Hours 33	45			
Licence	11.80	1 645	19 740	39 480	7.1%	Capital Employed 789 5	96			
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value 157 s	19			
VARIABLE COSTS	54.78	7 636	91 634	183 268	33.1%	Total Revenue 553 1	43			
Fuel	24.34	3 392	40 706	81 412	14.7%					
Lubrication	3.65	509	6 106	12 212	2.2%					
Tyres	0.00	0	0	0	0.0%					
Maintenance	23.69	3 302	39 622	79 244	14.3%					
Relocation	3.11	433	5 200	10 400	1.9%					
TOTAL COST / REVENUE	165.35	23 048	276 571	553 143	100.0%					



9.80 US\$/hour 1.1 # 0.00 US\$/hour 0.0 #

0.0%

6.0 days 96.0 Hrs 90.0 Hrs 6.0 Hrs 3.0 Hrs

3.0 Hrs 3.0 Hrs 0.00 US\$/day 51 744 US\$s 2 205 US\$s

34.01 US\$/mhr

km m3 km/hr

min km/hr



## MACHINE DESCRIPTION : CFDDC (Morbark 2355) OPERATION : Delimb, Debark, Chip, Load STUDY FOR : MSc PREPARED BY : McEwan NOTE: ALL FIGURES QUOTED ARE ESTIMATES,SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS CFDDC (Morbark 2355) Delimb, Debark, Chip, Load MSc McEwan

A CADITAL EMPLOYED						2 1 VEHICI E OPER	ATING COSTS				3 1 LABOUR COSTS		
Machine Price Eve VAT			Г	1 059 368	e	Evel Consumption		ſ	104 9	Inter	Driver Wage	9.80	shr
Lass Cost of Turge/Tracke/Pi	inging			1003 000	e	Fuel Cost			1 17	81	No Drivers/Shift	11	#
Dius additional equipment	radio			0	e	Oil % Euel Cost			15%	OFL.	Labour Wage	0.00	Shr
Plus additional equipment	combican			0	8	Oil Cost			10 /	S.A.	No Labourers/Shift	0.00	#
	other			0	e	Turse/Tracke/Dissing				] down	Contributions	0.0%	
	other		-	0	0	Tyres/Tracks/Rigging	Oh	Cost	Life		Operating Days Meek	6.0%	dave
	other			0	0	Chaine	224	0031	20		Operating Days/Week	0.0	dave
Cub total additional any inmar	lother			0	0	Disa Kaluas	12	24	50		Basia Hours week	90.0	Los
Sub total additional equipment	ni			4 050 200	3	Disc Knives	12	24	00		Tatal Quadima passwaak	50.0	Lin
Total Capital Employed				1 059 368	3	Trans	0	0			Time and a Half assurable	0.0	HIS
Annual HP payment				223 159	\$	Tyres	0	0			Double Time per Week	3.0	His
1.2 HP Calculation			20.000	044 974	10	Other Fuel Cent	0		400 70	C Imbr	Shift or Other Allowance	0.00	rirs ¢/dou
Residual value @			20.00%	211 6/4	3	Puel,Cost			122.13	S/mhr	Annual Normal Time	E4 744	siday
Interest per annum				8.00%	months	Turne Treeke/Diseine	Cast		10.41	S/mhr	Annual Time and a Half	01744	\$
Payment period				40.507	months	Tyres/Tracks/Rigging	g Cost		282.027	e simm	Annual Time and a Hair	220	8
Monthly payment			_	10 097	3	Annual Fuel Costs			502 921	\$	Annual Double Time	1 240	
						Annual Lube Cost	inging Cost		212 050	¢	Annual Shift or Other Allowerse	4 312	e
Total Dava				-	1	2 2 VEHICLE MAINT	TENANCE COST		212 959	\$	Total Appual Crew Cost	56 504	0
Total Days			-	365		2.2 VEHICLE MAINI	TENANCE COSTS	<b>`</b> г	4000/	1	Total Annual Crew Cost	00 001	3 Clashe
weekend Days				52		Maint,% Cap.Cost/m	achine life (mnrs)		70.62	Cimbr	Total Crew Cost per Machine Hr	10.13	24mm
Statutory Leave Days				13		Annual Maintenance	Cont		220 240	e south			
Sick Leave Days	harffill Clans			0		2 2 PELOCATION C	COST		220 343	\$	A 1 WORK STUDY ANALYSIS		
Total Appual Braduation Dava	ner/Mill Stops			200	Dave	2.3 RELOCATION C	0313	Г		1	Auerage Tree Volume		1-2
Chiff leasth			-	300	Days	Cost per Moves pe	annum		4 200	*	Average free volume		#
Shift length				0	#	Cost per Move	ort		F 200	\$	ethor		*
Number of Shifts per day				100.00	"	Releastion Cost post	Ust Hashing Hour		0 200	2 Canho	debranch debady ship Load		min
Machine Availability				100.0%		Relocation Cost per l	Machine Hour	-	1.0/	\$/mm	debranch, debark, chip, Load		min
Machine Utilisation				65.0%	Hours	5.1 Machine Require	ements	Г	496 000	1-2	other		min
Machine hours per Day				10.4	Hours	Annual Volume			100 000	IIIS make	other		min
Machine nours per Annum			- F	3 120	Hours	Houny volume Requ	Dansing	2	09.02	msymnr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines	s Required	-	1.00	#	other		min
Machine Life Years				4.81	Years	Fleet Reserve	abiana Described		0%		other		min
						Exact Number of Mar	chines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of	venicies Required	-		#	cycle time	0.00	min
			E		1.						cycle time	0.00	nrs
Annual Licence Fees & insurar	nce			21 187	12						Machine Output per Hour	59.7	m3/mnr
											Machine Output per Day	621	m3/day
1.5 Overheads			10.00%	117980	\$						Machine Output per Annum	186 264	m3/year
6.1 SUMMARY				-		D.Z FLEET SUMMAP	KT						
	P	ER MACHI	NE	FLEET	%					0.00			
0.050.051.00	sinr	\$/month	s/year	s/year	oriotal	s per ms		0.98	Inc. Profit	8.0			
EVER COSTS	37.81	9 632	117 980	117 980	9.09%	Number of Machines		1					
FIXED COSTS	30.43	19 507	300 920	300 928	17 20	Number of Operators		4					
HP Com	/1.03	18 597	223 159	223 159	17.2%	Machine Hours	1	2 4 2 0					
Crew	18.13	4 /15	06 081	56 581	4.4%	Conital Employed		3 120					
Dermit & Tell (con	6.79	1 766	21 18/	21 187	1.6%	Residual Malua	1	244 074					
Permit & Toll fees	0.0	70 000	070 970	0	0.0%	Total Davague		211 8/4					
VARIABLE COSTS	281.69	73 239	8/8 8/3	878 873	67.7%	i otal Revenue	1	29/ /81					
Fuel	122.73	31 911	382 927	382 927	29.5%								
Lubrication	18.41	4 787	57 439	57 439	4.4%								
Maintenance	70.62	18 362	220 349	220 349	17.0%								
Relocation	1.67	433	5 200	5 200	0.4%	5							
TOTAL COST / REVENUE	415.96	108 148	1 297 781	1 297 781	100.0%	0							



## CFDDC System – Tree volume 0.40m<sup>3</sup>



SYSTEM DESCRIPTION		CFDDC
OPERATION		Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)				7		\$1.23	210 000	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$2.55	210 000	2	2	4	300
CFDDC (Morbark 2355)						\$6.18	210 000	1	2	2	300
				Total		R 9.96 R 0.00		4		9	
				TOTAL		R 9.96		4	1.1	8.8	



Wheeled Feller Buncher (Tigercat 720E)

MACHINE DESCRIPTION

:

OPERATION STUDY FOR	:	Felling an MSc	nd bunchin	9								人民	
PREPARED BY NOTE: ALL FIGURES QUOTE	: D ARE ESTIM	McEwan ATES, SITE	SPECIFIC &	ASSUME FULL	Y TRAINEL	OPERATORS							OLUTIONS
1.1 CAPITAL EMPLOYED				-	_	2.1 VEHICLE OPERAT	ING COSTS			_	3.1 LABOUR COSTS		
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption		1	15.2	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	gging			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	combican			0	US\$s	Oil Cost				US\$1	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	0.0
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
Section and area	other		all and	0	US\$s	Tyres	0	0	0		Operating Hours/Week	96.0	days
Sub total additional equipment	nt			0	US\$s	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	US\$s	Other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation					1.7	Other	0	0	0	1.1.1.1	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	63 143	US\$s	Fuel,Cost			17.78	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			2.67	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	ost		3.72	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs			38 070	US\$S	Annual Double Time	300	US\$s
						Annual Lube Cost			5 711	US\$S	Annual Bonus	0	US\$s
1.3 OPERATING HOURS					1	Annual Tyre/Track/Rigg	ing Cost		7 963	05\$5	Annual Shift or Other Allowance	0	US\$S
Total Days				300		Z.Z VEHICLE MAINTEN	ANCE COSIS	) (	4009/	1	Annual Contributions	50.000	US\$S
Weekend Days				52		Maint, % Cap.Cost/mach	nine lite (mnrs)		100%	UCCAR	Total Annual Crew Cost	52 269	US\$S
Sight Logue Days				13	1	Annual Maintenance Cost	et.		21.00	USSAMIN	Total Crew Cost per Machine Hr	24.42	Jostymnr
Breductive Days	or All Stone					2 3 PELOCATION COS	Te	-	40 007	03\$5	A A WORK STUDY ANALYSIS		
Total Annual Broduction David	ien/will Stops			200	Dave	2.3 RELOCATION COS	13	1		-	4.T WORK STUDT ANALTSIS		1
Shift length				300	Hours	Cost per Move	inium		1 300	11550	Average Tree volume		min
Number of Shifts per day				2	#	Annual Relocation Cost 5 200 US\$s				hunch		min	
Machine Availability				100.0%		Annual Relocation Cost 5 200 US\$s				US\$/mhr	niace		min
Machine Litilisation				44.6%		5 1 Machine Requirem	ants		4.40	000011111	move		min
Machine hours per Day				7.1	Hours	Annual Volume	ento	1	210 000	m3	other		min
Machine hours per Annum				2 141	Hours	Hourly Volume Required	1		98.10	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Re	equired		1.00	#	other		min
Machine Life Years				7.01	Years	Fleet Reserve	oquireu		0%		other		min
						Exact Number of Machin	nes Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of veh	icles Required		1	#	cycle time	0.00	min
						1					cycle time	0.000	hrs
Annual Licence Fees & insurar	nce			14 207	US\$s						Machine Output per Hour	98.1	m3/mhr
frank and a second second second											Machine Output per Day	700	m3/day
1.5 Overheads			10.00%	23498	US\$s						Machine Output per Annum	210 002	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY					The second second		
	P	ER MACHI	NE	FLEET	%	and the second second	_		-				
a Carto and	US\$/hr U	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		1.23	Inc. Profit	1.42			
OVERHEADS	10.98	1 958	23 498	23 498	9.09%	Number of Machines		1					
FIXED COSTS	62.12	11 082	132 983	132 983	51.4%	Number of Operators		2					
Нр	31.07	5 542	66 507	66 507	25.7%		-						
Crew	24.42	4 356	52 269	52 269	20.2%	Machine Hours		2 141					
Licence	6.64	1 184	14 207	14 207	5.5%	Capital Employed	1.00	315 717					
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value		63 143					
VARIABLE COSTS	47.65	8 500	102 001	102 001	39.5%	Total Revenue		258 482					
Fuel	17.78	3 173	38 070	38 070	14.7%								
Lubrication	2.67	476	5711	5711	2.2%								
Maintenance	21.05	3 755	45 057	45 057	17.4%								
Relocation	2.43	433	5 200	5 200	2.0%								
TOTAL COST / REVENUE	120.75	21 540	258 482	258 482	100.0%								_

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MACHINE DESCRIPTION	:	Grapple S	Skidder (Tig	gercat 630D)									
OPERATION	:	Tree leng	th extractio	on									A
STUDY FOR		MSC										26	CONSISTER.
PREPARED BY	:	MCEwan			TRAINER	005047000						10	
NOTE: ALL FIGURES QUOTEL	DAREESTI	MATES, SITE	SPECIFIC &	ASSUME FULLY	TRAINED	OPERATORS							and a
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERA	TING COSTS				3.1 LABOUR COSTS		
Machine Price, Exc.VAT				394 798	US\$s	Fuel Consumption			20.8	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost			1.17	US\$A	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost		l		US\$AL	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life	1	Operating Days/Week	6.0	days
Sector Control Sector	other			0	US\$s	front	0	0	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment	1			0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				83 166	05\$5	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Galculation			20.000/	78.000	Luces	other Fuel Cent	0		04.04	LICEME	Double Time per Week	3.0	HIS
Residual value @			20.00%	2 00%	0335	Oil Cost			24.34	US\$/mhr	Annual Narmal Time	54 744	UStraay
Payment period				6.00%	months	Tures/Tracks/Ringing	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	110535
Monthly navment				6.930	11580	Annual Fuel Costs	COSt		36 940	11580	Annual Double Time	2 040	11080
Internally payment				0 000	0000	Annual Lube Cost			5 541	11580	Annual Bonus	2 340	11980
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rid	aging Cost		0	USSS	Annual Shift or Other Allowance		11585
Total Days			1	365	1	2.2 VEHICLE MAINT	ENANCE COSTS			10000	Total Annual Crew Cost	56 889	11585
Weekend Days				52		Maint.% Cap.Cost/ma	chine life (mhr's)	[	90%	1	Total Crew Cost per Machine Hr	37.48	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69	US\$/mhr			
Sick Leave Days				0		Annual Maintenance	Cost		35 956	US\$s			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION CO	OSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	annum	ſ	4	#	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	US\$s	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Co	st		5 200	US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per N	Machine Hour		3.43	US\$/mhr	Load		min
Machine Utilisation				31.6%		5.1 Machine Require	ments				travel loaded		km/hr
Machine hours per Day				5.1	Hours	Annual Volume			210 000	m3	Off Load		min
Machine hours per Annum				1 518	Hours	Hourly Volume Requir	red		138.35	m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours			-	15 000	Hours	Number Of Machines	Required		2.00	#	Travel time loaded	#DIV/01	min
Machine Life Years			1	9.88	Years	Fleet Reserve			0%		Load	0.00	min
						Exact Number of Mac	hines Required		2.00	#	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of v	chicles Required	L	2	#	cycle time	#DIV/0!	min
Annual Lineare From			ſ	10 710	luce						cycle time	#DIV/0!	nrs
Annual Licence Fees			L	19 /40	0335						Machine Output per Hour	69.2	m3/mnr
1.5 Overheads			10.00%	24343	11550						Machine Output per Day	105 029	makeer
6.1 SUMMARY			10.0070	21010	0000	6.2 FLEET SUMMAR	Y	-			Machine Output per Annam	100 000	moryour
		PER MACHIN	NE	FLEET	%								
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1000	2.55	Inc. Profit	2.93	1		
OVERHEADS	16.04	2 029	24 343	48 686	9.09%	Number of Machines	200	2					
FIXED COSTS	105.27	13 316	159 794	319 589	59.7%	Number of Operators		4					
Hp's	54.79	6 930	83 166	166 331	31.1%								
Crew	37.48	4 741	56 889	113 778	21.2%	Machine Hours		3 0 3 6					
Licence	13.00	1 645	19 740	39 480	7.4%	Capital Employed		789 596					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1	157 919					
VARIABLE COSTS	55.10	6 970	83 637	167 273	31.2%	Total Revenue	1	535 549					
Fuel	24.34	3 078	36 940	73 880	13.8%								
Tyres	3.65	462	5 541	11 082	2.1%								
Maintenance	23.69	2 996	35 956	71 912	13.4%								
Relocation	3.43	433	5 200	10 400	1.9%								
TOTAL COST / REVENUE	176.41	22 315	267 774	535 549	100.0%								



Prime Num         i.e. Machine           PrestParke DB         We we with           We have the set of th	MACHINE DESCRIPTION	: 0	CFDDC (N	Norbark 235	5)									
ND DI LOUY         I Re man           NOTE ALL POURDE GUIDERS OUTORES THATES.STE SPECIFIC & ASSUME FLUX TRANED OPERATORS         Image: Control of the second s	OPERATION STUDY FOR		Jelimb, D	ebark, Chip,	Load								1	
HCP ALL D3         IN LENAI           L1 CANTA LEWLOYDE         Assume Tops           L2 CATA LEWLOYDE         Assume Tops           L3 CATA LEWLOYDE         Assume Tops           L4 CATA LEWLOYDE         Assume Tops           Las Coal Tyres/Track/Rigging         Coal           L1 CATA LEWLOYDE         Assume Tops           Las Coal Tyres/Track/Rigging         Coal           Las Coal Tyres/Track/Rigging         Coal           Las Coal Tyres/Track/Rigging Coal         Tops           L3 CATA LEWLOWER         Dool Tyres           L3 CATA LEWLOWER         Dool Tyres/Track/Rigging Coal           L3 CATA LEWLO	STUDY FOR		NSC										80	ORESTRY
Availability         1 <t< td=""><td>PREPARED BT</td><td>ADE ECTIMA</td><td>VICEWan</td><td></td><td></td><td></td><td>OPERATORS</td><td></td><td></td><td></td><td></td><td></td><td></td><td>solutions</td></t<>	PREPARED BT	ADE ECTIMA	VICEWan				OPERATORS							solutions
1.1 CAPTACHED Action PROFE_DK-1000000000000000000000000000000000000	NOTE: ALL FIGURES QUOTED	AREESTIMA	TES,SHE	SPECIFIC & A	SSUME FULL	YTRAINEL	OPERATORS							and
Action Profession         1.95 92 0 5         Fuel Cost         199 20 5         Fuel Cost         199 20 10	1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	TING COSTS	-			3.1 LABOUR COSTS		
Lack Good Tywer/Tracks/Ragong         0         5         Full Code         1,17         54.         Nonbrear/Shift         1,18           Pike additional equipment         0         5         OUX Full Code         1956         5.         Nonbrear/Shift         0.06         57           Guo bala id/Shift Code         0         5         OUX Full Code         1956         5.         OUX Full Code         0.06         57           Guo bala id/Shift Code         0         5         OUX Full Code         12         6         0.06         0.06         57           Guo bala id/Shift Code         12         2         6         0.06         0         0.06         57           Guo bala id/Shift Code         12         2         6         0.00         0	Machine Price, Exc. VAT				1 059 368	\$	Fuel Consumption			104.9	L/Hr	Driver Wage	9.80	\$/hr
Pile additional equipment         Galo         Gold         Sold Additional equipment         Gold Sold         Sold Additional equipment         Gold Sold         Controlloo         Gold Sold         Controlloo         Gold Sold         Gold Sold Sold Sold         Gold Sold Sold Sold Sold Sold Sold Sold S	Less Cost of Tyres/Tracks/Rigg	ging			0	\$	Fuel Cost			1.17	SIL	No.Drivers/Shift	1.1	#
combinism         0 5 s         0 Cold         24         Null-bound register         0.06           site stal additional exponent         0 0 S         0 Cold         Chart         Call         Controls         0.06           Site stal additional exponent         0 0 S         0 Cold         Chart         24         6         0 Cold         Controls         0.06         6.00         6.00         6.00	Plus additional equipment	radio			0	\$	Oil,% Fuel Cost			15%		Labour Wage	0.00	\$/hr
order         of set of arr         of set of arr         Tyres/TracksRigging         Contributions         0.05           Side total additional equipment         0.6         5         Chains         224         5.0         Chains         220         Chains         220         Chains         220         Chains         220         Chains         200         Chains         Chains         200         Chains	a far far an far far far	combican			0	5	Oil Cost				\$AL	No.Labourers/Shift	0.0	#
other         0         Club         C		other			0	S	Tyres/Tracks/Rigging					Contributions	0.0%	
Inter         Inter <t< td=""><td></td><td>other</td><td></td><td></td><td>0</td><td>5</td><td></td><td>Qty</td><td>Cost</td><td>Life</td><td></td><td>Operating Days/Week</td><td>6.0</td><td>days</td></t<>		other			0	5		Qty	Cost	Life		Operating Days/Week	6.0	days
Sub total additional quippind         10         5         Dite Knives         12         24         50         Basic Hoursele/diver         50.0 fris           Vancal JP payment         223 158 / 5         Types         0 <td></td> <td>other</td> <td></td> <td></td> <td>0</td> <td>S</td> <td>Chains</td> <td>234</td> <td>8</td> <td>30</td> <td></td> <td>Operating Hours/Week</td> <td>96.0</td> <td>days</td>		other			0	S	Chains	234	8	30		Operating Hours/Week	96.0	days
Part Capability Engloyed         Today 385 5         Dom         0	Sub total additional equipment	-		1	0	S	Disc Knives	12	24	50		Basic Hours/week/driver	90.0	Hrs
Spanial Expanded         Tyres         0	Total Capital Employed				1 059 368	S	Drum	0	0	0		Total Overtime per week	6.0	Hrs
2.4 PC Calculation         after         0         0         Double Time per Week         0.000         Status           Attende Value (0)         20.005         21.217         Sime         Annual Normal Time         0.000         Status         0.000         Status<	Annual HP payment				223 159	S	Tyres	0	0	0		Time and a Half per week	3.0	Hrs
Particular dam         20.005         21.972         Fuel Cod         12273         Smith         Shith or Other Allowance         0.00         5000           Varmest parand         600	1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Status         Status<	Residual Value @		[	20.00%	211 874	s	Euel Cost		-	122.73	s/mhr	Shift or Other Allowance	0.00	S/day
Annual Function         Color         State Provided	Interest per annum			20.00.0	8.00%		Oil Cost			18.41	\$/mhr	Annual Normal Time	51 744	s
System chards         Solution	Dayment period				60	months	Tyres/Tracks/Ripping (	ost	2	68 26	\$/mhr	Annual Time and a Half	225	s
Jonutry profile         Josep s         Annual Lob Costa         Bort 2 s         Annual Lob Costa         Bort 2 s         Annual Lob Costa         Annual Lo	Mosthly novmost				18 507	e	Annual Fuel Costs			382 027	e	Annual Double Time	300	\$
A OPERATING HOURS     Annual Tyde Tradu (Figging Cost)     21 496 g /s     Annual Shift of Other Allowance Total Annual Forder Cost of Statutory Leave Days Statutory Leave Day	Monthly payment				10 001		Annual Lube Cost			57 439	\$	Annual Bonus	4 312	\$
A OF LATING FORM         365         1000%         70000%         7000%	1 3 OPERATING HOURS						Annual Tyre/Track/Rig	ning Cost		212 959	\$	Annual Shift or Other Allowance		8
Join Logy         Join Viewend Days         J	Total Dave				265		2 2 VEHICLE MAINTE	NANCE COSTS		212 333	\$	Total Annual Crew Cost	56 581	\$
vecketing upges         0.0         maint, m Cap, Costinuation terr, (min sy cost)         100.2         four elem Cost per machine m (min sy cost)           sick Lave Days         0         13         Maintenance Cost         220.348         5           sick Lave Days         0         2.3 RELCOCATION COSTS         4.1 WORK STUDY ANALYSIS           Number of Points per day         2.9         2.4 RELCOCATION COSTS         4.1 WORK STUDY ANALYSIS           Number of Points per day         2.4 RELCOCATION COSTS         4.1 WORK STUDY ANALYSIS           Anchine Availability         100.0 %         5.1 Machine Hour         1.637 Smhr           Adachine Availability         100.0 %         5.1 Machine Hour         1.637 Smhr           Adachine Usiasion         5.1 Machine Requirements         1.000 min         6.1 Machine Hour           Adachine Usi per Anum         15.000 Mours         Number of Machines Required         1.00 #         6.731 m///min           Adachine Usi per Anum         1.600 Mours         Number of Machines Required         1.00 #         6.731 m//min         6.147 min           Adachine Usi per Anum         1.839         9.00 /mours         Number of Machines Required         1.00 #         6.741 m//min         6.14 min           Adachine Using Par Anu         1.60 /min         1.00 #         1.00 # <td>Maakaad Dava</td> <td></td> <td></td> <td></td> <td>505</td> <td></td> <td>Maint % Can Cost/man</td> <td>hing life (mhrs)</td> <td><b></b></td> <td>100%</td> <td></td> <td>Total Crow Cost per Machine Hr</td> <td>10 42</td> <td>¢/mhr</td>	Maakaad Dava				505		Maint % Can Cost/man	hing life (mhrs)	<b></b>	100%		Total Crow Cost per Machine Hr	10 42	¢/mhr
Annual Mathematica Gost         2003         000000000000000000000000000000000000	Statuteer Leave Dave				12		Maintenance Cost	nine me (nini s)		70.62	¢/mhr	Total clew cost per machine Hi	10.10	Sum
Joint Lays     1     1     2	Statutory Leave Days				13		Annual Maintenance Cost			220 240	s/IIIII e			
Construction Days         0         2.3 RELOCATION COSTS         4         4         Average Tee Volume         1.300, S           Cost per Move         0         2.9 Relocation Days         4         4         Average Tee Volume         m3           Sthill length         8         Hours         Cost per Move         1.300, S         Number of trees/grab         #           Mumber of Shift per day         100.0%         8         Average Tee Volume         1.37         Shift Number of trees/grab         #         #           Machine Availability         100.0%         8         Anorage Tee Volume         1.37         Shift Number of Trees/grab         #         #         #         Average Tee Volume         min         min           Machine Life Years         100.0%         5.10         Anorage Tee Volume         Other         min         min           Average Tee Volume         13.00         Floors         Anorage Tee Volume         Other         min         min           Actine Life Years         15.000         Hours         14.001         Tee Cost Monder         1.000         Other         min         min           A VOERHEADS         Soverheads         10.00%         117980 S         6.2 FLEET SUMMARY         Other         1	Sick Leave Days	ALL CLOBE			0		Annual Maintenance C	USI ETC		220 343	\$	A A WORK STUDY ANALYSIS		
Jobu Days         Jobu Days         Number of Nove         Jobu Days         Jobu Days         Jobu Days         Jobu Days         Jobu Days         Jobu Days         Jobu	Productive Days Lost to Weather	r/Mill Stops		200		0	2.3 RELOCATION CO	515				4.1 WORK STODT ANALTSIS		1
inflittingin	Total Annual Production Days			-	300	Days	Cost per Maus	annum		4 000		Average free volume		1113
umber of shins per day dachine dulisation dachine values per Annum dachine dulisation dachine blury dachine blury dachine blury dachine blury per Day dachine blury per Day dachine blury per Annum dachine Life Hours dachine Cutput per Hour dachine Cutput per Hour dachine Cutput per Annum 210 288 m3/yee     0 ther minin minin minin dachine Cutput per Annum 210 288 m3/yee     0 ther minin minin minin dachine Cutput per Annum 210 288 m3/yee       VPERHEADS vper Heads (15 Works dachine Cutput per Annum 1813 (17 4715 do das 16 567 do do do do do do do do do do do do do do d	Shift length				8	Hours	Cost per Move			1 300	3	Number of trees/grab		#
Machine Valiability         100.0%         Hetocation Costs per Machine Hour         1.87 / ym/r         declarch, debars, chip, Load         min           Machine Hours per Day         10.4 Hours         Annual Volume         210.000         m3         other         min           Machine Hours per Day         3120         Hours         Annual Volume         210.000         m3         other         min           Machine Life Years         16 000         Hours         Annual Volume         10.00 #         other         min           A OVERHEADS         4.81 Years         Fleet Reserve         0.00 #         other         min           .4 OVERHEADS         10.00%         117980 \$         Serverback         other         0.00 #           .5 Overheads         10.00%         117980 \$         Ser Total         Ser Total         Machine Output per Day         701           .1 SUMMARY         Ser ELECT         Ser Machines         Ser Total         Ser	Number of Shifts per day				2	#	Annual Relocation Cos			5 200	3	other		
Jachine Ullisation         5.0%         5.1 Machine Requirements         0 dher         min           Machine hours per Annum         3 120         Hours         Annual Volume Required         3 0 dher         min           Machine Life Hours         15 000 Hours         Number Of Machines Required         1.00         #         other         min           Machine Life Years         4.81         Years         File Reserve         0%         0/mer         1         min           A OVERHEADS         4.31         Years         File Reserve         0%         0/mer         1         min           4.0 VERHEADS         10.00%         117980 \$         Annual Volume required         1,00         #         other         1         min           4.1 SUMMARY         21187         \$         S         Achine Volut Per Joay         701         m3/dachine Kequired         1         #         Other         1         min           5.0 verheads         10.00%         117980 \$         S         S         F         Machine Output per Day         701         m3/dachine Kequired         1         #         Other         1         min           10000%         117980 \$         S         S         S         S	Machine Availability				100.0%		Relocation Cost per Ma	Ichine Hour		1.67	\$/mnr	debranch, debark, chip, Load		min
Jachine hours per Dary     10.4 Hours     Annual Volume     210.000 m3     other     min       Jachine hours per Annum     15.000     Hours     Houry Volume Required     67.31 m3/mbr     other     min       Jachine Life Years     4.81 Years     4.81 Years     Keavine Life Years     0ther     0ther     min       J.4 OVERHEADS     4.81 Years     Exact Number of Machines Required     0.00     0ther     0ther     min       J.5 Overheads     10.00%     117980 S     S     0ther     0ther     0ther     min       J.5 Overheads     10.00%     117980 S     S     0ther     0ther     0.00 min       Sthr     Syser     Syser     other     0ther     0ther     0ther     0ther       VPERHEADS     37.81 8 832     117980 S     S     0ther     0.00 min     0ther     0.00 min       VPERHEADS     37.81 8 832     117980 S     S     0ther     0ther     0.00 min       VPERHEADS     37.81 9 832     117980 S     S     S     0ther     0ther     0ther       VPERHEADS     37.81 9 832     117980 S     S     S     S     Number of Machines     1     1       VPERHEADS     37.81 9 832     117980 S     S     S     S	Machine Utilisation				65.0%		5.1 Machine Requiren	nents			1	other		min
Jachine Life Years     J 120, Hours     15000 Hours     1000 #     other     100 #     other     min       Achine Life Years     J 15000 Hours     Number Of Machines Required     0%     0/00 #     other     1     min       .4 OVERHEADS	Machine hours per Day				10.4	Hours	Annual Volume			210 000	<i>m</i> 3	other		min
Machine Life Hours     15 000 /Hours     Number Of Machines Required     1.00 #     other     min       Aachine Life Years     4.81 Years     4.81 Years     0%     other     1     min       .4 OVERHEADS     4.81 Years     0.00 /#<	Machine hours per Annum				3 120	Hours	Hourly Volume Require	d		67.31	m3/mhr	other		min
Aachine Life Years       4.81 Years       4.81 Years       1ele Reserve       0%       ofter       1       min         .4 OVERHEADS       A OVERHEADS       1.00 #       0.00 #       other       0.00 min         .4 OVERHEADS       21 187 \$       S       0.00 #       0.00 #       other       0.00 min         .5 Overheads       10.00%       117980 \$       5       0.2 FLEET SUMMARY       Machine Output per Day       701 m3/da         .5 Overheads       10.00%       117980 \$       6.2 FLEET SUMMARY       Machine Output per Day       701 m3/da         VERHEADS       37.81       9.832       117.980 \$       9.09%       Number of Machines       1       Machine Output per Annum       210 288 m3/yee         VVERHEADS       37.81       9.832       117.980 \$       9.09%       Number of Machines       1       Number of Operators       2       1         tip       71.53       18.597       223 159       23.25%       Number of Operators       2       1       109 388       1	Machine Life Hours			-	15 000	Hours	Number Of Machines F	Required		1.00	#	other		min
A OVERHEADS     Exact Number of Machines Required     1.00 #     other     min       .4 OVERHEADS     21 187     s     Rounded number of vehicles Required     1 #     other     0.00 min       .5 Overheads     10.00%     117980 \$     Achine Cutput per Hour     6.74     m3/m       .5 Overheads     10.00%     117980 \$     6.2 FLEET SUMMARY     Machine Output per Annum     210 288     m3/m       .1 SUMMARY     FER MACHINE     FLEET     %     \$ per m3     6.18     Inc. Profit     7.11       .1 SUMMARY     Signer     Signer     9.645     25 077     300 928     300 928     23.2%       NURber of Machines     1     1     1 ms. Profit     7.11     117 880     9.09%       VERHEADS     3.781     9.832     117 980     9.09%     Number of Machines     1       VERHEADS     3.781     9.832     117 880     9.09%     Number of Operators     2       titze costs     9.6.45     25 077     300 928     300 928     23.2%     Number of Deprators     2       titzence     6.79     1.766     21 187     21 187     1.6%     Capital Employed     1.059 368       titzence     0.0     0.0     0.0%     1.297 781     1.297 781     1.297 781	Machine Life Years				4.81	Years	Fleet Reserve			0%		other 1		min
.4 OVERHEADS       21 187 \$       Rounded number of vehicles Required       1 #       cycle time       0.00       min         .5 Overheads       10.00%       117980 \$       Machine Output per Day       701       m3/da         .5 Overheads       10.00%       117980 \$       6.2 FLEET SUMMARY       Machine Output per Annum       210 288       m3/yee         .1 SUMMARY        6.2 FLEET SUMMARY       6.18       Inc. Profit       7.11         VPERHEADS       37.81       9.832       117.980       9.009.28       300.928       23.22%         Number of Machines       1       117.980       117.980       9.009.28       300.928       23.22%         VPERHEADS       37.81       9.832       117.980       117.980       9.009.28       300.928       23.25%         right       7.153       18.8597       223.159       17.2%       Number of Machines       1         crew       18.13       4.715       56.581       4.4%       Machine Hours       3.120         crew       18.13       4.715       56.581       56.581       4.4%       Machine Hours       3.120         crew       1.841       4.787       57.438       4.4%       Fotal Revenue       1.297.781 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Exact Number of Mach</td> <td>ines Required</td> <td></td> <td>1.00</td> <td>#</td> <td>other</td> <td></td> <td>min</td>							Exact Number of Mach	ines Required		1.00	#	other		min
Soverheads         21 187 S         S         Generation         Cycle time         0.00 /rs           .5 Overheads         10.00%         117980 S         Machine Output per Day Machine Output per Day Machine Output per Day Machine Output per Annum         701         m3/m3           .1 SUMMARY         6.2 FLEET SUMMARY         6.2 FLEET SUMMARY         Machine Output per Annum         210 288         m3/m2           .1 SUMMARY         S/hr         S/month         Syver         of Total         S per m3         6.18         Inc. Profit         7.11           DVERHEADS         37.81         9 832         117 980         9.09%         Number of Machines         1           tixeD COSTS         96.45         25 077         300 928         23.2%         Number of Operators         2           tip         711.53         18 597         223 159         223 159         7.7%           tip         715.65         15 65 561         4.4%         Machine Hours         3 120           icence         6.79         1766         21 187         21 187         1.6%           tip         1         105 9 368         10 59 368         1         1.5%           tip         10.66         7.743         57.439         4.4%         4	1.4 OVERHEADS						Rounded number of ve	hicles Required		1	#	cycle time	0.00	min
Annual Licence Fees & insurance       21 187 \$       Machine Output per Hour Machine Output per Hour Machine Output per Day Machine Output per Day Machine Output per Annum       67.4 m3/min Machine Output per Day Machine Output per Annum       701       m3/da         .5 Overheads       10.00%       117980 \$       6.2 FLEET SUMMARY       Machine Output per Annum       210 288       m3/da         .1 SUMMARY       \$/hr       \$/hor Machine Signal       \$/hor Signal				-								cycle time	0.00	hrs
Soverheads         10.00%         117980 \$         Machine Output per Day Machine Output per Annum         701 m3/da 210 288 m3/ye           .1 SUMMARY	Annual Licence Fees & insurance	e			21 187	\$						Machine Output per Hour	67.4	m3/mhr
5.5 Overheads       10.00%       117980 [\$       Machine Output per Annum       210 288 m3/yet         1.1 SUMMARY       6.2 FLEET SUMMARY       6.2 FLEET SUMMARY       6.2 FLEET SUMMARY       6.2 FLEET SUMMARY         S/hr       S/m       S/year       of Total       Sper m3       6.18       Inc. Profit       7.11         VVERHEADS       37.81       9 832       117 980       9.09%       Number of Machines       1         iXED COSTS       96.45       25 077       300 928       320.22%       Number of Operators       2         ip       71.55       18.597       223 159       17.2%       Machine Hours       3 120         crew       18.13       4 715       56 581       56 581       4.4%       Machine Hours       3 120         crew       18.13       4 715       56 581       56 581       67.7%       10.6%       Residual Value       211 874         crew       18.13       4 715       56 581       56 77.8%       10.6%       Residual Value       211 874         view       122.73       31 911       382 927       382 927       29.5%       10.2%       10.8%       1297 781         view       122.73       31 911       382 927       362 927												Machine Output per Day	701	m3/day
5.1 SUMMARY       6.2 FLEET SUMMARY         Shr       PER MACHINE       FLEET         Shr       Symanth       Syear       of Total         Symanth       Syear       Strigges         Symanth       Syear       Strigges         Symanth       Syear       Strigges         Symanth       Syear       Strigges         Symanth       Strigges       Strigges         Symanth       Strigges       Strigges         Symanth       Strigges       Strigges	1.5 Overheads			10.00%	117980	\$						Machine Output per Annum	210 288	m3/year
FRE MACHINE         FLEET         %           S/hr         S/month         Syear         Syear         of 764         \$ per m3         6.18         Inc. Profit         7.11           DVERHEADS         37.81         9832         117 980         91.099         Number of Machines         1           Given Costs         96.45         25 077         300 928         300 928         23.26%         Number of Operators         2           Ipp         71.53         18 597         223 159         223 159         17.2%         Number of Operators         2           Icrew         18.13         4 715         56 581         56 581         4.4%         Machine Hours         3 120           Icrew         18.13         4 715         56 581         21 187         1.6%         Capital Employed         1 059 368           oremit & Toll fees         0         0         0.0%         Residual Value         21 874           Yees         68.26         77 329         878 873         67.7%         Total Revenue         1 297 781           Ubrication         18.41         4 787         57 439         57 439         4 4%           Mathemance         10.62         17 774         220 349         17	6.1 SUMMARY	-					6.2 FLEET SUMMARY							
Shr         Shr         Shr         Shr         Shr         Syear         Syear         of 100 and 17 and		PE	ER MACHIN	IE	FLEET	%				100 100				
Optimization         37.81         9.832         117.980         117.980         20.9%         Number of Machines         1           ip         71.53         96.45         25 077         300.928         300.928         23.9%         Number of Operators         2           ip         71.53         18.597         223.159         17.2%         2         2           crew         18.13         4.715         56.581         56.581         4.4%         Machine Hours         3 120           cleence         6.79         1.766         21.187         1.6%         Capital Employed         1.059.368           Permit & Toll fees         0         0         0.0%         Residual Value         211.874           Vale         122.73         31.911         382.927         382.927         29.5%           vale         122.73         31.911         382.927         382.927         29.5%           vale         122.73         31.911         382.927         382.927         29.5%           vale         122.73         31.911         382.927         382.925         16.4%           faintenance         70.62         18.862         20.349         17.0%           faintenance		\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3		6.18	Inc. Profit	7.1	1		
HXED COSTS     96.45     25 077     300 928     300 928     23.2%     Number of Operators     2       tp     71.53     18 597     223 159     223 159     12.2%     Number of Operators     2       tp     71.53     18 597     223 159     223 159     12.2%     Number of Operators     2       treew     18.13     4715     56 581     56 581     4.4%     Machine Hours     3 120       treemit & Toll fees     0.0     0     0.0%     Residual Value     211 874       ARABLE COSTS     281.69     73 239     878 873     67.7%     Total Revenue     1 297 781       tirel     122.73     31 911     382 927     382 927     29.5%     4.4%       virel     18.41     4787     57 439     57 439     4.4%       vires     68.26     17 747     212 959     16.4%       taintenance     70.62     18 362     220 349     220 349     17.0%       telocation     1.67     433     5200     5200     0.4%       OTAL COST / REVENUE     415.96     108 148     1 297 781     1 200.78	OVERHEADS	37.81	9 832	117 980	117 980	9.09%	Number of Machines		1					
ip     71.53     18.597     223 159     223 159     223 159     17.2%       crew     18.13     4715     56 581     56 581     4.4%     Machine Hours     3 120       icence     6.79     1 766     21 187     21 187     1.6%     Capital Employed     1 059 368       ermit & Toll fees     0.0     0     0.0%     Residual Value     211 874       /ARIABLE COSTS     281.69     73 239     878 873     67.7%     Total Revenue     1 297 781       uel     122.73     31 911     382 927     382 927     29.5%     1     1       yres     6.82.61     17 747     212 959     212 959     16.4%       Ialintenance     70.62     18 362     220 349     220 349     17.0%       telocation     1.67     433     5 200     5 200     0.4%       OTAL COST / REVENUE     4158     108 148     1297 781     100.0%	FIXED COSTS	96.45	25 077	300 928	300 928	23.2%	Number of Operators		2					
Jrew         18:13         4 715         56 581         56 581         4 4%         Machine Hours         3 120           icence         6.79         1 766         21 187         21 187         1.6%         Capital Employed         1 059 368           ermit & Toll fees         0         0         0.0%         Residual Value         21 187           YARIABLE COSTS         281.69         73 239         878 873         878 873         67.7%         Total Revenue         1 297 781           'uel         122.73         31 911         382 927         382 927         29.5%         1 1 874         1 297 781           ubrication         18.44         4 787         57 439         57 439         4 4%         1 297 781         1 297 781           faintenance         68.26         17 747         12 959         16.4%         1 297 781         1 200 7%           telocation         1.67         433         5 200         5 200         0.4%         1 297 781         1 1 207 781         1 207 781	Нр	71.53	18 597	223 159	223 159	17.2%								
Jdence         6.79         1 766         21 187         21 187         21 8%         Capital Employed         1 059 368           Permit & Toll fees         0.0         0         0.0%         Residual Value         211 874           ARIABLE COSTS         28.69         73 239         878 873         878 873         67.7%         Total Revenue         1 297 781           Yuel         122.73         31 911         382 927         362 927         29.5%         1 297 781           Ubrication         18.41         4 787         57 439         57 439         1 43%         200 349         1 207 781           faintenance         70.62         18 862         220 349         220 349         1 7.0%         1 43%         5 200         0 45%           Velocation         1.67         433         5 200         0 45%         5 200         0 45%           OTAL COST / REVENUE         415.85         108 148         1 297 781         1 200 78         1 100.0%	Crew	18,13	4 715	56 581	56 581	4.4%	Machine Hours		3 120					
Variable CoSTS         0.0         0         0.0%         Residual Value         211 874           /ARIABLE COSTS         281.69         73 239         878 873         67.7%         Total Revenue         1 297 781           /uel         122.73         31 911         382 927         382 927         29.5%         1 297 781         1 297 781           /uel         18.41         4787         57 439         4 4%         1 297 781         1 297 781           /yres         68.26         17 747         212 959         212 959         16.4%         1 297 781         1 297 781           /alaintenance         70.62         18 362         220 349         220 349         1 7.0%           celocation         1.67         433         5 200         5 200         0.4%           OTAL COST / REVENUE         415.96         108 148         1 297 781         1 00.0%	Licence	6.79	1 766	21 187	21 187	1.6%	Capital Employed	11	059 368					
VARIABLE COSTS         281.69         73 239         878 873         878 873         67.7%         Total Revenue         1 297 781           'uel         122.73         31 911         382 927         382 927         29.5%            ubrication         18.41         4 767         57 439         57 439         4.4%           yres         68.26         17 747         212 959         212 959         16.4%           Ialintenance         70.62         18 362         220 349         220 349         17.0%           Relocation         1.67         433         5200         5200         0.4%           OTAL COST / REVENUE         415.96         108 148         1 297 781         100.0%	Permit & Toll fees	0.0		0	0	0.0%	Residual Value		211 874					
uel         122.73         31 911         382 927         382 927         382 927         382 927           ubrication         18.41         4.767         57 439         57 439         4.4%           yres         68.26         17 747         212 959         212 959         16.4%           faintenance         70.62         18 362         220 349         220 349         17.0%           telocation         1.67         433         5 200         5 200         0.4%           OTAL COST / REVENUE         413:95         108 148         1 297 781         1 2097 781         100.0%	VARIABLE COSTS	281.69	73 239	878 873	878 873	67.7%	Total Revenue	1	297 781					
ubrication         18.41         4 787         57 439         57 439         4.4%           yres         68.26         17 747         212 959         212 959         16.4%           faintenance         70.62         18 362         220 349         17.0%           elocation         1.67         433         5.200         5.200         0.4%           OTAL COST / REVENUE         415.96         108 148         1 297 781         100.0%	Fuel	122.73	31 911	382 927	382 927	29.5%	2							
yres         68.2c         17 / 4/         212 959         212 959         16.4%           faintenance         70.62         18 362         220 349         20 349         17.0%           kelocation         1.67         433         5 200         5 200         0.4%           OTAL COST / REVENUE         415.96         108 148         1 297 781         100.0%	Lubrication	18.41	4 787	57 439	57 439	4.4%								
Maintenance         70.02         10.02         220.049         220.049         70.05           Relocation         1.67         433         5.200         5.200         0.4%           OTAL COST / REVENUE         415.96         108.148         1.297.781         1.20.7%         1.00.0%	Tyres	68.26	17 747	212 959	212 959	16.4%								
OTAL COST / REVENUE 415.96 108 148 1 297 781 1 297 781 100.0%	Relocation	167	433	5 200	5 200	0.4%								
	TOTAL COST / REVENUE	415.96	108 148	1 297 781	1 297 781	100.0%	2							



CFDD&C System – Tree volume 0.075m<sup>3</sup>



SYSTEM DESCRIPTION	:	CFDD&C
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)				1		\$3.13	90 500	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$5.81	90 500	2	2	4	300
CFDD (Precision Husky 2300-4)						\$9.90	90 500	1	2	2	300
Chipper (Presicion Husky 2366-KBL)						\$6.46	90 500	1	2	2	300
				Total		R 25.30		5		11	
						R 0.00		0		0	
				TOTAL		R 25.30		5		11	



11 CAPITAL EMPLOYED			2 1 VEHICLE
NOTE: ALL FIGURES QUOTED A	RE EST	IMATES, SITE SPECIFIC & ASSUME FULLY TRAINE	DOPERATORS
PREPARED BY	:	McEwan	
STUDY FOR	:	MSc	
OPERATION	:	Felling and bunching	
MACHINE DESCRIPTION	:	Wheeled Feller Buncher (Tigercat 720E)	

1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	ING COSIS			1	3.1 LABOUR COSTS		-
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost			1.17	US\$1L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hou
the second second	combican			0	US\$s	Oil Cost				US\$AL	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	6
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Tyres	0	0	0		Operating Hours/Week	96.0	davs
Sub total additional equipment				0	USSS	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	USSS	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0	Hrs
Annual HP navment				66 507	11580	Other	0	0	0		Time and a Half ner week	3.0	Hrs
1 2 HP Calculation			-	00007	0000	Other	0	0	0		Double Time per Week	3.0	Hre
Desidual Value @			20.00%	62 442	11000	Fuel Cost			17 79	1100 make	Shift or Other Allowage	0.00	11CC Man
Residual value @		L	20.00%	03 143	0335	Oil Cost			17.70	USSIM	Annual Marmal Time	54 744	USSIday
Interest per annum				8.00%		Oil, Cost	10		2.67	USS/mnr	Annual Normai Time	51 /44	US\$S
Payment period				60	months	Tyres/Tracks/Rigging C	ost		3.72	US\$/mnr	Annual Time and a Half	225	05\$5
Monthly payment				5 542	US\$s	Annual Fuel Costs			47 079	US\$s	Annual Double Time	300	US\$s
					_	Annual Lube Cost			7 062	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigg	ing Cost		9 848	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTER	VANCE COST	S	_		Annual Contributions	0	US\$s
Weekend Days				52		Maint,% Cap.Cost/mac	nine life (mhr's)		100%		Total Annual Crew Cost	52 269	US\$s
Statutory Leave Days				13		Maintenance Cost			21.05	US\$/mhr	Total Crew Cost per Machine Hr	19.74	US\$/mhr
Sick Leave Days				0		Annual Maintenance Co	ost		55 719	US\$s			
Productive Days Lost to Weather	er/Mill Stops			0		2.3 RELOCATION COS	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per a	nnum	1	4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	US\$s	bunch		min
Machine Availability				100.0%		Relocation Cost per Ma	chine Hour		1.96	US\$/mbr	place		min
Machine Utilisation				55.2%		5.1 Machine Requirem	ents	_			move		min
Machine hours per Day				9.9	Hours	Annual Volume	ento	Г	90 500	m2	other		min
Machine hours per Day				2 647	Hours	Hourly Volume Pequire			24.10	m2/mhr	other		min
Machine Hours per Annum				15 000	Hours	Number Of Machines D	a secolar ad		34.19	#	other		min
Machine Life Hours				15 000	Hours	Number Of Machines R	equirea		1.00	#	other		min
Machine Life Years			E	5.67	Years	Fleet Reserve			0%		other		min
Sector and the sector of the						Exact Number of Machi	nes Required		1.00	#	other	-	min
1.4 OVERHEADS						Rounded number of vel	nicles Required	1	1	#	cycle time	0.00	min
			-								cycle time	0.000	hrs
Annual Licence Fees & insurance	e			14 207	US\$s						Machine Output per Hour	34.2	m3/mhr
											Machine Output per Day	302	m3/day
1.5 Overheads			10.00%	25789	US\$s					_	Machine Output per Annum	90 537	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%								
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		3.13	Inc. Profit	3.60			
OVERHEADS	9.74	2 149	25 789	25 789	9.09%	Number of Machines		1			1 m		
FIXED COSTS	50.23	11 082	132 983	132 983	46.9%	Number of Operators	15	2					
Ho	25 12	5.542	66 507	66 507	23 4%	in an operators	-	-					
Crown	10.74	4 256	52 260	52 260	10.4%	Machine Hours		2 6 4 7					
Lissano	5.27	1 104	14 207	14 207	E 000	Capital Employed	100	245 747					
Dermit & Toll food	0.3/	1104	14 207	14 207	0.0%	Desidual Value	1.0	62 142					
	0.0	40.400	101000	0	0.0%	Residual value		03 143					
VARIABLE COSTS	47.18	10 409	124 908	124 908	44.0%	i otal Revenue		283 681					
Fuel	17.78	3 923	47 079	47 079	16.6%								
Lubrication	2.67	588	7 062	7 062	2.5%								
Tyres Maintenance	3.72	821	9 848	9 848	3.5%								
Relocation	1.05	4043	5 200	5 200	1 8%								
		100	0200	- 100	110 10								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	: : :	Grapple Skidder (* Tree length extrac MSc McEwan	Figercat 630D) tion	TRAINER	OPERATORS			
1.1 CAPITAL EMPLOYED	AREES	TIMATES, SITE SPECIFIC	& ASSUME FULLY	RAINEL	2.1 VEHICLE OPE	RATING COSTS		
Machine Price, Exc. VAT			394 798	US\$s	Fuel Consumption			
Less Cost of Tyres/Tracks/Rigg	ging		0 US\$s Fuel Cost					
Plus additional equipment	radio		0	US\$s	Oil,% Fuel Cost			
and the marked of the	other		0	US\$s	Oil Cost			
	other		0	US\$s	Tyres/Tracks/Rigg	ing		
	other		0	US\$s		Qty		
	other		0	US\$s	front	0		
Sub total additional equipment			0	US\$s	rear	0		
Total Capital Employed			394 798	US\$s	tracks Eco 0			

Annual Ho's					1.000	
				83 166	US\$s	other
1.2 HP Calculation					Line .	other
Residual Value @		L	20.00%	78 960	US\$s	Fuel,Cost
Interest per annum				8.00%	ternine.	Oil, Cost
Payment period				60	months	Tyres/Tracks/F
Monthly payment			-	6 930	US\$s	Annual Fuel C
1.3 OPERATING HOURS						Annual Tyre/Tr
Total Days				365		2.2 VEHICLE
Weekend Days				52		Maint,% Cap.C
Statutory Leave Days				13		Maintenance C
Sick Leave Days				0		Annual Mainter
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCAT
Total Annual Production Days				300	Days	Number of mov
Shift length				8	Hours	Cost per Move
Number of Shifts per day				2	#	Annual Reloca
Machine Availability				100.0%		Relocation Cos
Machine Utilisation				29.8%		5.1 Machine R
Machine hours per Day				4.8	Hours	Annual Volume
Machine hours per Annum			1 432	Hours	Hourly Volume	
Machine Life Hours			15 000	Hours	Number Of Ma	
maximic Life rivula				riouro		
Machine Life Years				10.48	Years	Fleet Reserve
Machine Life Years				10.48	Years	Fleet Reserve Exact Number
1.4 OVERHEADS				10.48	Years	Fleet Reserve Exact Number Rounded numb
Machine Life Years 1.4 OVERHEADS Annual Licence Fees				10.48	Years US\$s	Fleet Reserve Exact Number Rounded numi
Machine Life Years 1.4 OVERHEADS Annual Licence Fees			0	10.48 19 740	Vears	Fleet Reserve Exact Number Rounded numb
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads			10.00%	10.48 19 740 23899	Vears US\$s US\$s	Fleet Reserve Exact Number Rounded numb
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY			10.00%	10.48 19 740 23899	Vears US\$s US\$s	Fleet Reserve Exact Number Rounded numb
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY	PE		10.00% E	10.48 19 740 23899 FLEET	Years US\$s US\$s	Fleet Reserve Exact Number Rounded numt
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY	PE US\$/hr U	ER MACHIN	10.00% E US\$/year	10.48 19 740 23899 FLEET US\$/year	Years US\$s US\$s of Total	Fleet Reserve Exact Number Rounded numt 6.2 FLEET SU US\$ per m3
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS	PE US\$/hr U 16.69	ER MACHIN S\$/month 1 992	10.00% E US\$/year 23 899	10.48 19 740 23899 FLEET US\$/year 47 798	Years US\$s US\$s of Total 9.09%	Fleet Reserve Exact Number Rounded numb 6.2 FLEET SU US\$ per m3 Number of Mac
Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS	PE US\$/hr U 16.69 111.59	ER MACHIN (\$\$/month 1 992 13 316	10.00% E US\$/year 23 899 159 794	10.48 19 740 23899 FLEET US\$year 47 798 319 589	Years US\$s US\$s of Total 9.09% 60.8%	Fleet Reserve Exact Number Rounded numb 6.2 FLEET SU US\$ per m3 Number of Ope
Machine Life Years Annual Licence Fees I.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's	PE US\$/hr U 16.69 111.59 58.08	ER MACHIN (\$\$/month 1 992 13 316 6 930	10.00% E US\$Vyear 23 899 159 794 83 166	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331	Vears VS\$s US\$s of Total 9.09% 60.8% 31.6%	Fleet Reserve Exact Number Rounded numb 6.2 FLEET SU US\$ per m3 Number of Mai Number of Ope
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew	US\$/hr U 16.69 111.59 58.08 39.73	ER MACHIN IS\$/month 1 992 13 316 6 930 4 741	10.00% E US\$/year 23899 159794 83166 56889	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778	Vears VS\$s US\$s of Total 9.09% 60.8% 31.6% 21.6%	Fleet Reserve Exact Number Rounded numt 6.2 FLEET SU US\$ per m3 Number of Mat Number of Opt Machine Hours
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees <u>1.5 Overheads</u> 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence	PE US\$/hr U 16.69 111.59 58.08 39.73 13.79	R MACHIN 1992 13 316 6 930 4 741 1 645	10.00% E US\$year 23899 159794 83166 56889 19740	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778 39 480	Vears US\$s US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5%	Fleet Reserve Exact Number Rounded numi 6.2 FLEET SU US\$ per m3 Number of Mat Number of Opt Machine Hours Capital Employ
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence Permit & Toll fees	PE US\$/hr U 16.69 111.59 58.08 39.73 13.79 0.0	ER MACHIN IS\$/month 1 992 13 316 6 930 4 741 1 645	10.00% E US\$/year 23 899 159 794 83 166 56 839 19 740 9 19 740 0	10.48 19 740 23899 FLEET US\$/year 47 798 319 589 166 331 113 778 39 480 0	VS\$s US\$s US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5% 0.0%	Fleet Reserve Exact Number Rounded numi 6.2 FLEET SU US\$ per m3 Number of Ope Machine Hours Capital Employ Residual Value
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence Permit & Toll fees VARIABLE COSTS	US\$/hr U 16.69 111.59 58.08 39.73 13.79 0.0 55.31	ER MACHIN IS\$/month 1992 13.316 6.930 4.741 1.645 6.600	10.00% E US\$/year 23899 155 794 83166 56 869 19 740 0 79 196	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778 39 480 0 0	Vears VS\$s US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5% 0.0% 30.1%	Fleet Reserve Exact Number Rounded number 6.2 FLEET SU US\$ per m3 Number of Mar Number of Oper Machine Hours Capital Employ Residual Value Total Revenue
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hyp's Crew Licence Permit & Toll fees VARIABLE COSTS Fuel	PE US\$/hr 16.69 111.59 111.59 58.08 39.73 13.79 0.0 55.31 24.34	ER MACHIN (\$\$/month 1 992 13 316 6 930 4 741 1 645 6 600 2 904	10.00% E US\$/year 23 899 159 794 83 166 56 889 19 740 0 0 79 195 34 849	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778 39 480 0 0 0 158 393 69 697	Vears VS\$s US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5% 0.0% 30.1% 13.3%	Fleet Reserve Exact Number Rounded numt 6.2 FLEET SU US\$ per m3 Number of Mat Number of Ope Machine Hours Capital Employ Residual Value Total Revenue
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence Permit & Toll fees VARIABLE COSTS Fuel Lubrication	PE US\$/hr U 16.69 111.59 58.08 39.73 13.79 0.0 55.31 24.34 3.65	ER MACHIN 1992 13 316 6 930 4 741 1 645 6 600 2 904 4 36	10.00% E US\$year 23 899 159 794 83 166 56 889 19 740 0 79 196 34 849 5 227	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778 39 480 0 158 393 69 697 10 455	US\$s US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5% 0.0% 30.1% 13.3% 2.0%	Fleet Reserve Exact Number Rounded numi 6.2 FLEET SU US\$ per m3 Number of Mac Number of Ope Machine Hours Capital Employ Residual Value Total Revenue
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence Permit & Toll fees VARIABLE COSTS Fuel Lubrication Tyres	PE US\$/hr U 16.69 111.59 58.08 39.73 13.79 0.0 55.31 24.34 3.65 0.00	ER MACHIN IS\$/month 1 992 13 316 6 930 4 741 1 645 6 600 2 904 4 366 0 0	10.00% E US\$year 23899 155794 83166 56889 19740 0 79195 34849 0 79195 3227 0 2005	10.48 19 740 23899 FLEET US\$/year 47 798 319 589 166 331 113 778 39 480 0 158 393 69 697 10 455 0	Vears Vsss US\$s of Total 9.09% 60.8% 31.6% 21.6% 7.5% 0.0% 30.1% 13.3% 2.0% 0.0%	Fleet Reserve Exact Number Rounded numb 6.2 FLEET SU US\$ per m3 Number of Mat Number of Ope Machine Hours Capital Employ Residual Value Total Revenue
Machine Life Years Machine Life Years 1.4 OVERHEADS Annual Licence Fees 1.5 Overheads 6.1 SUMMARY OVERHEADS FIXED COSTS Hp's Crew Licence Permit & Toll fees VARIABLE COSTS Fuel Lubrication Tyres Maintenance Peloration	US\$/hr U 16.69 111.59 58.08 39.73 13.79 0.0 55.31 24.34 3.65 0.00 23.69 2.89	ER MACHIN [\$\$/month 1 992 13 316 6 530 4 741 1 645 6 600 2 904 4 36 0 2 827 4 33	10.00% E US\$/year 23 899 155 746 58 859 19 740 0 79 195 34 849 5 227 0 33 921 5 200	10.48 19 740 23899 FLEET US\$year 47 798 319 589 166 331 113 778 39 480 0 158 393 69 697 10 455 0 67 841 10 48	Vears VS\$s US\$s of Total 9.09% 60.8% 21.6% 7.5% 21.6% 30.1% 13.3% 2.0% 0.0% 12.9%	Fleet Reserve Exact Number Rounded numb 6.2 FLEET SU US\$ per m3 Number of Mar Number of Ope Machine Hours Capital Employ Residual Value Total Revenue

Fuel Consumption     20.8     L/Hr     Driver Wage       Fuel Cost     1.17     US\$L     No.Drivers/Shift       Oil,% Fuel Cost     15%     Labour Wage     US\$L       Oil Cost     US\$L     No.Labourers/Shift     Contributions       Tyres/Tracks/Rigging     US\$L     Operating Days/Week       Control 0     0     0       rear     0     0       rear     0     0       other     0     0       other     0     0       other     0     0       Fuel,Cost     24.34     US\$/mhr       Fuel,Cost     24.34     US\$/mhr       Annual Fuel Costs     3.65     US\$/mhr       Annual Fuel Costs     3.484     US\$       Annual Tyre/Track/Rigging Cost     0.0     US\$       Annual Tyre/Track/Rigging Cost     0.US\$     Annual Bonus       Annual Tyre/Track/Rigging Cost     0.US\$     Annual Bonus       Annual Tyre/Track/Rigging Cost     0.US\$     Annual Crew Cost       Maintenance Cost     23.69     US\$       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4,#	.80 US\$/houi 1.1 # .00 US\$/houi 0.0 # .00 days .00 days .00 days .00 drs .00 drs .00 Hrs .00 Hrs .00 Hrs .00 Hrs .00 US\$/day US\$/say .05 S
Fuel Cost     1.17     US\$L     No.Drivers/Shift       Oil, % Fuel Cost     15%     US\$L     No.Labourers/Shift       Oil Cost     US\$L     No.Labourers/Shift       Tyres/Tracks/Rigging     Contributions     Operating Days/Week       front     0     0     0       rear     0     0     0       tracks Eco     0     0     0       other     0     0     0       other     0     0     0       foot     0     0     0       tracks Eco     0     0     Total Overtime per week       other     0     0     0       other     0     0     0       olil, Cost     24.34     US\$/mhr     Shift or Other Allowance       Oil, Cost     34849     US\$s     Annual Time and a Half       Annual Lube Cost     5 227     US\$s     Annual Bonus       Annual Lube Cost     5 227     US\$s     Annual Shift or Other Allowance       Total Crew Cost     5 227     US\$s     Annual Shift or Other Allowance       Zu VEHICLE MAINTENANCE COSTS     US\$/mhr     Annual Shift or Other Allowance       Maintenance Cost     33921     US\$     Total Crew Cost per Machine Hr       2.3 RELOCATION COSTS     Numbe	1.1 # 00 US\$/houi 00% 0% 0% 0% 0% 0% 0% 0% 0% 0
Oil,% Fuel Cost     15%     Labour Wage       Oil Cost     VSS/L     No.LabourerShift     No.LabourerShift       Tyres/Tracks/Rigging     Qty     Cost     Life     Operating Days/Week       front     0     0     0     Operating Hours/Week       for     0     0     0     Total Overtime per week       other     0     0     0     Total Overtime per week       Oil, Cost     24.34     USS/mhr     Shift or Other Allowance       Oil, Cost     3.65     USS/mhr     Annual Time and a Half       Annual Fuel Costs     34 849     USS     Annual Bonus       Annual Fuel Costs     34 849     USS     Annual Bonus       Annual Tyre/Track/Rigging Cost     0     USS     Annual Bonus       Annual Tyre/Tracks/Rigging Cost     0     USS     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     0     USS     Annual Bonus       Maintenance Cost     33 921     USS     Annual Shift or Other Allowance       2.3 RELOCATION COSTS     33 921     USS <t< td=""><td>000 US\$/houi 000 # 6.0 days 6.0 days 6.0 Hrs 6.0 Hrs 6.0 Hrs 6.0 Hrs 8.0 Hrs 8.0 Hrs 8.0 Hrs 8.0 US\$/day 744 US\$s 205 US\$s 400 US\$s</td></t<>	000 US\$/houi 000 # 6.0 days 6.0 days 6.0 Hrs 6.0 Hrs 6.0 Hrs 6.0 Hrs 8.0 Hrs 8.0 Hrs 8.0 Hrs 8.0 US\$/day 744 US\$s 205 US\$s 400 US\$s
Oil Cost     US\$/L     No.Labourers/Shift       Tyres/Tracks/Rigging     Operating Days/Week       font     0     0       rear     0     0       other     0     0       other     0     0       other     0     0       Fuel,Cost     24.34     US\$/mhr       Shift or Other Allowance     Annual Fuel Costs     3.65       Oil, Cost     3.65     US\$/mhr       Annual Fuel Costs     34 849     US\$       Annual Lube Cost     5 227     US\$s       Annual Tyre/Track/Rigging Cost     0     US\$/mhr       Annual Tyre/Track/Rigging Cost     0     US\$/mhr       Annual Tyre/Track/Rigging Cost     0     US\$/mhr       Annual Tyre/Track/Rigging Cost     0     US\$       Annual Tyre/Track/Rigging Cost     0     US\$       Annual Tyre/Track/Rigging Cost     0     US\$       Annual Maintenance Cost     33 921     US\$       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4/#	0.0 # 6.0 days 6.0 Hrs 0.0 Hrs 0.0 Hrs 6.0 Hrs 3.0 Hrs 3.0 Hrs 3.0 Hrs 0.0 US\$/day 744 US\$s 205 US\$s
Tyres/Tracks/Rigging     City     Cost     Life     Operating Days/Week       front     0     0     0     Operating Days/Week       rear     0     0     0     Basic Hours/Week/driver       tracks Eco     0     0     0     Total Overtime per week       other     0     0     0     Total Overtime per week       other     0     0     0     Double Time per Week       Dil, Cost     24.34     US\$/mhr     Annual Normal Time       Tyres/Tracks/Rigging Cost     0.00     US\$/mhr     Annual Normal Time       Annual Lube Cost     5 227     US\$     Annual Borus       Annual Lube Cost     5 227     US\$     Annual Shift or Other Allowance       Z2 VEHICLE MAINTERNANCE COSTS     0     US\$/mhr     Annual Shift or Other Allowance       Maintenance Cost     23.85     US\$/mhr     Total Annual Crew Cost       Annual Maintenance Cost     33.921     US\$     Total Crew Cost per Machine Hr       2.3 RELOCATION COSTS     Number of moves per annum     4     4     Lead Distance	0% 6.0 days 6.0 Hrs 6.0 Hrs 3.0 Hrs 3.0 Hrs 3.0 US\$/day 744 US\$s 205 US\$s 400 US\$s
Qty         Cost         Life         Operating Days/Week           front         0         0         0         Operating Days/Week         Days/Week         Days/Week         Days/Week         Days/Week         Days/Week <td>6.0         days           6.0         Hrs           6.0         Hrs           6.0         Hrs           3.0         Hrs           3.0         Hrs           0.00         US\$/day           744         US\$s           205         US\$s           440         US\$s</td>	6.0         days           6.0         Hrs           6.0         Hrs           6.0         Hrs           3.0         Hrs           3.0         Hrs           0.00         US\$/day           744         US\$s           205         US\$s           440         US\$s
front         0 <td>6.0 Hrs 0.0 Hrs 6.0 Hrs 3.0 Hrs 3.0 Hrs 00 US\$/day US\$/day US\$s US\$s US\$s US\$s US\$s</td>	6.0 Hrs 0.0 Hrs 6.0 Hrs 3.0 Hrs 3.0 Hrs 00 US\$/day US\$/day US\$s US\$s US\$s US\$s US\$s
rear     0     0     0       tracks Eco     0     0     0       other     0     0     0       other     0     0     0       fuel,Cost     24.34     US\$/mhr       Fuel,Cost     24.34     US\$/mhr       Oil, Cost     3.65     US\$/mhr       Annual Fuel Costs     3.65     US\$/mhr       Annual Fuel Costs     3.65     US\$/mhr       Annual Lube Costs     34 849     US\$       Annual Tyre/Track/Rigging Cost     0.00     US\$/mhr       Annual Stref/Track/Rigging Cost     0.00     US\$/mhr       Annual Stref/Track/Rigging Cost     0.00     US\$/mhr       Annual Maintenance Cost     32.89     US\$/mhr       Annual Maintenance Cost     33 921     US\$/mhr       Annual Maintenance Costs     33 921     US\$/mhr       Annual Maintenance Costs     33 921     US\$/mhr       Annual Maintenance Costs     33 921     US\$       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4/#	0.0 Hrs 6.0 Hrs 3.0 Hrs 3.0 Hrs 0.00 US\$/day 744 US\$s 205 US\$s 940 US\$s
tracks Eco     0     0     0       other     0     0     0       other     0     0     0       other     0     0     0       fuel,Cost     24.34     US\$/mhr       Oil, Cost     3.85     US\$/mhr       Tyres/Tracks/Rigging Cost     0.00     US\$/mhr       Annual Fuel Costs     34 849     US\$       Annual Lube Cost     5 227     US\$       Annual Lube Cost     5 227     US\$       Annual Shift or Other Allowance     0       Journal Lube Cost     5 227     US\$       Annual Shift or Other Allowance     0     US\$       Maintenance Cost     0     00%       Maintenance Cost     390%     US\$/mhr       Annual Maintenance Cost     32921     US\$       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4,#     Ead Distance	6.0 Hrs 3.0 Hrs 3.0 Hrs .00 US\$/day 744 US\$s 205 US\$s 340 US\$s
other     0     0     0       other     0     0     0       other     0     0     0       Fuel, Cost     24.34     US\$/mhr       Oil, Cost     3.65     US\$/mhr       Jyres/Track/Rigging Cost     0.00     US\$/mhr       Annual Fuel Costs     34 849     US\$       Annual Lube Cost     5 227     US\$       Annual Lube Cost     5 227     US\$       Maintenance Cost     0     00%       Maintenance Cost     390%     Time and a Haif       Annual Shift or Other Allowance     Total Crew Cost     55       Z3 RELOCATION COSTS     32821     US\$       Number of moves per annum     4     4	3.0 Hrs 3.0 Hrs .00 US\$/day 744 US\$s 205 US\$s 440 US\$s
other     0     0       Fuel, Cost     24.34     USS/mhr       Oil, Cost     3.65     USS/mhr       Annual Fuel Costs     0.00     USS/mhr       Annual Fuel Costs     34 849     USSs       Annual Fuel Costs     34 849     USSs       Annual Fuel Costs     5 227     USSs       Annual Tyre/Track/Rigging Cost     0     USSs       Annual Tyre/Track/Rigging Cost     0     USSs       Annual Tyre/Track/Rigging Cost     0     USSs       Annual Maintenance Cost     33 921     USSs       Annual Maintenance Cost     33 921     USSs       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4.4     Lead Distance	3.0         Hrs           .00         US\$/day           744         US\$s           205         US\$s           340         US\$s
Fuel, Cost     24.34     US\$/mhr     Shift or Other Allowance       Oil, Cost     3.65     US\$/mhr     Annual Normal Time     51       Tyres/Tracks/Rigging Cost     0.00     US\$/mhr     Annual Time and a Haif     41       Annual Lube Costs     34 849     US\$     Annual Double Time     22       Annual Tyre/Track/Rigging Cost     0     US\$     Annual Double Time     23       Annual Tyre/Track/Rigging Cost     0     US\$     Annual Bonus     Annual Bonus       Annual Tyre/Track/Rigging Cost     0     US\$     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     0     US\$     Annual Crew Cost     56       Mainténance Cost     23.69     US\$     Annual Crew Cost     56       2.3 RELOCATION COSTS     33 921     US\$     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4     #     Lead Distance	.00 US\$/day 744 US\$s 205 US\$s 340 US\$s
Oil, Cost     3.65     US\$/mhr     Annual Normal Time     51       Tyres/Tracks//Rigging Cost     0.00     US\$/mhr     Annual Time and a Half     Annual Time and a Half       Annual Fuel Costs     34 849     US\$     Annual Duble Time     Annual Shift of Other Allowance       Annual Tyre/Track//Rigging Cost     0     US\$     Annual Shift of Other Allowance     Annual Shift of Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     0     US\$     Annual Shift of Other Allowance     56       Maint,% Cap.Cost/machine life (mhr/s)     90%     US\$/mhr     Annual Crew Cost     56       Annual Maintenance Cost     23.69     US\$/mhr     Annual Crew Cost per Machine Hr     3       2.3 RELOCATION COSTS     32     4.1 WORK STUDY ANALYSIS     Lead Distance     4	744 US\$s 205 US\$s 940 US\$s
Tyres/Tracks/Rigging Cost     0.00     US\$/mhr     Annual Time and a Half     2       Annual Fuel Costs     34 849     US\$s     Annual Double Time     2       Annual Lube Cost     5 227     US\$s     Annual Double Time     2       Annual Lube Cost     5 227     US\$s     Annual Shift or Other Allowance       Annual Tyre/Track/Rigging Cost     0     US\$s     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     Total Annual Crew Cost     56       Maintenance Cost     23.659     US\$/mhr     Total Crew Cost per Machine Hr       Annual Maintenance Cost     33.921     US\$s     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4,#     Lead Distance     1	205 US\$s 940 US\$s
Annual Fuel Costs     34 849     US\$s     Annual Double Time     2       Annual Lube Cost     5 227     US\$s     Annual Bonus     Annual Bonus       Annual Tyre/Track/Rigging Cost     0     US\$s     Annual Romus     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     0     US\$s     Annual Crew Cost     566       Maint, & Cap. Cost/machine life (mhr/s)     90%     Total Crew Cost per Machine Hr     3       Maintenance Cost     23.69     US\$/mhr     3 921     US\$s       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS     Lead Distance	040 US\$s
Annual Lube Cost     5 227     US\$s     Annual Bonus       Annual Tyre/Track/Rigging Cost     0     US\$s     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     Total Annual Shift or Other Allowance     Total Annual Crew Cost     56       Maint,% Cap.Cost/machine life (mhr/s)     90%     Total Crew Cost per Machine Hr     3       Maintenance Cost     23.69     US\$/mhr     33 921     US\$s       2.3 RELOCATION COSTS     4.1 WORK STUDY ANALYSIS     Mance     4#	
Annual Tyre/Track/Rigging Cost     0     US\$s     Annual Shift or Other Allowance       2.2 VEHICLE MAINTENANCE COSTS     Total Annual Crew Cost     Total Annual Crew Cost     56       Maint,% Cap.Cost/machine life (mhr/s)     90%     23.69     US\$/mhr     Total Crew Cost per Machine Hr     3       Annual Maintenance Cost     23.69     US\$/mhr     Annual Shift or Other Allowance     56       Annual Maintenance Cost     23.82     US\$/mhr     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4.4     Lead Distance     56	0 US\$s
2.2 VEHICLE MAINTENANCE COSTS     Total Annual Crew Cost     56       Maint,% Cap.Cost/machine life (mhr/s)     90%     23.69     US\$/mhr       Annual Maintenance Cost     23.69     US\$/mhr       2.3 RELOCATION COSTS     91     US\$       Number of moves per annum     4, #     Lead Distance	0 USSS
Maint,% Cap.Cost/machine life (mhr/s)     90%     Total Crew Cost per Machine Hr     3       Maintenance Cost     23.69     US\$/mhr     3       Annual Maintenance Cost     33 921     US\$/s     4.1 WORK STUDY ANALYSIS       Number of moves per annum     4.#     Lead Distance	11555
Maintenance Cost         23.69         US\$/mhr           Annual Maintenance Cost         33.921         US\$s           2.3 RELOCATION COSTS         4.1 WORK STUDY ANALYSIS           Number of moves per annum         4.#	73 1/5\$/mbr
Annual Maintenance Cost 33 921 US\$s 2.3 RELOCATION COSTS Number of moves per annum 4 # Lead Distance	o o o o o o o o o o o o o o o o o o o
2.3 RELOCATION COSTS 4.1 WORK STUDY ANALYSIS Unwher of moves per annum 4 # Lead Distance	
Number of moves per annum 4 # Lead Distance	
Inditiber of moves per annum + +	km
Cost per Mayo	m2
Appual Releastion Cost	limbe
Palacetian Cost and Mashim Hours	KIIVII
Relocation Cost per Machine Hour 3.03 US3/minr Load	min
Annual Values	KIIVIII
Annual Volume 90 500 m3 Off Load	min
Houny volume Required 53.20 ms/mnr Travel time empty #Div	min
Number Of Machines Required 2.00 # Travel time loaded #Div	min
Fleet Reserve	.00 min
Exact Number of Machines Required 2.00 # Off Load	.00 min
Rounded number of vehicles Required 2 # cycle time #DIV	01 min
cycle time #DIV	bl hrs
Machine Output per Hour	1.6 m3/mhr
	and the second second
Machine Output per Day	151 m3/day
Machine Output per Hour	1.6 m3

3.1 LABOUR COSTS



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTE	D ARE ESTIMA	CFDD (Pr Delimb & MSc McEwan ATES, SITE :	ecision Hus Debark SPECIFIC & AS	ky 2300-4) SSUME FULLY	TRAINED	OPERATORS							
1.1 CAPITAL EMPLOYED					-	2.1 VEHICLE OPERAT	TING COSTS			_	3.1 LABOUR COSTS		-
Machine Price Exc VAT			- F	734 324	5	Fuel Consumption		E	57.9	L/Hr	Driver Wage	9.80	\$/hr
Lass Cost of Turge/Tracks/Rig	naina			104 014	e	Eugl Cost			1 17	\$0	No Drivers (Shift	1.1	
Dive additional equipment	India			0		Oil & Evel Cent			4.50	S/L	No. Drivers/Shint	0.00	
Plus additional equipment	radio			0	3	Oil, % Puer Cost			13%		Labour wage	0.00	Synr
	combican			0	3	Oil Cost		L		3/L	No.Labourers/Shift	0.0	#
	other			0	\$	Tyres/Tracks/Rigging					Contributions	0.0%	100
	other			0	\$		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	\$	Chains	312	8	40		Operating Hours/Week	96.0	days
Sub total additional equipmen	it			0	5	Other	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				734 324	5	Drum	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				154 688	\$	Tyres	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation	_					other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		[	20,00%	146 865	s	Fuel Cost		- T	67.74	s/mhr	Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%		Oil Cost			10.46	\$/mhr	Annual Normal Time	51 744	s
Doumont period				0.00%	months	Turne (TracketDianing (	Sect		50.10	Clocks	Assuel Time and a Hold	01144	
Payment period				60	months	Tyres/Tracks/reigging C	JUSE		02.40	simm	Annual Time and a Mair	225	
Monthly payment				12 891	3	Annual Fuel Costs			208 757	3	Annual Double Time	300	3
						Annual Lube Cost	1000		31 314	\$	Annual Bonus	4 312	5
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigg	ging Cost		192 292	\$	Annual Shift or Other Allowance	0	\$
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS	_			Total Annual Crew Cost	56 581	\$
Weekend Days				52		Maint,% Cap.Cost/mac	thine life (mhr's)		100%		Total Crew Cost per Machine Hr	18.36	\$/mhr
Statutory Leave Days				13		Maintenance Cost			48.95	\$/mhr	A second s		
Sick Leave Days				0		Annual Maintenance Co	ost		150 860	\$			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION CO	STS			-	4.1 WORK STUDY ANALYSIS	_	-
Total Annual Production Days	and an ender			300	Davs	Number of moves per a	munne		4		Average Tree Volume		m3
Shift langth				8	Hours	Cost per Move		-	1 300		Number of trace/grab		#
Number of Shifts per day				2	4	Annual Palacation Cor			E 200		other		
Number of Shints per day				100.00		Palaastias Cost ass Ma	ables Maur		0 200	e la ba	dataset datast atta t and		-
Machine Availability				100.0%		Relocation Cost per Ma	schine Hour		1.09	symnr	debranch, debark, chip, Load		min
Machine Utilisation				64.2%		5.1 Machine Requirem	nents	-			other		min
Machine hours per Day				10.3	Hours	Annual Volume			90 500	m3	other		min
Machine hours per Annum				3 082	Hours	Hourly Volume Require	id		29.37	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines F	Required		1.00	8	other		min
Machine Life Years				4.87	Years	Fleet Reserve			0%		other		min
						Exact Number of Mach	ines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of vel	hicles Required		1	#	cycle time	0.00	min
								-			cycle time	0.00	brs
Annual Licence Fees & insuran	00			14 686	\$						Machine Output per Hour	20.4	m2/mbr
				14 000							Machine Output per Day	202	m3/dm
1.5 Overheads		1	10.00%	81438	*						Machine Output per Day	00 500	m24mm
A 1 SUMMARY	_		10.0070	01400	4	6.2 FLEET SUMMARY					Internine Output per Annum	20.020	maryou
	PI	ER MACHIN	E	FLEET	%	1							
	She	\$/month	Stear	Sivear	of Total	\$ per m3	1100	9.90	Inc. Profe	14.9			
OVERHEADS	26.42	6 700	81 430	84 422	0.000	Number of Mashing	1000	0.00	ine. From	11.0			
ENTER COSTS	20.43	40.000	01400	01438	3.03%	Number of Machines	10						
TIAED GUSTS	73.32	18 830	225 955	225 955	25.2%	Number of Operators		2					
нр	50.20	12 891	154 688	154 688	17.3%	the second second	_	and and					
Crew	18.36	4 715	56 581	56 581	6.3%	Machine Hours	100	3 082					
Licence	4.77	1 224	14 686	14 686	1.6%	Capital Employed	1	734 324					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		146 865					
VARIABLE COSTS	190.95	49 035	588 422	588 422	65.7%	Total Revenue		895 815			1		
Fuel	67.74	17 396	208 757	208 757	23.3%								
Lubrication	10.16	2 609	31 314	31 314	3.5%								
Tyres	62.40	16 024	192 292	192 292	21.5%								
Maintenance	48.95	12 572	150 860	150 860	16.8%								
Relocation	1.69	433	5 200	5 200	0.6%								
TOTAL COST / REVENUE	290.70	74 651	895 815	895 815	100.0%								



MACHINE DESCRIPTION	:	Chipper (Presicion Husky 2366-KBL)
OPERATION	:	Chip
STUDY FOR	:	MSc
PREPARED BY	:	McEwan
NOTE: ALL FIGURES QUOTED AN	RE EST	IMATES, SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS

1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	ING COSTS			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				589 848	\$	Fuel Consumption			46.9 L/Hr	Driver Wage	9.80 \$	Mr
Less Cost of Tyres/Tracks/Riggi	ing			0	\$	Fuel Cost			1.17 \$/L	No.Drivers/Shift	1.1 #	*
Plus additional equipment	radio			0	\$	Oil,% Fuel Cost			15%	Labour Wage	0.00 \$	Mr .
	combican			0	\$	Oil Cost			\$12	No.Labourers/Shift	0.0 #	ŧ
	other			0	\$	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	\$		Qty	Cost	Life	Operating Days/Week	6.0 d	lays
	other			0	\$	Other	0	0	0	Operating Hours/Week	96.0 d	lays
Sub total additional equipment				0	\$	Disc Knives	12	24	50	Basic Hours/week/driver	90.0 H	Irs
Total Capital Employed				589 848	\$	Drum	0	0	0	Total Overtime per week	6.0 H	trs
Annual HP payment			-	124 253	\$	Tyres	0	0	0	Time and a Half per week	3.0 H	irs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0 H	irs
Residual Value @			20.00%	117 970	\$	Fuel,Cost			54.87 \$/mhr	Shift or Other Allowance	0.00 \$	/day
Interest per annum				8.00%		Oil, Cost			8.23 \$/mhr	Annual Normal Time	51 744 \$	
Payment period				60	months	Tyres/Tracks/Rigging C	ost		5.86 \$/mhr	Annual Time and a Half	225 \$	p
Monthly payment				10 354	\$	Annual Fuel Costs			169 097 \$	Annual Double Time	300 \$	5
					-	Annual Lube Cost			25 364 \$	Annual Bonus	4 312 \$	5
1.3 OPERATING HOURS						Annual Tyre/Track/Rigg	ing Cost		18 046 \$	Annual Shift or Other Allowance	0 \$	
Total Days				365		2.2 VEHICLE MAINTEN	NANCE COSTS	6		Total Annual Crew Cost	56 581 \$	5
Weekend Days				52		Maint,% Cap.Cost/mach	hine life (mhr's)		100%	Total Crew Cost per Machine Hr	18.36 \$	/mhr
Statutory Leave Days				13		Maintenance Cost			39.32 \$/mhr			
Sick Leave Days				0		Annual Maintenance Co	ost		121 178 \$	and the second sec		
Productive Days Lost to Weather/	Mill Stops			0		2.3 RELOCATION COS	TS			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per a	nnum		4 #	Average Tree Volume	m	n3
Shift length				8	Hours	Cost per Move			1 300 \$	Number of trees/grab	#	6 n
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 \$	other		
Machine Availability				100.0%		Relocation Cost per Ma	chine Hour		1.69 \$/mhr	debranch, debark, chip, Load	m	nin
Machine Utilisation				64.2%		5.1 Machine Requirem	ents			other	m	nin
Machine hours per Day				10.3	Hours	Annual Volume			90 500 m3	other	m	nin
Machine hours per Annum				3 082	Hours	Hourly Volume Required	d		29.37 m3/mhr	other	m	nin
Machine Life Hours				15 000	Hours	Number Of Machines R	equired		1.00 #	other	m	nin
Machine Life Years				4.87	Years	Fleet Reserve			0%	other 1	m	nin
						Exact Number of Machin	nes Required		1.00 #	other	m	nin
1.4 OVERHEADS						Rounded number of veh	nicles Required		1 #	cycle time	0.00 m	nin
										cycle time	0.00 h	rs
Annual Licence Fees & insurance				11 797	\$					Machine Output per Hour	29.4 m	n3/mhr
										Machine Output per Day	302 m	n3/day
1.5 Overheads			10.00%	53152	\$	Section and the				Machine Output per Annum	90 599 m	n3/year
6.1 SUMMARY	_	_				6.2 FLEET SUMMARY						
	P	ER MACHIN	IE .	FLEET	%			-				
· · · · · · · · · · · · · · · · · · ·	\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3	1.00	6.46	Inc. Profit 7.43			
OVERHEADS	17.25	4 429	53 152	53 152	9.09%	Number of Machines		1				
FIXED COSTS	62.51	16 053	192 631	192 631	32.9%	Number of Operators		2				
Нр	40.32	10 354	124 253	124 253	21.3%			_		1		
Crew	18.36	4715	56 581	56 581	9.7%	Machine Hours		3 082				
Licence	3.83	983	11 797	11 797	2.0%	Capital Employed		589 848				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		117 970				
VARIABLE COSTS	109.97	28 240	338 885	338 885	58.0%	Total Revenue		584 668				
Fuel	54.87	14 091	169 097	169 097	28.9%	1.000						
Lubrication	8.23	2 114	25 364	25 364	4.3%							
Tyres	5.86	1 504	18 046	18 046	3.1%							
Maintenance	39.32	10 098	121 178	121 178	20.7%							
TOTAL COST / REVENUE	189.73	48722	584 668	584 668	100.0%							



CFDD&C System – Tree volume 0.15m<sup>3</sup>



SYSTEM DESCRIPTION	:	CFDD&C
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

FORESTRY

Locality	Stand	Extraction	Roadside	Forest Road	Millyard	Cost	Annual System	Equip #	# of	Staff #	Working days /
Activity		route	Landing			(R/m3)	Production		SNITTS		annum
Wheeled Feller Buncher (Tigercat 720E)				-		\$1.99	137 500	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$3.85	137 500	2	2	4	300
CFDD (Precision Husky 2300-4)						\$6.57	137 500	1	2	2	300
Chipper (Presicion Husky 2366-KBL)						\$4.29	137 500	1	2	2	300
				Total		R 16.70		5		11	
				TOTAL		R 0.00		0	- 1 C	0	
				TOTAL		R 16.70		5		11	



OPERATION	: 1	Wheeled Felling an	feller Bund d bunching	cher (Tigerca 9	t 720E)							1	
STUDY FOR	: 1	MSc										4	
PREPARED BY	: 1	McEwan										C CC	ORESTRY
NOTE: ALL FIGURES QUOTE	D ARE ESTIMA	TES, SITE	SPECIFIC &	ASSUME FULL	Y TRAINED	OPERATORS							
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	ING COSTS	-			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	gging			0	US\$s	Fuel Cost			1.17	US\$AL	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	combican			0	US\$s	Oil Cost				US\$AL	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qtv	Cost	Life		Operating Days/Week	6.0	davs
	other			0	USSS	Tyres	0	0	0		Operating Hours/Week	96.0	davs
Sub total additional equipment	t			0	USSS	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	USSS	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	USSS	Other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						Other	0	0	0	1.00	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	63 143	USSS	Fuel Cost		1	17.78	USS/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil. Cost			2.67	US\$/mhr	Annual Normal Time	51 744	USSS
Payment period				60	months	Tyres/Tracks/Rigging C	ost		3.72	11SS/mhr	Annual Time and a Half	225	11580
Monthly navment				5 542	11580	Annual Fuel Costs	1031		43 441	11550	Annual Double Time	200	11980
International payment				0.044	0000	Annual Lube Cost			6 516	11580	Annual Double Time	300	11000
1 2 OPERATING HOURS					-	Annual Tyre/Track/Rigg	ing Cost		0.097	11000	Annual Shift or Other Allowance		11000
Total Dave			1	385		2 2 VEHICLE MAINTE	NANCE COSTS	2	3 007	0333	Annual Contributions		11580
Weekeed Dave				50		Maint % Can Cost/mac	hine life (mhre)	٦ آ	100%		Total Annual Craw Cost	62 260	11000
Statutage Lague Dave				42		Maint, % Cap.Costinac	une me (mm s)		24.05	1100 mbr	Total Crow Cost nos Mashina Hr	02 209	LICEmpe
Statutory Leave Days				13		Maintenance Cost			21.05	USSMAR	Total Crew Cost per Machine Hr	21.40	US\$/mnr
Sick Leave Days				0		Annual Maintenance Co	ost		51 414	0535			
Productive Days Lost to weath	ier/Mill Stops			0	-	2.3 RELOCATION COS	515				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per a	innum		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost	1		5 200	US\$s	bunch		min
Machine Availability				100.0%		Relocation Cost per Ma	ichine Hour		2.13	US\$/mhr	place		min
Machine Utilisation				50.9%		5.1 Machine Requirem	nents				move		min
Machine hours per Day				8.1	Hours	Annual Volume			137 500	<i>m</i> 3	other		min
Machine hours per Annum				2 443	Hours	Hourly Volume Require	d		56.29	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines R	equired		1.00	#	other		min
Machine Life Years				6.14	Years	Fleet Reserve			0%	1	other		min
						Exact Number of Machi	ines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of vel	hicles Required		1	#	cycle time	0.00	min
						10.000					cycle time	0.000	hrs
Annual Licence Fees & insuran	nce			14 207	US\$s						Machine Output per Hour	56.3	m3/mhr
											Machine Output per Day	458	m3/day
1.5 Overheads			10.00%	24864	US\$s						Machine Output per Annum	137 525	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY					1.0.0.0		
	PE	ER MACHI	VE	FLEET	%								
	US\$/hr U	IS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1.00	1.99	Inc. Profit	2.29	4		- 1
OVERHEADS	10.18	2 072	24 864	24 864	9.09%	Number of Machines	1 B	1					
FIXED COSTS	54.44	11 082	132 983	132 983	48.6%	Number of Operators		2					
Нр	27.23	5 542	66 507	66 507	24.3%	A start and a start							
Crew	21.40	4 356	52 269	52 269	19.1%	Machine Hours	1000	2 443					
Licence	5.82	1 184	14 207	14 207	5.2%	Capital Employed		315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	5 - H -	63 143					1
VARIABLE COSTS	47.35	9 638	115 658	115 658	42.3%	Total Revenue	1	273 505					
Fuel	17,78	3 620	43 441	43 441	15.9%								
Lubrication	2.67	543	6 516	6 516	2.4%								
Tyres Maintenance	3.72	1 284	9 087	9 087	3.3%								
Relocation	213	4204	5 200	5 200	1.9%								
TOTAL COST / REVENUE	111.97	22 792	273 505	273 505	100.0%								_



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: ARE ESTIM	Grapple S Tree lengt MSc McEwan ATES, SITE S	kidder (Tig h extraction	ercat 630D) n ASSUME FULLY	TRAINED	OPERATORS						(	AND A DECEMBER
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERA	TING COSTS				3.1 LABOUR COSTS		
Machine Price, Exc. VAT				394 798	US\$s	Fuel Consumption		1	20.8	LAHr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rigg	ging			B	US\$s	Fuel Cost			1.17	USSA	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
100 million 2012 201	other			0	US\$s	Oil Cost				US\$A	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
the state of the second second	other			0	US\$s	front	0	0	0		Operating Hours/Week	96,0	Hrs
Sub total additional equipment				0	US\$s	rear	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0		Total Overtime per week	6,0	Hrs
Annual Hp's		_		83 166	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation		1	00.000	70.000	lune	other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		L	20.00%	78 960	0535	Fuel, Cost			24.34	USSIMA	Shift or Other Allowance	0.00	US\$/day
Deument period				0.00%	months	Turos/Trooks/Pigging	Cost		0.00	USSIM	Annual Normal Time	01/44	0535
Monthly navment				6 930	11580	Annual Fuel Costs	COSt		35 755	11580	Annual Double Time	2 205	11580
Internally payment				0.000	10000	Annual Lube Cost			5 363	11550	Annual Bonus	1 340	11580
1.3 OPERATING HOURS						Annual Tyre/Track/Rid	aina Cost		0	USSS	Annual Shift or Other Allowance	0	11555
Total Days			T	365		2.2 VEHICLE MAINT	ENANCE COSTS				Total Annual Crew Cost	56 889	USSS
Weekend Days				52		Maint,% Cap.Cost/ma	chine life (mhr's)	- F	90%		Total Crew Cost per Machine Hr	38.72	US\$/mhr
Statutory Leave Days				13		Maintenance Cost	and a state of the		23,69	US\$/mhr			
Sick Leave Days				0		Annual Maintenance	Cost		34 802	US\$s	and the second sec		· · · · · · · · ·
Productive Days Lost to Weather	r/Mill Stops			0		2.3 RELOCATION CO	OSTS		to de		4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	annum	1	4	#	Lead Distance	-	km
Shift length				8	Hours	Cost per Move			1 300	US\$s	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Co	st		5 200	US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per N	lachine Hour		3.54	US\$/mhr	Load		min
Machine Utilisation				30.6%		5.1 Machine Require	ments				travel loaded		km/hr
Machine hours per Day				4.9	Hours	Annual Volume			137 500	m3	Off Load	_	min
Machine hours per Annum			-	1 469	Hours	Hourly Volume Requir	ed		93.59	m3/mhr	Travel time empty	#DIV/01	min
Machine Life Hours			_	15 000	Hours	Number Of Machines	Required		2.00	#	Travel time loaded	#DIV/01	min
Machine Life Years			-	10.21	Years	Fleet Reserve	No. Burney		0%	2	Load	0.00	min
1 4 OVERHEADS						Exact Number of Mac	nines Required		2.00	#	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of v	enicies Required		4	*	cycle time	#DIV/01	min
Annual Licence Fees				10 740	lucer						Machine Output per Hour	HUIVIUI	m2/mbc
Annual Licence rees			-	13 140	10000						Machine Output per Plou	220	m3/day
1.5 Overheads		1	10.00%	24091	USSS	1.					Machine Output per Day	68 759	m3/vear
6.1 SUMMARY						6.2 FLEET SUMMAR	Y				indenne odpar per saman		indi your
	P	ER MACHIN	E	FLEET	%	1							
1 C	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		3.85	Inc. Profit	4.43			
OVERHEADS	16.40	2 008	24 091	48 183	9.09%	Number of Machines		2					
FIXED COSTS	108.76	13 316	159 794	319 589	60.3%	Number of Operators	1	4					
Hp's	56.61	6 930	83 166	166 331	31.4%								
Crew	38.72	4 741	56 889	113 778	21.5%	Machine Hours		2 938					
Licence	13.44	1 645	19 740	39 480	7.4%	Capital Employed		789 596					
Permit & Toll fees	0.0	-	0	D	0.0%	Residual Value		157 919					
VARIABLE COSTS	55.21	6 760	81 120	162 240	30.6%	Total Revenue		530 012					
Fuel	24.34	2 980	35 755	71 509	13.5%								
Lubrication	3.65	447	5 363	10 726	2.0%								
Maintenance	23.69	2 900	34 802	69 605	13 1%								
Relocation	3.54	433	5 200	10 400	2.0%								
TOTAL COST / REVENUE	180.37	22 084	265 006	530 012	100.0%					_			



MACHINE DESCRIPTION	1 1	CFDD (Pr	ecision Hus	ky 2300-4)									
OPERATION	:	Delimb &	Debark										
STUDY FOR	1	MSc											
PREPARED BY		McEwan											
NOTE: ALL FIGURES QUOTE	D ARE ESTIM	TES,SITE	SPECIFIC & A	SSUME FULLY	TRAINED	OPERATORS							
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	ING COSTS				3.1 LABOUR COSTS		
Machine Price, Exc. VAT				734 324	\$	Fuel Consumption			57.9	L/Hr	Driver Wage	9.80	s/hr
Less Cost of Tyres/Tracks/Rig	ging			0	\$	Fuel Cost			1.17	S/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio	_		0	5	Oil,% Fuel Cost			15%		Labour Wage	0.00	\$/hr
The second second second	combican			0	5	Oil Cost				S/L	No.Labourers/Shift	0.0	#
	other			0	5	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	\$		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	\$	Chains	312	8	40		Operating Hours/Week	96.0	days
Sub total additional equipment	t			0	\$	Other	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				734 324	\$	Drum	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				154 588	\$	Tyres	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	146 865	\$	Fuel,Cost			67.74	\$/mhr	Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%		Oil, Cost			10.16	\$/mhr	Annual Normal Time	51 744	\$
Payment period				60	months	Tyres/Tracks/Rigging C	Cost		62.40	s/mhr	Annual Time and a Half	225	5
Monthly payment				12 891	\$	Annual Fuel Costs			211 358	5	Annual Double Time	300	\$
						Annual Lube Cost			31 704	3	Annual Bonus	4 312	5
1.3 OPERATING HOURS						Annual Tyre/Track/Rigg	ing Cost		194 688	5	Annual Shift or Other Allowance	0	5
Total Days				365		2.2 VEHICLE MAINTEN	NANCE COSTS	5			Total Annual Crew Cost	56 581	5
Weekend Days				52		Maint,% Cap.Cost/mac	hine life (mhr's)	)	100%		Total Crew Cost per Machine Hr	18.13	\$/mhr
Statutory Leave Days				13		Maintenance Cost			48.95	\$/mhr	a second s		
Sick Leave Days				0		Annual Maintenance Co	ost		152 739	\$			
Productive Days Lost to Weath	er/Mill Stops			0	1.000	2.3 RELOCATION COS	STS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per a	mum		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	\$	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cost	t	1	5 200	5	other	_	
Machine Availability				100.0%	1	Relocation Cost per Ma	chine Hour		1.67	\$/mhr	debranch, debark, chip, Load		min
Machine Utilisation				65.0%		5.1 Machine Requirem	nents				other		min
Machine hours per Day				10.4	Hours	Annual Volume			137 500	m3	other		min
Machine hours per Annum			1	3 120	Hours	Hourly Volume Require	d		44.07	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines R	tequired		1.00	#	other		min
Machine Life Years				4,81	Years	Fleet Reserve			0%		other 1		min
						Exact Number of Machi	ines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of veh	hicles Required		1	#	cycle time	0.00	min
			-		e						cycle time	0.00	hrs
Annual Licence Fees & insuran	ce			14 686	5						Machine Output per Hour	44.2	m3/mhr
											Machine Output per Day	460	m3/day
1.5 Overheads 6.1 SUMMARY		-	10.00%	82164	\$	6 2 ELEET SUMMARY					Machine Output per Annum	137 904	m3/year
U.I SUMMARY	Р	ER MACHI	NE	FLEET	%	D.2 FLEET SOMMARY							
	\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3		6.57	Inc. Profit	7.5	5		
OVERHEADS	26.33	6 847	82 164	82 164	9.09%	Number of Machines		1		-			
FIXED COSTS	72.42	18 830	225 955	225 955	25.0%	Number of Operators		2					
Нр	49.58	12 891	154 688	154 688	17.1%	A CONTRACTOR							
Crew	18:13	4 715	56 581	56 581	6.3%	Machine Hours		3 120					
Licence	4.71	1 224	14 685	14 686	1.6%	Capital Employed		734 324					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		146 865					
VARIABLE COSTS	190.93	49 641	595 689	595 689	65.9%	Total Revenue		903 809					
Fuel	67.74	17 613	211 358	211 358	23.4%								
Lubrication	10.16	2 642	31 704	31 704	3.5%								
Maintenance	48.95	16 224	194 688	194 688	21.5%								
Relocation	1.87	433	5 200	5 200	0.6%								
TOTAL COST / REVENUE	289.68	75 317	903 809	903 809	100.0%							_	



MACHINE DESCRIPTION		Chipper (	Presicion H	usky 2366-K	BL)							
OPERATION	:	Chip									4	1
STUDY FOR	:	MSc									1	-
PREPARED BY	:	McEwan										SOLUTIONS
NOTE: ALL FIGURES QUOTEL	DARE ESTIM	ATES,SITE	SPECIFIC & A	SSUME FULLY	TRAINEL	OPERATORS					10	
1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERAT	TING COSTS			3.1 LABOUR COSTS	-	
Machine Price Exc.VAT				589 848	s	Fuel Consumption		[	46.9 LAHr	Driver Wage	9.80	s/hr
Less Cost of Tyres/Tracks/Rig	ining			0	s	Fuel Cost			1 17 84	No Drivers/Shift	11	#
Plus additional equipment	radio			0	\$	Oil % Fuel Cost			15%	Labour Wage	0.00	Shr
r as additional equipment	combican			0	s	Oil Cost			570	No Labourare/Shift	0.00	#
	other			0	e	Turge/Tracke/Digging				Contributions	0.0%	
	other				e	ryrear rackartigging	Obi	Cort	Life	Operation Dave Micele	0.076	dava
	other			0	0	Other	Qiy	COSI	Life	Operating Days/week	0.0	days
	Torrier			0	2	Other Diss Kaises	0		50	Operating Hours/week	96.0	days
Sub total additional equipment				500 040	3	Disc Knives	12	24	50	Basic Hours/week/driver	90.0	HIS
Total Capital Employed				589 848	3	Drum	U	0	U	Total Overtime per week	6.0	Hrs
Annual HP payment				124 253	\$	Tyres	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation				AN E V AV		other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	117 970	\$	Fuel,Cost			54.87 \$/mhr	Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%		Oil, Cost			8.23 \$/mhr	Annual Normal Time	51 744	\$
Payment period				60	months	Tyres/Tracks/Rigging C	Cost		5.86 \$/mhr	Annual Time and a Half	225	\$
Monthly payment				10 354	\$	Annual Fuel Costs			171 204 \$	Annual Double Time	300	\$
						Annual Lube Cost			25 681 \$	Annual Bonus	4 312	\$
1.3 OPERATING HOURS					2	Annual Tyre/Track/Rigg	ging Cost	_	18 271 \$	Annual Shift or Other Allowance	0	\$
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS	3		Total Annual Crew Cost	56 581	\$
Weekend Days				52		Maint,% Cap.Cost/mac	hine life (mhr's)		100%	Total Crew Cost per Machine Hr	18.13	\$/mhr
Statutory Leave Days				13		Maintenance Cost			39.32 \$/mhr			
Sick Leave Days				0		Annual Maintenance C	ost		122 688 \$			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COS	STS			4.1 WORK STUDY ANALYSIS	_	
Total Annual Production Days				300	Days	Number of moves per a	annum	ſ	4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300 \$	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cos			5 200 \$	other	_	
Machine Availability				100.0%		Relocation Cost ner Ma	chine Hour		1.67 S/mhr	debranch debark chin Load		min
Machine I Itilisation				65.0%		5 1 Machine Requirem	ante		the print	other		min
Machine hours per Day				10.4	Hours	Annual Volume	icinta	Г	137 500 m2	other		min
Machine hours per Day				3 120	Hours	Houdy Volume Require	d		137 300 m3	other		min
Machine Life Hours			-	15 000	Hours	Number Of Machines B	u .		44.07 113/11/1	other		min
Machine Life Moors				15 000	Hours	Number Of Machines R	required		1.00 #	otrier		min
Machine Life Years				4.81	rears	Fleet Reserve			0%	other 1		min
a state and a state of the stat						Exact Number of Machi	ines Required		1.00 #	other		min
1.4 OVERHEADS						Rounded number of ve	hicles Required		1 #	cycle time	0.00	min
										cycle time	0.00	hrs
Annual Licence Fees & insuran	ce			11 797	\$					Machine Output per Hour	44.2	m3/mhr
		ſ								Machine Output per Day	460	m3/day
6.1 SUMMARY			10.00%	53567	2	6 2 ELEET SUMMARY				Machine Output per Annum	137 904	m3/year
	P	ER MACHIN	NE I	FLEET	%							
	S/hr	\$/month	\$/vear	\$/vear	of Total	\$ per m3		4 29	Inc. Profit 4 93			
OVERHEADS	17 17	4 464	53 567	53 567	9 09%	Number of Machines		4	4.00			
FIXED COSTS	61.74	16 053	192 631	192 624	32 70/	Number of Operatore		2				
Ho	30.82	10 354	124 253	124 252	21 10	runnor or operators	L	4				
Crew	18 12	4746	56 581	56 591	0,000	Machina Hours		2 1 20				
Licence	3 70	000	11 707	11 707	2.0%	Capital Employed		590 840				
Dermit & Toll fear	0.00	903	11/5/	11/3/	2.0%	Desidual Value		147 070				
VARIARI E COSTE	100.05	28 507	242.042	242.040	ED 00%	Total Revenue		590 040				
VARIABLE CUSIS	109.95	28 587	343 043	343 043	58.2%	rotal Revenue		589 242	· · · · · · · · · · · · · · · · · · ·			
ruei	54.87	14 267	1/1 204	171 204	29.1%							
Lubrication	8.23	2 140	25 681	25 681	4.4%							
Maintenance	39.32	10 224	122 688	122 688	20.8%							
Relocation	1.67	433	5 200	5 200	0.9%							
	400.00	40 104	580 242	580 242	100.0%							



CFDD&C System – Tree volume 0.25m<sup>3</sup>



	CFDD&C
:	Stump to Mill
:	MSc
	McEwan



Locality	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)						\$1.57	166 000	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$3.21	166 000	2	2	4	300
CFDD (Precision Husky 2300-4)						\$5.44	166 000	1	2	2	300
Chipper (Presicion Husky 2366-KBL)						\$3.55	166 000	1	2	2	300
				Total		R 13.77 R 0.00		5		11 0	
				TOTAL		R 13.77		5		11	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	: : :	Wheeled Felling an MSc McEwan	Feller Bund Id bunching	cher (Tigerca	t 720E)	OPERATORS						Constant Constant
NOTE: ALL FIGURES QUOTED	AREESTIMA	4/E3,5//E	SPECIFIC &	ASSUME FULL	TIRAINE	DOPERATORS						
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	TING COSTS			1	3.1 LABOUR COSTS	
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80 US\$/hot
Less Cost of Tyres/Tracks/Rigg	ging			6	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1 #
Plus additional equipment	radio		-	0	US\$s	Oil,% Fuel Cost			15%	1.1.1	Labour Wage	0.00 US\$/hot
	combican			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0 #
/	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0 days
the second second second	other			0	US\$s	Tyres	0	0	0		Operating Hours/Week	96.0 days
Sub total additional equipment				0	US\$s	Cutting disk	0	0	0		Basic Hours/week/driver	90.0 Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth	1	9 300	2 500		Total Overtime per week	6.0 Hrs
Annual HP payment		-		66 507	US\$s	Other	0	0	0		Time and a Half per week	3.0 Hrs
1.2 HP Calculation						Other	0	0	0		Double Time per Week	3.0 Hrs
Residual Value @			20.00%	63 143	US\$s	Fuel,Cost			17.78	US\$/mhr	Shift or Other Allowance	0.00 US\$/day
Interest per annum				8.00%		Oil, Cost			2.67	US\$/mhr	Annual Normal Time	51 744 US\$s
Payment period				60	months	Tyres/Tracks/Rigging (	Cost		3.72	US\$/mhr	Annual Time and a Half	225 US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs		- 1	38 795	USSS	Annual Double Time	300 US\$s
1						Annual Lube Cost			5 819	USSS	Annual Bonus	0 US\$s
1.3 OPERATING HOURS					/	Annual Tyre/Track/Rig	aina Cost		8 115	USSS	Annual Shift or Other Allowance	0 1/5\$5
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS				Annual Contributions	0 1/555
Weekend Days				52		Maint % Can Cost/mac	hine life (mhr's)	. I	100%	1	Total Annual Crew Cost	52 269 11555
Statutory Leave Days				13		Maintenance Cost	antie nie (nin s)		21.05	11SS/mhr	Total Craw Cost per Machine Hr	23 06 //SS/mh
Sick Leave Days				0		Annual Maintenance C	ost		45 915	11580	Total Crew Cost per Machine Th	23.80 03.0/11
Productive Days	Mill Stone					2 3 RELOCATION CO	STS		40.010	0045	A 1 WORK STUDY ANALYSIS	
Total Annual Production Days	in otopa			300	Dave	Number of moves per	annum	ſ	4		Average Tree Volume	m2
Chift leasth				300	Hours	Cost per Moves per a	annum		4 200	11000	Average free volume	mis
Number of Chiffe per day					#	Annual Releastion Con			F 200	11000	hungh	min
Machine Availability				100.0%		Relocation Cost per Ma	n achina Haur		0 200	10000	place	min
Machine Availability				100.0%		Relocation Cost per wa	achine Hour		2.38	USamnr	place	min
Machine Otilisation				40.4%	110.000	5.1 Machine Requiren	nents		100.000		move	min
Machine hours per Day				1.3	Hours	Annual Volume			166 000	ma	other	min
Machine hours per Annum				2 181	Hours	Houriy volume Require	ed .		76.10	m3/mnr	other	min
Machine Life Hours				15 000	Hours	Number Of Machines F	Required	-	1.00	#	other	min
Machine Life Years			1	6.88	Years	Fleet Reserve			0%		other	min
						Exact Number of Mach	ines Required		1.00	#	other	min
1.4 OVERHEADS						Rounded number of ve	nicles Required	L	1	#	cycle time	0.00 min
and the second second second					1						cycle time	0.000 hrs
Annual Licence Fees & insurance	e		L	14 207	JUS\$s						Machine Output per Hour	76.1 m3/mhr
		1			luna						Machine Output per Day	553 m3/day
1.5 Overheads			10.00%	23683	US\$S					_	Machine Output per Annum	166 008 m3/year
6.1 SUMMART						D.Z FLEET SUMMART						
	PI	ER MACHI	NE	FLEET	%							
and the second se	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		1.57	Inc. Profit	1.80		
OVERHEADS	10.86	1 974	23 683	23 683	9.09%	Number of Machines		1				
FIXED COSTS	60.96	11 082	132 983	132 983	51.0%	Number of Operators		2				
Нр	30.49	5 542	66 507	66 507	25.5%			7 5 5 5				
Crew	23.96	4 356	52 269	52 269	20.1%	Machine Hours		2 181				
Licence	6.51	1 184	14 207	14 207	5.5%	Capital Employed		315 717				
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value		63 143				
VARIABLE COSTS	47.60	8 654	103 844	103 844	39.9%	Total Revenue		260 509				
Fuel	17.78	3 233	38 795	38 795	14.9%	2						
Lubrication	2.67	485	5 819	5 819	2.2%	2						
Maintenance	21.05	3 826	45 915	45 915	17.6%							
Relocation	2.38	433	5 200	5 200	2.0%							
TOTAL COST / REVENUE	119.42	21 709	260 509	260 509	100.0%							



MACHINE DESCRIPTION	4 : (	Grapple S	kidder (Tig	ercat 630D)								
OPERATION	: 1	Tree lengt	h extractio	n								4
STUDY FOR	: 1	MSc									-	4
PREPARED BY	: 1	McEwan										SOLUTIONS
NOTE: ALL FIGURES QUOTE	D ARE ESTIMA	TES, SITE	SPECIFIC & A	SSUME FULLY	TRAINED	OPERATORS						
1 1 CAPITAL EMPLOYED						2 1 VEHICI E OPERAT	TING COSTS			3 1 LABOUR COSTS		
Machine Price Exc VAT				394 798	11980	Eucl Consumption	1140 00010	1	20.8 / 14	Driver Wage	9.80	USShour
Lass Cost of Turge/Tracke/Pi	anina			004100	11000	Fuel Cost			1 17 1/584	No Drivers/Shift	1.00	#
Plus additional aquinment	radio			0	11980	Oil % Evel Cost			15%	Labour Wage	0.00	USShour
Plus additional equipment	other			0	11580	Oil Cost			1159/	No Labourare/Shift	0.00	#
	other			0	11000	Turge/Tracks/Pigging			0.04/2	Contributions	0.0%	
	other			0	11000	Tyles/Tracks/Rigging	Otu	Cort	Life	Contributions	0.0%	daur
	other			0	11586	front	Qiy	CUSI	Life	Operating Days/week	0.0	lays
Sub total additional equipment	lottier			0	11000	nom	0	0		Basis Hourstweek/ddiver	90.0	Line
Total Conital Employed			4	204 700	11580	tracks Eas	0	0	0	Total Quadima nacusak	50.0	Line
Annual Hala				034 / 30	11000	ather	0	0		Time and a Holf assurable	0.0	rirs
Annual Hp S				03 100	0335	other	0	0	0	Time and a Hair per week	3.0	HIS
1.2 HP Calculation		1	20.00%	70 060	luces	Fuel Cost	0		24.24 1155 mbs	Chiff of Other Allewager	3.0	IS Han
Residual value @		1	20.00%	2 00%	0335	Oil Cost			24.34 US\$/mm	Annual Normal Time	54 744	USSIDAY
Interest per annum				6.00%	months	Turse Treaks (Bission C	and a		3.65 US\$/mhr	Annual Normal Time	51 /44	USSS
Payment period				60	months	Tyres/Tracks/Rigging C	JOST		0.00 USS/mhr	Annual Time and a Haif	2 205	US\$S
Monthly payment			-	6 930	0535	Annual Fuel Costs			36 329 0535	Annual Double Time	2 940	US\$S
A A OPERATING HOURS						Annual Lube Cost	ine Cost		5 449 0535	Annual Bonus	0	US\$S
1.3 OPERATING HOURS				205		Annual Tyre/Track/Rigg	ging Cost		0 0535	Annual Shift or Other Allowance		USSS
Total Days			-	303		2.2 VEHICLE MAINTE	NANCE CUSIS	1	001/	Total Annual Crew Cost	56 889	US\$S
Weekend Days				52		Maint,% Cap.Cost/mac	nine life (mnrs)		90%	Total Crew Cost per Machine Hr	38.11	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Co	ost		35 362 US\$S			
Productive Days Lost to Weath	er/Mill Stops			0	-	2.3 RELOCATION COS	515	1		4.1 WORK STUDY ANALYSIS	_	1.
Total Annual Production Days			-	300	Days	Number of moves per a	annum		4 #	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300 US\$s	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Cos	t		5 200 US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per Ma	achine Hour		3.48 US\$/mhr	Load		min
Machine Utilisation			-	31.1%		5.1 Machine Requirem	nents			travel loaded		km/hr
Machine hours per Day				5.0	Hours	Annual Volume			166 000 m3	Off Load		min
Machine hours per Annum			-	1 493	Hours	Hourly Volume Require	d		111.20 m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines R	Required		2.00 #	Travel time loaded	#DIV/0!	min
Machine Life Years				10.05	Years	Fleet Reserve			0%	Load	0.00	min
and the second sec						Exact Number of Machi	ines Required		2.00 #	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of vel	hicles Required		2 #	cycle time	#DIV/0!	min
a second and a second					Luis .					cycle time	#DIV/01	hrs
Annual Licence Fees				19 740	US\$s					Machine Output per Hour	55.6	m3/mhr
										Machine Output per Day	277	m3/day
1.5 Overheads			10.00%	24213	US\$s	E 2 EL EET SUMMADY				Machine Output per Annum	83 001	m3/year
0.1 SOMMART	P	ER MACHIN	IF I	FIFFT	9/6	0.2 FLEET SOMMART						
	US\$/hr L	IS\$/month	US\$/vear	US\$/vear	of Total	USS ner m3		3 21	Inc Profit 3.69			
OVERHEADS	16.22	2 018	24 213	48 427	9.09%	Number of Machines		2		-		
FIXED COSTS	107.04	13 316	159 794	319 589	60.0%	Number of Operators		4				
Hp's	55.71	6 930	83 166	166 331	31.2%	Contraction of Operations	-	*				
Crew	38 11	4 741	56 889	113 778	21 4%	Machine Hours		2 986				
Licence	13.22	1645	19 740	39 490	7 404	Capital Employed		789 596				
Permit & Toll fees	0.0	. 045	10/10	00 400	0.0%	Residual Value		157 919				
VARIABLE COSTS	55 16	6 862	82 340	164 690	30 0%	Total Revenue	1000	532 506				
Fuel	24.24	3.027	36 320	72 659	13 6%	i stal nevellue		002 000				
Lubrication	2.65	454	5 440	10,800	2.0%							
Tyres	0.00	0	0	10 099	0.0%							
Maintenance	23.69	2 947	35 362	70 723	13.3%							
Relocation	3.48	433	5 200	10 400	2.0%							
TOTAL COST / REVENUE	178.42	22 196	266 348	532 696	100.0%							



MACHINE DESCRIPTION	:	CFDD (Precision Husky 2300-4)		
OPERATION	:	Delimb & Debark		
STUDY FOR	:	MSc		
PREPARED BY	:	McEwan		
NOTE: ALL FIGURES QUOTED	ARE EST	TIMATES, SITE SPECIFIC & ASSUME FULL	Y TRAIN	IED OPERATORS
1.1 CAPITAL EMPLOYED				2.1 VEHICLE
Machine Price, Exc. VAT		734 32	4 5	Fuel Consump
Less Cost of Tyres/Tracks/Rig	ging		0 5	Fuel Cost
Plus additional equipment	radio		0 5	Oil,% Fuel Co
	combica	n	0 5	Oil Cost
				-

1.1 CAPITAL EMPLOYED					-	2.1 VEHICLE OPERAT	NG COSTS			3.1 LABOUR COSTS	
Machine Price, Exc. VAT				734 324	5	Fuel Consumption	Active Carl	[	57.9 L/Hr	Driver Wage	9.80 \$/hr
Less Cost of Tyres/Tracks/Ric	aina			0	5	Fuel Cost			1.17 5/1	No.Drivers/Shift	1.1 #
Plus additional equipment	radio			0	\$	Oil.% Fuel Cost			15%	Labour Wage	0.00 s/hr
	combican			0	\$	Oil Cost			SIL	No.Labourers/Shift	0.0 #
	other			0	\$	Tyres/Tracks/Rigging				Contributions	0.0%
	other			0	s		Otv	Cost	Life	Operating Days/Week	6.0 days
	other			0	s	Chains	312	8	40	Operating Hours Week	96 0 days
Sub total additional aquinman	(Otribi			0	e	Other	0	0	0	Basic Hours week/driver	90.0 Hrs
Total Capital Employed				724 224		Daim	0	0	0	Total Quetime per week	60 H/c
Total Capital Employed				134 324		Drum	0	0	0	Time and a Malf answerk	2.0 1/15
Annual PP payment			-	104 000	\$	tyres	0	0	0	Deuble Time per Meek	2.0 1/15
1.2 HP Calculation		T.	00.000	110 007		ouner	0		07.74 Simbs	Chie as Other Allevines	0.00 PH/S
Residual Value @		1	20.00%	146 865	3	Fuel,Cost			67.74 s/mnr	Shift or Other Allowance	0.00 s/day
Interest per annum				8.00%		Oil, Cost			10.16 S/mhr	Annual Normal Time	51 744 5
Payment period				60	months	Tyres/Tracks/Rigging C	ost	1	62.40 S/mhr	Annual Time and a Half	225 \$
Monthly payment				12 891	\$	Annual Fuel Costs			211 358 \$	Annual Double Time	300 \$
					_	Annual Lube Cost			31 704 \$	Annual Bonus	4 312 5
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigg	ing Cost		194 688 \$	Annual Shift or Other Allowance	0 5
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COSTS			Total Annual Crew Cost	56 581 \$
Weekend Days				52		Maint,% Cap.Cost/mach	nine life (mhr's)		100%	Total Crew Cost per Machine Hr	18.13 \$/mhr
Statutory Leave Days				13		Maintenance Cost			48.95 \$/mhr		
Sick Leave Days				0		Annual Maintenance Co	st		152 739 \$		
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COS	TS	1.1		4.1 WORK STUDY ANALYSIS	
Total Annual Production Days				300	Days	Number of moves per a	nnum		4 #	Average Tree Volume	m3
Shift length				8	Hours	Cost per Move			1 300 \$	Number of trees/grab	#
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 \$	other	
Machine Availability				100.0%		Relocation Cost per Ma	chine Hour		1.67 S/mhr	debranch, debark, chip, Load	min
Machine I Itilisation				65.0%		5.1 Machine Requirem	ents			other	min
Machine bours per Day				10.4	Hours	Annual Volume	-	Г	166 000 m3	other	min
Machine hours per denum				2 120	Hours	Heijirly Velume Deguires			53.24 m2/mbr	other	min
Machine Life Hours				15 000	Hours	Number Of Machiner P.	anuirod		100 #	other	min
Machine Life Hours				15 000	Veers	Floot Deserve	eduired	- F	1.00 #	other	min
Machine Life Years			1	4.01	rears	Fleet Reserve	Desided		1 00	other	min
						Exact Number of Machin	nes Required		1.00 #	other	min
1.4 OVERHEADS						Rounded number of ven	icles Required	L	1 #	cycle time	0.00 min
										cycle time	0.00 hrs
Annual Licence Fees & Insuran	ce			14 686	\$					Machine Output per Hour	53.3 m3/mhr
1				-	6					Machine Output per Day	554 m3/day
.5 Overheads			10.00%	82164	5			_		Machine Output per Annum	166 296 m3/year
5.1 SUMMARY						6.2 FLEET SUMMARY					
	F	PER MACHIN	VE	FLEET	%		-				
	\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3		5.44	Inc. Profit 6.26		
OVERHEADS	26.33	6 847	82 164	82 164	9.09%	Number of Machines	1	1			
IXED COSTS	72.42	18 830	225 955	225 955	25.0%	Number of Operators		2			
1p	49.58	12 891	154 688	154 588	17.1%			_			
Crew	18.13	4715	56 581	56 581	6.3%	Machine Hours		3 120			
icence	4.71	1 224	14 686	14 686	1.6%	Capital Employed		734 324			
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1.00	146 865			
ARIABLE COSTS	190.93	49 641	595 689	595 689	65.9%	Total Revenue		903 809			
uel	67.74	17 613	211 358	211 358	23.4%	the second se					
ubrication	10 16	2 642	31 704	31 704	3 5%						
fyres	62.40	16 224	194 688	194 688	21.5%						
Aaintenance	48.95	12 728	152 739	152 739	16.9%						
Relocation	1.67	433	5 200	5 200	0.6%						



OPERATION		Chipper (i	Presicion H	usky 2000-N	BL)						
STUDY FOR	1.1	MSc								and a	
PREPARED BY		McEwan								10	ORISTRY
NOTE: ALL EIGURES OUOTED	APEESTIM	ATES SITE		SCHME EIIII		OPERATORS					-
NOTE. ALL FIGURES GOOTED	ARE ESTIM	A123,3112 \	SPECIFIC & A	SSUME FULL	TINAIVEL	OPERATORS					and a start
1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERATING C	OSTS		3.1 LABOUR COSTS		
Machine Price, Exc. VAT				589 848	\$	Fuel Consumption		46.9 L/Hr	Driver Wage	9.80	\$/hr
Less Cost of Tyres/Tracks/Rigg	ing			0	\$	Fuel Cost		1.17 \$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	\$	Oil,% Fuel Cost		15%	Labour Wage	0.00	\$/hr
	combican			0	\$	Oil Cost	1	\$1	No.Labourers/Shift	0.0	#
	other			0	\$	Tyres/Tracks/Rigging			Contributions	0.0%	1
	other			0	\$		ty Cost	Life	Operating Days/Week	6.0	days
	other			0	\$	Other	0 0	0	Operating Hours/Week	96.0	days
Sub total additional equipment				0	\$	Disc Knives	12 24	50	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				589 848	\$	Drum	0 0	0	Total Overtime per week	6.0	Hrs
Annual HP payment				124 253	\$	Tyres	0 0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0 0	0	Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	117 970	\$	Fuel,Cost		54.87 \$/mhr	Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%		Oil, Cost		8.23 \$/mhr	Annual Normal Time	51 744	\$
Payment period				60	months	Tyres/Tracks/Rigging Cost		5.86 \$/mhr	Annual Time and a Half	225	\$
Monthly payment				10 354	\$	Annual Fuel Costs		171 204 \$	Annual Double Time	300	\$
						Annual Lube Cost		25 681 \$	Annual Bonus	4 312	\$
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging Co	st	18 271 \$	Annual Shift or Other Allowance	0	\$
Total Days				365		2.2 VEHICLE MAINTENANCE	COSTS		Total Annual Crew Cost	56 581	\$
Weekend Days				52		Maint,% Cap.Cost/machine life	e (mhr's)	100%	Total Crew Cost per Machine Hr	18.13	\$/mhr
Statutory Leave Days				13		Maintenance Cost		39.32 \$/mhr			
Sick Leave Days				0		Annual Maintenance Cost		122 688 \$			
Productive Days Lost to Weather	/Mill Stops			0		2.3 RELOCATION COSTS			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per annum	1	4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move		1 300 \$	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Cost		5 200 \$	other		
Machine Availability				100.0%		Relocation Cost per Machine H	Hour	1.67 \$/mhr	debranch, debark, chip, Load		min
Machine Utilisation				65.0%		5.1 Machine Requirements			other		min
Machine hours per Day				10.4	Hours	Annual Volume		166 000 m3	other	_	min
Machine hours per Annum				3 120	Hours	Hourly Volume Required		53.21 m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Required	d	1.00 #	other		min
Machine Life Years				4.81	Years	Fleet Reserve		0%	other 1		min
					, our o	Exact Number of Machines Re	auired	1.00 #	other	-	min
14 OVERHEADS						Rounded number of vehicles F	Required	1 #	cycle time	0.00	min
in other and the							Lodanoa L		cycle time	0.00	hrs
Annual Licence Fees & insurance				11 797	le				Machine Output per Hour	82.3	m3/mbr
	•		-		14				Machine Output per Plou	554	m3/day
1.5 Overheads			10.00%	53567	\$				Machine Output per Annum	166 296	m3/year
6.1 SUMMARY	_	_				6.2 FLEET SUMMARY					
	P	ER MACHIN	E	FLEET	%						
	\$/hr	\$/month	\$/year	\$/year	of Total	s per m3	3.55	Inc. Profit 4.08			
OVERHEADS	17.17	4 464	53 567	53 567	9.09%	Number of Machines	1				
FIXED COSTS	61.74	16 053	192 631	192 631	32.7%	Number of Operators	2				
Нр	39.82	10 354	124 253	124 253	21.1%	Same acres					
Crew	18.13	4 715	56 581	56 581	9.6%	Machine Hours	3 120				
Licence	3.78	983	11 797	11 797	2.0%	Capital Employed	589 848				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	117 970				
VARIABLE COSTS	109.95	28 587	343 043	343 043	58.2%	Total Revenue	589 242				
Fuel	54.87	14 267	171 204	171 204	29.1%						
Lubrication	8.23	2 140	25 681	25 681	4.4%						
Tyres	5.86	1 523	18 271	18 271	3.1%						
Maintenance			177 688	122 688	211 806						
Relocation	39.32	433	5 200	5 200	0 9%						



CFDD&C System – Tree volume 0.40m<sup>3</sup>



SYSTEM DESCRIPTION	:	CFDD&C
OPERATION		Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

FORESTRY

Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (R/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)						\$1.30	191 000	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$2.72	191 000	2	2	4	300
CFDD (Precision Husky 2300-4)						\$4.73	191 000	1	2	2	300
Chipper (Presicion Husky 2366-KBL)						\$3.09	191 000	1	2	2	300
				Total		R 11.84		5		11	
				TOTAL		R 11.84	3	5	-	11	



MACHINE DESCRIPTION	1	Wheeled F	eller Bunch	ner (Tigerca	t 720E)							
OPERATION	:	Felling and	d bunching								â	
STUDY FOR	:	MSC										CHARLEN .
PREPARED BY		McEwan				denter and the second sec						SOLUTIONS
NOTE: ALL FIGURES QUOTED	ARE ESTIM	ATES, SITE S	SPECIFIC & A	SSUME FULL	Y TRAINEL	OPERATORS						and a state of the
1.1 CAPITAL EMPLOYED	_				5	2.1 VEHICLE OPERATING	COSTS			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				315 717	US\$s	Fuel Consumption		ſ	15.2 L/Hr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost			1.17 US\$A	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%	Labour Wage	0.00	US\$/hou
	combican			0	US\$s	Oil Cost			US\$A	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	USSS		Qtv	Cost	Life	Operating Days/Week	6.0	davs
	other			0	USSS	Tyres	0	0	0	Operating Hours/Week	96.0	davs
Sub total additional equipment				0	USSS	Cutting disk	0	0	0	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	USSS	Cutting teeth	1	9 300	2 500	Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	US\$s	Other	0	0	0	Time and a Half per week	3.0	Hrs
1 2 HP Calculation						Other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	63 143	USSS	Fuel Cost		1	17.78 US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest ner annum		-	2010070	8.00%		Oil Cost			2.67 USS/mbr	Annual Normal Time	51 744	11585
Payment period				60	months	Tyres/Tracks/Ringing Cost			3.72 1/SS/mbr	Annual Time and a Half	225	USSE
Monthly navment				5.542	11555	Annual Fuel Costs			34 633 1/580	Annual Double Time	300	11555
Internal balanceur			-	0 042	10000	Annual Lube Cost			5 195 1195	Annual Boous	000	USSE
1 2 OPERATING HOURS						Annual Ture/Track/Pigging (	Cost		7 244 11580	Annual Shift or Other Allowance		11000
Total Dava				265		2 2 VEHICLE MAINTENAN	CECOSTS	_	1 244 0333	Annual Contributions		11080
Total Days				505		Maint & Can Contimaching	UE COSIS		1009/	Total Appual Craw Cost	50.000	00335
Weekend Days			51	52		Maint, % Cap.Costmachine	me (mm s)		100%	Total Annual Crew Cost	02 209	0535
Statutory Leave Days				13		Accurate Maintenance Cost			21.05 033/11/1	Total Crew Cost per Machine Hr	20.04	USSMIN
Sick Leave Days				0		Annual Maintenance Cost			40 999 0232	A HIGDI CTUDY ANALYON		
Productive Days Lost to weather	er/Mill Stops			200	0	2.3 RELOCATION COSTS			14	4.1 WORK STUDT ANALTSIS	-	1
Total Annual Production Days				300	Days	Number of moves per annur	m		4 #	Average Tree Volume		ms
Shift length				8	Hours	Cost per Move			1 300 US\$5	tell		min
Number of Shifts per day				2	#	Annual Relocation Cost	a deside		5 200 0535	bunch		min
Machine Availability				100.0%		Relocation Cost per Machine	e Hour	-	2.67 US\$/mhr	place		min
Machine Utilisation				40.6%	1.000	5.1 Machine Requirements				move		min
Machine hours per Day				6.5	Hours	Annual Volume			191 000 m3	other		min
Machine hours per Annum				1 947	Hours	Hourly Volume Required	1.1		98.08 m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Requir	red	-	1.00 #	other		min
Machine Life Years				7.70	Years	Fleet Reserve			0%	other		min
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1						Exact Number of Machines F	Required		1.00 #	other	_	min
1.4 OVERHEADS						Rounded number of vehicles	s Required		1 #	cycle time	0.00	min
Section of the section of the					1					cycle time	0.000	hrs
Annual Licence Fees & insurance	ce		L	14 207	US\$s					Machine Output per Hour	98.1	m3/mhr
										Machine Output per Day	637	m3/day
1.5 Overheads			10.00%	22624	US\$s					Machine Output per Annum	191 041	m3/year
6.1 SUMMARY	_	Sector and		1417		6.2 FLEET SUMMARY						
	P	ER MACHIN	E	FLEET	%	and the second	-		-			
- Linder	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1.3	1.30	Inc. Profit 1.50			
OVERHEADS	11.62	1 885	22 624	22 624	9.09%	Number of Machines		1				
FIXED COSTS	68.29	11 082	132 983	132 983	53.4%	Number of Operators		2				
Нр	34,15	5 542	66 507	66 507	26.7%	Constant of the second		-				
Crew	26.84	4 356	52 269	52 269	21.0%	Machine Hours		1 947				
Licence	7.30	1 184	14 207	14 207	5.7%	Capital Employed	31	5 717				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	6	3 143				
VARIABLE COSTS	47.89	7 772	93 261	93 261	37.5%	Total Revenue	24	8 868				
Fuel	17.78	2 886	34 633	34 633	13.9%							
Lubrication	2.67	433	5 195	5 195	2.1%							
Tyres	3.72	604	7 244	7 244	2.9%							
Relocation	21.05	3 4 16	40 989	40 989	16.5%							
TOTAL COST / REVENUE	127 79	20 739	248 868	248 868	100.0%							

Wheeled Feller Buncher (Tigercat 720E)



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	N : (	Grapple S Tree lengt MSc McEwan	kidder (Tige h extraction	ercat 630D) I								A DARBERTRY TOLUTIONS
NOTE: ALL FIGURES QUOTE	ED ARE ESTIMA	ATES, SITE S	SPECIFIC & A	SSUME FULLY	TRAINED	OPERATORS		_				and a second
1.1 CAPITAL EMPLOYED			_			2.1 VEHICLE OPERATIN	IG COSTS			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				394 798	US\$s	Fuel Consumption			20.8 L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Ri	igging			0	US\$s	Fuel Cost			1.17 US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%	Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost		l	US\$AL	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life	Operating Days/Week	6.0	days
Sector Constant of Street of	other			0	US\$s	front	0	0	0	Operating Hours/Week	96.0	Hrs
Sub total additional equipment	nt			0	US\$s	rear	0	0	0	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				394 798	US\$s	tracks Eco	0	0	0	Total Overtime per week	6.0	Hrs
Annual Hp's				83 166	US\$s	other	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @		1	20.00%	78 960	US\$s	Fuel,Cost			24.34 US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			3.65 US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cos	st		0.00 US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 930	US\$s	Annual Fuel Costs			33 585 US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost			5 038 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Riggin	g Cost	L	0 US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENA	NCE COSTS			Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/machin	ne life (mhr's)		90%	Total Crew Cost per Machine Hr	41.22	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			23.69 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost			32 691 US\$s			
Productive Days Lost to Weath	her/Mill Stops			0		2.3 RELOCATION COST	S			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per ann	num		4 #	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300 US\$s	Volume per Load		<i>m</i> 3
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per Mach	ine Hour		3.77 US\$/mhr	Load		min
Machine Utilisation				28.8%		5.1 Machine Requirement	nts	2		travel loaded		km/hr
Machine hours per Day				4.6	Hours	Annual Volume			191 000 m3	Off Load		min
Machine hours per Annum				1 380	Hours	Hourly Volume Required			138.40 m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines Rec	uired		2.00 #	Travel time loaded	#DIV/0!	min
Machine Life Years				10.87	Years	Fleet Reserve			0%	Load	0.00	min
						Exact Number of Machine	s Required		2.00 #	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of vehic	les Required		2 #	cycle time	#DIV/01	min
						(				cycle time	#DIV/01	hrs
Annual Licence Fees				19 740	US\$s					Machine Output per Hour	69.2	m3/mhr
										Machine Output per Day	318	m3/day
1.5 Overheads			10.00%	23631	US\$s	N 1 1 1 1 1 1 1				Machine Output per Annum	95 501	m3/year
6.1 SUMMARY	-					6.2 FLEET SUMMARY						
	PI	ER MACHIN	E	FLEET	%		-					
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.72	Inc. Profit 3.13			
OVERHEADS	17.12	1 969	23 631	47 262	9.09%	Number of Machines		2				
FIXED COSTS	115.79	13 316	159 794	319 589	61.5%	Number of Operators		4				
Hp's	60.26	6 930	83 166	166 331	32.0%	and a second						
Crew	41.22	4 741	56 889	113 778	21.9%	Machine Hours		2 760				
Licence	14.30	1 645	19 740	39 480	7.6%	Capital Employed		789 596				
Permit & Toll fees	0.0	100	0	0	0.0%	Residual Value		157 919				
VARIABLE COSTS	55.44	6 376	76 514	153 029	29.4%	Total Revenue		519 879				
Fuel	24.34	2 799	33 585	67 171	12.9%	1.						
Lubrication	3,65	420	5 038	10 076	1.9%							
Tyres	0.00	0	0	0	0.0%							
Maintenance	23.69	2 724	32 691	65 382	12.6%							
TOTAL COST / REVENUE	188.35	433	259 940	519 870	2.0%							
ISTAL COST TREVENUE	100,00	21002	200 040	0100/9	100.078							



STUDY FOR	: 1	ASC ASC	Debark								
PREPARED BY	: 1	AcEwan									
NOTE: ALL FIGURES QUOTED	ARE ESTIMA	TES, SITE S	PECIFIC & AS	SUME FULLY	TRAINED	OPERATORS					
					_						
1.1 CAPITAL EMPLOYED					1 C	2.1 VEHICLE OPERATING	COSTS			3.1 LABOUR COSTS	
Machine Price, Exc. VAT	-			734 324	3	Fuel Consumption		57.9	UHr	Driver Wage	9.80 5/11
Less Cost of Tyres/Tracks/Rigg	Ing			0	3	Fuel Cost		1.1/	3/L	No.Drivers/Shift	1.1 #
Plus additional equipment	radio			0	3	Oil,% Fuel Cost		15%	en	Labour vvage	0.00 5/11
	comoican			0		On Cost			PL.	No. Labourers/Shift	0.0
	other			0		Tyres/Tracks/reigging	Obi Cost	Life		Operating Days Meak	6.0 days
	other			0		Chaine	312 8	40		Operating Hours Meek	OF D days
Sub total additional equipment	Cotton			0	\$	Other	0 0	0		Basic Hours/week/driver	90.0 Hrs
Total Capital Employed				734 324	5	Drum	0 0	0		Total Overtime per week	60 Hrs
Annual HP navment				154 688	\$	Tyres	0 0	0		Time and a Half ner week	3.0 Hrs
1.2 HP Calculation			-	104 000		other	0 0	0		Double Time per Week	30 Hrs
Residual Value @		L	20.00%	146 865	5	Fuel Cost		67.74	\$/mhr	Shift or Other Allowance	0.00 S/day
Interest per annum				8.00%		Oil Cost		10.16	\$/mhr	Annual Normal Time	51 744 \$
Payment period				60	months	Tyres/Tracks/Rigging Cost		62.40	\$/mhr	Annual Time and a Half	225 \$
Monthly payment				12 891	\$	Annual Fuel Costs		211 358	5	Annual Double Time	300 \$
and a second sec			_			Annual Lube Cost		31 704	5	Annual Bonus	4 312 5
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging C	ost	194 688	5	Annual Shift or Other Allowance	0 5
Total Days			11	365		2.2 VEHICLE MAINTENANO	E COSTS			Total Annual Crew Cost	56 581 5
Weekend Days				52		Maint,% Cap.Cost/machine	ife (mhr's)	100%		Total Crew Cost per Machine Hr	18.13 S/mhr
Statutory Leave Days				13		Maintenance Cost 48.95					
Sick Leave Days				0		Annual Maintenance Cost 152 739					
Productive Days Lost to Weather	Mill Stops			0		2.3 RELOCATION COSTS				4.1 WORK STUDY ANALYSIS	
Total Annual Production Days			8	300	Days	Number of moves per annun	1	#	Average Tree Volume	m3	
Shift length				8	Hours	Cost per Move		\$	Number of trees/grab	#	
Number of Shifts per day				2	#	Annual Relocation Cost		\$	other		
Machine Availability				100.0%		Relocation Cost per Machine	Hour	\$/mhr	debranch, debark, chip, Load	min	
Machine Utilisation				65.0%		5.1 Machine Requirements				other	min
Machine hours per Day				10.4	Hours	Annual Volume		191 000	m3	other	min
Machine hours per Annum				3 120	Hours	Hourly Volume Required		61.22	m3/mhr	other	min
Machine Life Hours				15 000	Hours	Number Of Machines Requir	ed	1.00	#	other	min
Machine Life Years				4.81	Years	Fleet Reserve		0%		other 1	min
						Exact Number of Machines F	Required	1.00	ti -	other	min
1.4 OVERHEADS						Rounded number of vehicles	Required	1	ti -	cycle time	0.00 min
			-							cycle time	0.00 hrs
Annual Licence Fees & insurance	2			14 686	\$					Machine Output per Hour	61.3 m3/mhr
		-								Machine Output per Day	638 m3/day
1.5 Overheads			10.00%	82164	\$					Machine Output per Annum	191 256 m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY				The second s	
	PE	ER MACHIN	E	FLEET	%	distant in the second sec			-		
1	\$/hr	\$/month	\$/year	\$/year	of Total	\$ per m3	4.73	Inc. Profit	5,44		
OVERHEADS	26.33	6 847	82 164	82 164	9.09%	Number of Machines	1				
FIXED COSTS	72.42	18 830	225 955	225 955	25.0%	Number of Operators	2				
нр	49.58	12 891	154 688	154 688	17.1%	a succession of					
Crew	18.13	4 715	56 581	56 581	6.3%	Machine Hours	3 120				
Licence	4.71	1 224	14 686	14 686	1.6%	Capital Employed	734 324				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	146 865				
VARIABLE COSTS	190.93	49 641	595 689	595 689	65.9%	Total Revenue	903 809				
Fuel	87.74	17 613	211 358	211 358	23.4%						
Lubrication	10.16	2 642	31 704	31 704	3.5%						
Maintenance	48.95	12 728	152 739	152 739	16.9%						
Relocation	1.67	433	5 200	5 200	0.6%						
TOTAL COST / REVENUE	289.68	75 317	903 809	903 809	100.0%	1.					



MACHINE DESCRIPTION	:	Chipper (Presicion Husky 2366-KBL)
OPERATION	:	Chip
STUDY FOR	:	MSc
PREPARED BY	:	McEwan
NOTE: ALL FIGURES OUDTED A	REEST	IMATES SITE SPECIFIC & ASSUME FULLY TRAINED



PERATORS

			_		_			_				-
1.1 CAPITAL EMPLOYED					1.	2.1 VEHICLE OPERA	TING COSTS			3.1 LABOUR COSTS		7
Machine Price, Exc. VAI	Sec.			589 848	3	Fuel Consumption			46.9 L/Hr	Driver Wage	9.80	s/nr
Less Cost of Tyres/Tracks/Rig	gging			0	5	Fuel Cost			1.17 \$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	\$	Oil,% Fuel Cost			15%	Labour Wage	0.00	\$/hr
	combican			0	\$	Oil Cost		L	\$1	No.Labourers/Shift	0.0	)#
	other			0	\$	Tyres/Tracks/Rigging				Contributions	0.0%	6
	other			0	\$		Qty	Cost	Life	Operating Days/Week	6.0	) days
	other			0	\$	Other	0	0	0	Operating Hours/Week	96.0	) days
Sub total additional equipment	nt			0	\$	Disc Knives	12	24	50	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				589 848	\$	Drum	0	0	0	Total Overtime per week	6.0	Hrs
Annual HP payment				124 253	\$	Tyres	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	117 970	\$	Fuel,Cost			54.87 \$/mh	r Shift or Other Allowance	0.00	\$/day
Interest per annum				8.00%		Oil, Cost			8.23 \$/mh	Annual Normal Time	51 744	4 5
Payment period				60	months	Tyres/Tracks/Rigging	Cost		5.86 S/mh	Annual Time and a Half	225	5 5
Monthly payment			1	10 354	5	Annual Fuel Costs			171 204 5	Annual Double Time	300	s
			-			Annual Lube Cost			25 681 5	Annual Bonus	4 312	2 5
1 3 OPERATING HOURS						Annual Tyre/Track/Rin	aina Cost		18 271 5	Annual Shift or Other Allowance		e e
Total Dave				265	1	2 2 VEHICI E MAINTE	NANCE COST	9	10 211 3	Total Annual Crew Cost	56 594	1
Weekeed Dave				500		Maint % Can Cost/ma	this life (mbre)	, L	100%	Total Crow Cost por Machina Hr	40.41	Cimbr
Statutes Leave Dave				12		Maint, 76 Cap.Costina	chine ine (min s)	' <b> </b>	20.20 6 (mb	rotal crew cost per machine Hr	10,13	Summ
Statutory Leave Days				13		Maintenance Cost			39.32 5/11/1			
SICK Leave Days	A REPORT			0	M La H	Annual Maintenance C	ost		122 088 3			
Productive Days Lost to weath	ner/Mill Stops			0		2.3 RELOCATION CO	515			4.1 WORK STUDY ANALYSIS		1.
Total Annual Production Days			-	300	Days	Number of moves per	annum		4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300 \$	Number of trees/grab		#
Number of Shifts per day				2	#	Annual Relocation Co	st		5 200 \$	other		- C.
Machine Availability				100.0%		Relocation Cost per M	achine Hour		1.67 \$/mh	debranch, debark, chip, Load		min
Machine Utilisation			-	65.0%		5.1 Machine Require	ments			other		min
Machine hours per Day				10.4	Hours	Annual Volume			191 000 m3	other		min
Machine hours per Annum				3 120	Hours	Hourly Volume Requir	ed		61.22 m3/n	nhr other		min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		1.00 #	other		min
Machine Life Years				4.81	Years	Fleet Reserve			0%	other 1		min
						Exact Number of Mach	nines Required		1.00 #	other		min
1.4 OVERHEADS						Rounded number of ve	hicles Required	1	1 #	cycle time	0.00	min
						1				cycle time	0.00	hrs
Annual Licence Fees & insurar	nce			11 797	s					Machine Output per Hour	61.3	m3/mh
										Machine Output per Day	638	m3/day
1.5 Overheads			10.00%	53567	s					Machine Output per Annum	191 256	m3/ver
6.1 SUMMARY					*	6.2 FLEET SUMMAR	(			indenine superportantant		inter jou
	P	ER MACHIN	IE	FLEET	%	1						
	s/hr	\$/month	\$/vear	\$/vear	of Total	S per m3		3.09	Inc. Profit	3.55		
OVERHEADS	17 17	AARA	53 567	53 567	9 09%	Number of Machines		4				
EIXED COSTS	61.74	15 052	102 634	102 634	32 70	Number of Operators	1					
Hn.	20.90	10 354	124 252	104 000	34.170	interimber of Operators		2				
np Gran	39.62	10 354	124 203	124 253	21.1%	Machine House		2 4 0 0				
Crew	18.13	4 /15	56 581	56 581	9.6%	Machine Hours		3 120				
Licence	3.78	983	11 797	11 797	2.0%	Capital Employed		589 848				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		117 970				
VARIABLE COSTS	109.95	28 587	343 043	343 043	58.2%	Total Revenue		589 242				
Fuel	54.87	14 267	171 204	171 204	29.1%							
Lubrication	8.23	2 140	25 681	25 681	4.4%							
Tyres	5.86	1 523	18 271	18 271	3.1%							
Relocation	39,32	423	5 200	5 200	0.0%							
TOTAL COST / REVENUE	188.86	49 104	589 242	589 242	100.0%							



## DHP System – Tree volume 0.075m<sup>3</sup>


SYSTEM DESCRIPTION	:	DHP
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

FORESTRY SOLUTIONS (PTY) LTD

Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)		62				\$3.53	90 500	1	2	2	300
Grapple Skidder (Tigercat 630D)		6				\$3.73	90 500	1	2	2.2	300
DHP (Hitachi ZAxis200 with SP 591)						\$13.16	90 500	3	2	6.6	300
Tracked loader (Tigercat T234 with slasher)						\$3.11	90 500	1	2	2.2	300
				Total		\$23.53 \$0.00		6 0		13.2 0	
				TOTAL		\$23.53		6	-	13.2	



#### MACHINE DESCRIPTION Wheeled Feller Buncher (Tigercat 720E) OPERATION Felling and bunching Euc full trees STUDY FOR MSc NY BOLUTIONS (PTY) LTD PREPARED BY McEwan NOTE: ALL FIGURES QUOTED ARE ESTIMATES, SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS 1.1 CAPITAL EMPLOYED 2.1 VEHICLE OPERATING COSTS 3.1 LABOUR COSTS 315 717 US\$s Machine Price, Exc. VAT 15.2 UH 9.80 USS/hou Driver Wage **Fuel Consumption** 1.1 # 5.68 US\$/hou Less Cost of Tyres/Tracks/Riggin USSS Fuel Cost 1.17 US\$/L No.Drivers/Shift US\$s radio 0 Oil,% Fuel Consumption 15% Labour Wage Plus additional equipment combican 0 US\$s Oil Cost USSA No.Labourers/Shift 1.2 # Tyres/Tracks/Rigging 0 US\$s 0.0% other Contributions other 0 US\$s Operating Days/Week 6.0 days Oh 0 US\$s other Tyres 9 300 2 500 Operating Hours/Week 96.0 days Sub total additional equipment US\$s utting disk 0 Basic Hours/week/driver 90.0 Hrs 0 315 717 Total Capital Employed US\$s Cutting teeth 0 0 0 Total Overtime per week 6.0 Hrs Time and a Half per week Annual HP payment 66 507 US\$s Other 0 3.0 Hrs 1.2 HP Calculation Other Double Time per Week 3.0 Hrs ò ò Residual Value @ 20.00% 63 143 US\$s Fuel,Cost 17.78 JS\$/mh Shift or Other Allowance 0.00 US\$/day Interest per annum 8.00% Oil. Cost 2.67 US\$/mhr Annual Normal Time 84 461 US\$s Tyres/Tracks/Rigging Cost Payment period 60 3.72 US\$/mhr Annual Time and a Half 225 US\$s nonths Monthly payment 5 542 US\$s Annual Fuel Costs 47 079 US\$s Annual Double Time 300 US\$s Annual Lube Cost Annual Bonus 7 062 US\$s US\$s Annual Tyre/Track/Rigging Cost 2.2 VEHICLE MAINTENANCE COSTS 1.3 OPERATING HOURS 9 848 US\$s Annual Shift or Other Allo 0 US\$s 365 0 US\$s Total Days Annual Contributions 100% 21.05 US\$/mhr 84 986 US\$s Weekend Days 52 Maint,% Cap.Cost/machine life (mhr's) Total Annual Crew Cost Maintenance Cost Statutory Leave Days 13 Total Crew Cost per Machi 32.10 US\$/mh Sick Leave Days 0 Annual Maintenance Cos 55 719 US\$s Productive Days Lost to Weather/Mill Stops 2.3 RELOCATION COSTS 4.1 WORK STUDY ANALYSIS 0 Total Annual Production Days 300 Days Number of moves per annum 4 # m3 Average Tree Volume 1 300 US\$s Shift length 8 Hours Cost per Move min ell Number of Shifts per day 2 # Annual Relocation Cost US\$s 5 200 unch min Machine Availability 100.0% Relocation Cost per Machine Hour 1.96 US\$/mhi place min Machine Utilisation 5.1 Machine Requirements min 55.2% nove Machine hours per Day 8.8 Hours Annual Volume 90 500 m3 ther min 34.19 m3/mhr Machine hours per Annum 2 647 Hours fourly Volume Required ther min Machine Life Hours 15 000 Hours Number Of Machines Required 1.00 # other min Machine Life Years 5.67 Years Fleet Reserve 0% ther nin Exact Number of Machines Required other in 1.4 OVERHEADS Rounded number of vehicles Required 0.00 1 : cycle time nin cycle time hrs 14 207 US\$s Annual Licence Fees & insurance Machine Output per Hour m3/mhi Machine Output per Day n3/day 29061 US\$s 10.00% Machine Output per Annum 1.5 Overheads 6.1 SUMMARY 90 537 m3/year 6.2 FLEET SUMMARY PER MACHINE FLEET % US\$ per m3 US\$/hr US\$/month US\$/year US\$/year of Tota 3.53 29 06 29 061 165 700 OVERHEADS 10.98 2 422 9.09 Number of Machines Number of Operators FIXED COSTS 13 808 51.8 62.59 Hp 25.12 5 54 66 50 66 50 20.8 32.10 7 082 84 98 84 986 26.6 achine Hours 2 647 Crew Capital Employed Residual Value Licence 5.3 1 184 14 20 14 200 4.4 315 717 Permit & Toll fees 63 143 VARIABLE COSTS 47.18 10 409 124 908 124 908 **39.1**9 Total Revenue Fuel 3 92 47 07 47 079 2.67 58 82 4 64 7 062 9 848 55 7 19 7 06 9 84 55 71 22 3.1 17.4 Lubrication Tyres Maintenance 433 5 200 100.0 TOTAL COST / REVENUE 120.75 319 66



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: : ARE ESTIMA	Grapple S Tree lengt MSc McEwan TES, SITE SI	kidder (Tige th extraction	rcat 630D) UME FULLY TR	AINED OP	ERATORS				Stepp	ATRY SOLUTIO	NB (PTY) LT
1 1 CAPITAL EMPLOYED						2 1 VEHICI E OPERATI	NG COSTS	-		3 1 LABOUR COSTS		_
Machine Price Eve VAT				381 224	11580	Evel Consumption	10 00010		20.8 ////	Driver Wage	9.80	lissho
Lase Cost of Turse/Tracke/Riss	ina			301 224	11580	Fuel Cost			1 17 1158/	No Drivers/Shift	1.00	#
Less Cost of Tyres/Tracks/Rigg	ling				0000	Oll A Fuel Commention			4EN/ USAL	I obave Wass	0.00	licen
Plus additional equipment	radio			0	1108-	Oil Cost			1370	Labour wage	0.00	033/10
	other			0	0335	Oil Cost		-	USAL	No. Labourers/Shift	0.0	
	other			0	USAS	Tyres/Tracks/Rigging	~		1.10	Contributions	0.0%	4.4
	other			0	US\$s	100	Qty	Cost	Lite	Operating Days/Week	6.0	days
where the start of the second	other			0	US\$s	front	0	0	0	Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	US\$s	rear	0	0	0	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				381 224	US\$s	tracks Eco	0	0	0	Total Overtime per week	6.0	Hrs
Annual Hp's				80 306	US\$s	other	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	76 245	US\$s	Fuel,Cost			24.34 US\$/mhi	Shift or Other Allowance	0.00	US\$/da
Interest per annum				8.00%	1.1	Oil, Cost			3.65 US\$/mh/	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	st		0.00 US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 692	US\$s	Annual Fuel Costs			69 735 US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost			10 460 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riggin	ng Cost		0 US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COSTS			Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's)		90%	Total Crew Cost per Machine Hr	19.85	US\$/mi
Statutory Leave Days				13	100	Maintenance Cost			22.87 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cos	t		65 544 US\$s			
Productive Days Lost to Weather	Mill Stops			0		2.3 RELOCATION COST	TS	_		4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	Contrast and pro-		6	300	Davs	Number of moves per an	num		4 #	Lead Distance		km
Shift leadth				8	Houre	Cost per Move			1 300 11550	Volume per Load		m3
Number of Chiffe per deu				2	4	Appual Balagation Cost			E 200 USSS	travel empty		km/hr
Number of Shins per day				100.0%		Palaastias Cast ass Mas	Alex Dave		1.00 1158/mh	Land		Kiturii
Machine Availability				E0 7%		E 1 Machine Deguiser	nine nour		1.01 0.34/11/1	topic landed		inur for
Machine Ublisation				59.1%	Deven	5.1 Machine Requireme	ints		00 500	travel loaded		Kminr
Machine nours per Day				9.0	Hours	Annual Volume			90 500 m3	Un Load	AND IN CASE OF	min
Machine nours per Annum			-	2 865	Hours	Houriy Volume Required			31.58 m3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours			-	15 000	Hours	Number Of Machines Re	quired	_	1.00 #	Travel time loaded	#DIV/01	min
Machine Life Years				5.23	Years	Fleet Reserve		_	0%	Load	0.00	min
						Exact Number of Machin	es Required		1.00 #	Off Load	0.00	min
1.4 OVERHEADS						Rounded number of vehi	cles Required		1 #	cycle time	#DIV/0!	min
			_			and the second second				cycle time	#DIV/01	hrs
Annual Licence Fees				19 061	US\$s					Machine Output per Hour	31.6	m3/mhi
										Machine Output per Day	302	m3/day
1.5 Overheads			10.00%	30720	US\$s					Machine Output per Annum	90 550	m3/yea
6.1 SUMMARY	_					6.2 FLEET SUMMARY						
	P	ER MACHIN	E	FLEET	%							
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		3.73				
OVERHEADS	10.72	2 560	30 720	30 720	9.09%	Number of Machines		1				
FIXED COSTS	54.53	13 021	156 256	156 256	46.2%	Number of Operators		2				
Hp's	28.03	6 692	80 306	80 306	23.8%	and the second second						
Crew	19.85	4 741	56 889	56 889	16.8%	Machine Hours	1000	2 866				
Licence	6 65	1 588	19.061	19 061	5.6%	Capital Employed		381 224				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		76 245				
VARIABLE COSTS	52 67	12 578	150 939	150 930	44 7%	Total Revenue		337 915				
Filel	24.24	5.811	89 735	60 725	20.8%	The state is a second sec		301 010				
Lubrication	3.05	872	10 460	10 450	3.40							
Tyres	0.00	0/2	10 460	10 460	0.0%							
Maintenance	22.87	5 462	85 544	65 544	19.4%							
Relocation	1.81	433	5 200	5 200	1.5%	1						
TOTAL COST / REVENUE	117.93	28 160	337 915	337 915	100.0%					2		



STRY BOLUTIONS (PTY) LTB

# MACHINE DESCRIPTION : DHP (Hitachi ZAxis200 with SP 591) OPERATION : Debranching and debarking Euc pulp (full trees) STUDY FOR : MSc PREPARED BY : Forestry Solutions NOTE: ALL FIGURES QUOTED ARE ESTIMATES.SITE SPECIFIC & ASSUME FULLY TRAINED OPERATORS 3.1 LABOUR COSTS 1.1 CAPITAL EMPLOYED 2.1 VEHICLE OPERATING COSTS 3.1 LABOUR COSTS

Machine Price, Exc. VAT				428 571	US\$s	Fuel Consumption			19	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rigg	ing			0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Consumpt	ion		20%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s	1.200 201 201 201 201 201 201	Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400	200		Operating Hours/Week	96.0	davs
Sub total additional equipment				0	USSS	Chain	1	145	50	10.00	Basic Hours/week	90.0	Hrs
Total Capital Employed				428 571	US\$s	Tracks	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				90 280	USSS	Head	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation			-			other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		Г	20.00%	85 714	USSs	Fuel Cost		-	22.23	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum		-		8.00%		Oil Cost			4.45	US\$/mhr	Annual Normal Time	51 744	USSE
Payment period				60	months	Tyres/Tracks/Ringing	Cost		4 90	US\$/mhr	Annual Time and a Half	225	11550
Monthly navment				7 523	USSE	Annual Fuel Costs	0001		69 136	115.80	Annual Double Time	300	11550
Interiority payment					0000	Annual Lube Cost			13 827	11580	Annual Boous	000	11580
1 3 OPERATING HOURS					-	Annual Tyre/Track/Riv	naina Cost		15 230	11580	Annual Shift or Other Allowance	0	11550
Total Davs				365		2 2 VEHICLE MAINT	ENANCE COSTS	_	10 200	0043	Total Annual Crew Cost	52 260	115.50
Meekaad Dave				52		Maint % Can Costima	china life (mbr/s)		110%	1	Total Craw Cost per Machina Hr	17	USSahr
Statuten Lenus Dour				12		Maintananao Cost	conne me (man s)		24.42	licelahe	Total Crew Cost per Machine Fit		USAMM
Statutory Leave Days				15		Annual Maintenance Cost			07.744	USQ/IIII	1.7		
Sick Leave Days	ALL CLARK			0		Annual Maintenance C	LOSI	_	9/ /44	0335	A A MODIC OTHINK ANALYOIC		
Tatal Annual Braduation Dava	nin Stops			200	Davis	2.3 RELOCATION CO	313	E		1	4.1 WORK STUDT ANALTSIS		-2
Chile landth				300	Days	Number of moves per	arinum		4 707		Average Tree Volume		ms
Shint length				0	Hours	Cost per move			1 300	0535	Tell		min
Number of Shifts per day				400.00	*	Annual Relocation Co	St		5 200	0535	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per N	lachine Hour		7.67	USSymnr	crosscut		min
Machine Utilisation				54.8%		5.1 Machine Require	ments				place		min
Machine hours per Day				10.4	Hours	Annual Volume			90 500	m3	bunch		min
Machine hours per Annum			-	3 110	Hours	Hourly Volume Requir	ed		29.10	m3/hr	move		min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		3.00	#	other		min
Machine Life Years				4.82	Years	Fleet Reserve	and the second		0%		other		min
						Exact Number of Mac	hines Required		3,00	#	other		min
h tanana ara						Rounded number of v	ehicles Required		3	#	cycle time	0.00	min
1.4 OVERHEADS				1200							cycle time	0.000	hrs
Annual Licence Fees & insurance	Ð		L	17 143	US\$s						Machine Output per Machine Hr	9.7	m3/mhr
Concernance and the second		-					× .				Machine Output per Day	101	m3/day
1.5 Overheads			10.00%	36084	US\$s					_	Machine Output per Annum	30 167	m3/year
6.1 SUMMARY						6.2 FLEET SUMMAR	Y						
	P	ER MACHINI	E	FLEET	%	300 A 100	-						
at and the	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		13.16					
OVERHEADS	11.60	3 007	36 084	108 251	9.09%	Number of Machines		3					- 1
FIXED COSTS	51.35	13 308	159 692	479 075	40.2%	Number of Operators		7					
Нр	29.03	7 523	90 280	270 840	22.7%								
Crew	16.81	4 356	52 269	156 807	13 2%	Machine Hours		9 330					
Licence	5.51	1 429	17 143	51 429	4 3%	Capital Employed	1	285 713					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1	257 143					
VARIABLE COSTS	64.68	16 762	201 146	603 439	50.7%	Total Revenue	1	190 765					
Fuel	22.23	5 761	69 136	207 408	17 4%	1							
Lubrication	4.45	1 152	13 827	41 482	3 596								
Tyres	4.90	1 270	15 239	45 717	3.8%								
Relocation	31.43	6 145	5 200	293 231	1 200								
TOTAL COST / REVENUE	127.63	33 077	396 922	1 190 765	100.0%								-
										_			



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY		Tracked Id Slash MSc McEwan	oader (Tige	rcat T234 wit	h slash	er)				Fore	STRY SOLUTIONS (PTY) LTD
NOTE: ALL FIGURES QUOTED	ARE ESTIMA	TES, SITE S	PECIFIC & AS	SUME FULLY T	RAINED	OPERATORS					
1.1 CAPITAL EMPLOYED					-	2.1 VEHICLE OPERATING COS	TS		-	3.1 LABOUR COSTS	
Machine Price, Exc. VAT				428 571	US\$s	Fuel Consumption		17.	3 L/Hr	Driver Wage	9.80 US\$/hour
Less Cost of Tyres/Tracks/Rigg	aing			0	US\$s	Fuel Cost		1.1	7 US\$/L	No.Drivers/Shift	1.1 #
Plus additional equipment	slasher			0	US\$s	Oil.% Fuel Consumption		15	6	Labour Wage	0.00 US\$/hour
the second states	Truck 2ns h	and		0	USSS	Oil Cost		10	US\$/L	No Labourers/Shift	0.0 #
	trailer	un u		0	11550	Tyree/Tracke/Rigging			10002	Contributions	0.0%
	other			0	11540	Chu Chu		Cost Lit		Operating Dave/Meak	6.0 dave
	other			0	10000	Per		74.4 25		Operating Days Week	06.0 days
Published and divisional and immediate	omer			0	10000	Caraclat				Denis Usurstungkiddings	00.0 Uays
Sub total additional equipment					0535	Sprocket		0		Basic Hours/week/driver	90.0 His
Total Capital Employed				428 571	US\$S	Tracks		0		Total Overtime per week	6.0 Hrs
Annual HP payment				90 280	US\$s	Chain 1		195 7	0	Time and a Half per week	3.0 Hrs
1.2 HP Calculation						other 0		0	D	Double Time per Week	3.0 Hrs
Residual Value @		L	20.00%	85 714	US\$s	Fuel,Cost		20.2	4 US\$/mhr	Shift or Other Allowance	0.00 US\$/day
Interest per annum				8.00%		Oil, Cost		3.0	4 US\$/mhr	Annual Normal Time	51 744 US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		4.8	3 US\$/mhr	Annual Time and a Half	225 US\$s
Monthly payment				7 523	US\$s	Annual Fuel Costs		38 18	7 US\$s	Annual Double Time	300 US\$s
					1.1.1.1	Annual Lube Cost		572	B US\$s	Annual Bonus	0 US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging Cost	_	9 10	4 US\$s	Annual Shift or Other Allowance	0 US\$s
Total Davs				365		2.2 VEHICLE MAINTENANCE C	OSTS			Total Annual Crew Cost	52 269 US\$s
Weekend Days				52		Maint % Cap.Cost/machine life (r	mhr's)	90	6	Total Crew Cost per Machine Hr	27.71 USS/mhr
Statutory Leave Days				13		Maintenance Cost		25.7	USS/mhr	lease the state of the state of the	
Sick Leave Dave				0		Annual Maintenance Cost		48.51	3 1/559		
Broductive Dave Lost to Weather	Mill Stops			0		2 3 RELOCATION COSTS		40.01	0000	A 1 WORK STUDY ANALYSIS	
Tatel Accural Draductice Days	in otops			200	Dave	Number of mouse per appum			1.	Truck Valuma	m2
Chill leasth				0	Hours	Cost per Moue		1 20	11570	ave log volume	min
Shint length				0	Hours	Cost per move		1 30	10000	Clear 2 Land	Toto
Number of Shifts per day				100.00		Annual Relocation Cost		520	UCEMP	Siash & Load	min
Machine Availability				100.0%		Relocation Cost per Machine Hol	ur	2.1	USS/mnr	other	min
Machine Utilisation				39.3%	100	5.1 Machine Requirements		-		other	min
Machine hours per Day				6.3	Hours	Annual Volume		90 50	0 m3	other	min
Machine hours per Annum				1 887	Hours	Hourly Volume Required		47.9	7 m3/mhr	other	min
Machine Life Hours			_	15 000	Hours	Number Of Machines Required		1.0	0 #	other	min
Machine Life Years				7.95	Years	Fleet Reserve		04	6	other	min
						Exact Number of Machines Requ	lired	1.0	D #	other	m3
1.4 OVERHEADS						Rounded number of vehicles Rec	quired		1 #	cycle time	0.00 min
			1	_						cycle time	0.000 hrs
Annual Licence Fees & insurance	e			6 429	US\$s					Machine Output per Hour	48.000 m3/mhr
										Machine Output per Day	302 m3/day
1.5 Overheads			10.00%	25571	US\$s					Machine Output per Annum	90 558 m3/year
6.1 SUMMARY	12					6.2 FLEET SUMMARY				A CONTRACTOR OF THE OWNER OF	
	P	ER MACHIN	E	FLEET	%						
	US\$/hr U	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3		3.11			
OVERHEADS	13.55	2 131	25 571	25 571	9.09%	Number of Machines		1			
FIXED COSTS	78.97	12 415	148 977	148 977	53.0%	Number of Operators		2			
Ho	47.85	7 523	90 280	90,280	32 100						
Crow	27.74	4 350	57 260	52 260	18 604	Machine Hours		887			
Licence	2.44	630	6 400	6 400	2 204	Capital Employed	400	571			
Dermit & Tell fees	3.47	000	0 429	0 429	2.3%	Desidual Value	428	74.4			
remit à Toll fees	0.0	0.00	0	0	0.0%	Transidial Value	65	2004			
VARIABLE COSTS	36.57	8 894	106 732	106 732	37.9%	rotal Kevenue	281	281			
Fuel	20.24	3 182	38 187	38 187	13.6%						
Lubrication	3.04	477	5728	5 728	2.0%	2					
lyres Maintenance	4.83	759	9 104	9 104	3.2%						
mannenance	20.71	4 043	5 200	5 200	1.8%					1	
Relocation	2.781	10.5.51									



### DHP System – Tree volume 0.15m<sup>3</sup>



.

SYSTEM DESCRIPTIC	N	:	DHP								
OPERATION			Stump to Mill						X	T	
STUDY FOR			MSc						1	FORESTRY SOL	UTIONS (PTY) LTD
PREPARED BY		:	McEwan						4	Ann (1	
Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)	-5	6E				\$2.20	142 500	1	2	2	300
Grapple Skidder (Tigercat 630D)						\$2.44	142 500	1	2	2.2	300
DHP (Hitachi ZAxis200 with SP 591)						\$5.58	142 500	2	2	4.4	300
Tracked loader (Tigercat T234 with slasher)						\$1.71	142 500	1	2	2.2	300
				Total		\$11.94		5		11	
						\$0.00		0	-	0	
				TOTAL		\$11.94		5	-	11	-



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	N 1 1	Wheeled Felling an MSc McEwan	Feller Bund Ind bunching	cher (Tigerca g Euc full tre	at 720E) ees						PORES	TRY SOLUTION	45 (PTY) LTD
NOTE: ALL FIGURES QUOTER	D ARE ESTIMA	TES, SITE S	PECIFIC & AS	SSUME FULLY	TRAINED	OPERATORS						-	
1.1 CAPITAL EMPLOYED	-					2.1 VEHICLE OPERA	TING COSTS	-			3.1 LABOUR COSTS		
Machine Price, Exc. VAT			1	315 717	US\$s	Fuel Consumption			15.2	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging				US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Consumpti	on		15%		Labour Wage	5.68	US\$/hour
	combican			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	1.2	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	-
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Tyres	1	9 300	2 500		Operating Hours/Week	96.0	days
Sub total additional equipmen	nt			0	US\$s	Cutting disk	0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	US\$s	Other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						Other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	63 143	US\$s	Fuel,Cost			17.78	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			2.67	US\$/mhr	Annual Normal Time	84 461	US\$s
Payment period				60	months	Tyres/Tracks/Rigging	Cost		3.72	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	US\$s	Annual Fuel Costs			45 015	US\$s	Annual Double Time	300	US\$s
1						Annual Lube Cost			6 752	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS				_		Annual Tyre/Track/Rid	aina Cost		9 416	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS	-			Annual Contributions	0	USSS
Weekend Dave				52		Maint % Can Cost/ma	chine life (mhr's)		100%		Total Annual Crew Cost	84 986	11585
Statutory Leave Days				13		Maintenance Cost	chine hie (min s)		21.05	US\$/mhr	Total Crew Cost per Machine Hr	33 58	US\$/mhr
Sick Leave Days						Annual Maintenance	Cont		53 276	11000	For a bien book per machine rin	00.00	0000
Broductive Days	ar/Mill Stope			0		2 3 PELOCATION CO	SUSE		55 210	0343	A 1 WORK STUDY ANALYSIS	-	_
Total Appual Production Days	ennalin oropa			300	Dave	Number of movies per	20010		4	-	Average Tree Volume		m 2
Chift leasth				000	Hours	Cost por Maus	annum		1 200	USEA	foll		min
Number of Chiffe and day				0	Hours	Cost per move		-	F 200	11080	hungh		min
Number of Shifts per day				400.00	"	Annual Relocation Co	54		5 200	0005	bunch		min
Machine Availability				100.0%	1	Relocation Cost per N	lachine Hour		2.05	USymnr	place		min
Machine Utilisation				52.1%		5.1 Machine Require	ments				move		min
Machine hours per Day				8.4	Hours	Annual Volume			142 500	m3	other		min
Machine hours per Annum			-	2 531	Hours	Houriy Volume Requir	ed		56.30	m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		1.00	#	other		min
Machine Life Years				5.93	Years	Fleet Reserve			0%	0	other		min
and the second second						Exact Number of Mac	hines Required		1.00	#	other		min
1.4 OVERHEADS						Rounded number of v	ehicles Required		1	#	cycle time	0.00	min
in the second second second					-						cycle time	0.000	hrs
Annual Licence Fees & insuran	nce		L	14 207	US\$s	1					Machine Output per Hour	56.3	m3/mhr
10000											Machine Output per Day	475	m3/day
1.5 Overheads			10.00%	28536	US\$s						Machine Output per Annum	142 506	m3/year
6.1 SUMMARY	_					6.2 FLEET SUMMAR	r				-		
	P	ER MACHIN	NE	FLEET	%	1	_	_					
100 miles	US\$/hr U	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.20					
OVERHEADS	11.27	2 378	28 536	28 536	9.09%	Number of Machines		1					
FIXED COSTS	65.46	13 808	165 700	165 700	52.8%	Number of Operators	-	2					
Hp	26.27	5 542	66 507	66 507	21.2%		-	-					
Crew	33.58	7 082	84 986	84 986	27.1%	Machine Hours		2 531					
Licence	5.61	1 184	14 207	14 207	4.5%	Capital Employed		315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		63 143					
VARIABLE COSTS	47.27	9 972	119 659	119 659	38.1%	Total Revenue		313 895					
Fuel	17.78	3 751	45 015	45 015	14.3%								
Lubrication	2.67	563	6 752	6 752	2.2%	5							
Tyres	3.72	785	9 416	9 416	3.0%	à							
Maintenance	21.05	4 440	53 276	53 276	17.0%	5							
Relocation	2.05	433	5 200	5 200	1 7%								
TOTAL COST / REVENUE	124.01	20 138	313 095	313 895	100.0%	2							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	:	Grapple S Tree lengt MSc McEwan	kidder (Tige	ercat 630D) n	4000 00	5047000				Por	STRY SOLUTION	NS (PTY) LTD
NOTE: ALL FIGURES QUOTED.	ARE ESTIMA	ATES,SITE SP	PECIFIC & ASS	SOME FULLY IR	AINED OF	ERATORS					2	
1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERATING C	OSTS			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				381 224	US\$s	Fuel Consumption		20.8	UHr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Riggi	ing			0	US\$s	Fuel Cost		1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Consumption		15%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost	1		US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	1.
	other			0	US\$s		Qty Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	front	0 0	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	US\$s	rear	0 0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				381 224	US\$s	tracks Eco	0 0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				80 306	US\$s	other	0 0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0 0	0		Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	76 245	US\$s	Fuel,Cost		24.34	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		3.65	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 692	US\$s	Annual Fuel Costs		74 176	US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost		11 126	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging Co	st	0	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENANCE	COSTS			Total Annual Crew Cost	56 889	US\$s
Weekend Davs				52		Maint % Cap.Cost/machine life	(mhr's)	90%		Total Crew Cost per Machine Hr	18.66	US\$/mhr
Statutory Leave Days				13	1	Maintenance Cost		22.87	US\$/mhr			
Sick Leave Days				0	1.00	Annual Maintenance Cost		69 718	USSS			
Productive Days Lost to Weather	Mill Stons			0		2.3 RELOCATION COSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Dave	rivina otopa			300	Dave	Number of moves per annum	[	4	#	Lead Distance		km
Chiff length					Hours	Cost per Maye		1 300	11580	Volume per Load		m3
Shint length				2	#	Appual Palacation Cost		5 200	115 80	travel emotiv		km/hr
Number of Shifts per day				100.0%	-	Palacation Cost per Machine I	lour	1.74	US\$/mhr	Load		min
Machine Availability				63 69/		E d Machine Deguizemente	ioui	1.7.1	03\$mm	travel leaded		km/hr
Machine buisation				10.2	Haura	Annual Valuma	I I	142 500	m 2	Offload		min
Machine hours per Day				2 0.49	Hours	House Volume Dequired		49.75	m2/mhr	Travel time empty	#DI1//01	min
Machine hours per Annum			-	15 000	Hours	Number Of Machines Desile		40.75	mornin .	Travel time landed	#DIVIOI	rimi m/m
Machine Life Hours				15 000	Hours	Number Of Machines Required		1.00	#	I ravel time loaded	WDIVIU:	min
Machine Life Years				4.92	rears	Fleet Reserve		0%		Load	0.00	mun
						Exact Number of Machines Re	quirea	1.00	#	Official	0.00	min
1.4 OVERHEADS						Rounded number of vehicles H	equired		#	cycle time	#010/0!	min
			-							cycle time	#DIV/0!	hrs
Annual Licence Fees				19 061	US\$s					Machine Output per Hour	46.6	m3/mhr
Children and State					1.00					Machine Output per Day	475	m3/day
1.5 Overheads			10.00%	31648	US\$s					Machine Output per Annum	142 646	m3/year
6.1 SUMMARY	-					6.2 FLEET SUMMARY						
	1	PER MACHIN	E	FLEET	%							
	US\$/hr	US\$/month	US\$/year	US\$/year	of Total	US\$ per m3	2.44					
OVERHEADS	10.38	2 637	31 648	31 648	9.09%	Number of Machines	1					
FIXED COSTS	51.27	13 021	156 256	156 256	44.9%	Number of Operators	2					
Hp's	26.35	6 692	80 306	80 306	23.19	in the second second				1		
Crew	18.66	4 741	56 889	56 889	16.3%	Machine Hours	3 048			1		
Licence	6.25	1 588	19 061	19 061	5.5%	Capital Employed	381 224					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	76 245					
VARIABLE COSTS	52.57	13 352	160 221	160 221	46.0%	Total Revenue	348 125					
Fuel	24.34	6 181	74 176	74 176	21.3%							
Lubrication	3.65	927	11 126	11 126	3.2%							
Tyres	0.00	6 9 10	60 710	60 740	0.0%							
Relocation	1.71	433	5 200	5 200	1.5%							
	444.24	20 010	348 125	249 125	100 02/							



BOLUTIONS (PTY) LTD

MACHINE DESCRIPTION	:	DH
OPERATION	:	De
STUDY FOR	:	MS
PREPARED BY	:	For
NOTE ALL FIGURES QUOTED A	RE ESTI	MATES

HP (Hitachi ZAxis200 with SP 591) ebranching and debarking Euc pulp (full trees) ISc

Forestry Solutions





MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	: : : : : : : : : : : : : : : : : : :	Tracked I Slash MSc McEwan	oader (Tige	rcat T234 wi	th slashe	pepatops				FORE	ITRY SOLUTIO	KS (PTY) I
NOTE ALL FIGURES QUOTED.	ARE ESTIMA	120,0112 0	FEOIFIC & AC	SUME FULL	TRAINED C	PERATORS					-	
1.1 CAPITAL EMPLOYED			-		1.00	2.1 VEHICLE OPERATING	COSTS	_		3.1 LABOUR COSTS		1
Machine Price, Exc. VAT				325 900	US\$s	Fuel Consumption			17.3 L/Hr	Driver Wage	9.80	US\$/h
Less Cost of Tyres/Tracks/Riggi	ng			0	US\$s	Fuel Cost			1.17 US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	slasher			0	US\$s	Oil,% Fuel Consumption			15%	Labour Wage	0.00	US\$A
	Truck 2ns h	and		0	US\$s	Oil Cost			US\$/L	No.Labourers/Shift	0.0	#
	traller			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life	Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	714	350	Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$s	Sprocket	0	0	0	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				325 900	US\$s	Tracks	0	0	0	Total Overtime per week	6.0	Hrs
Annual HP payment				68 652	US\$s	Chain	1	195	70	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	65 180	US\$s	Fuel,Cost			20.24 US\$/mhr	Shift or Other Allowance	0.00	US\$/d
Interest per annum				8.00%		Oil, Cost			3.04 US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost			4.83 US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 721	US\$s	Annual Fuel Costs			38 477 US\$s	Annual Double Time	300	US\$s
a de la de						Annual Lube Cost			5 772 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging	Cost		9 173 US\$s	Annual Shift or Other Allowance	0	US\$s
Total Davs				.365		2.2 VEHICLE MAINTENAN	CE COSTS			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52	1	Maint,% Cap.Cost/machine	life (mhr's)		90%	Total Crew Cost per Machine Hr	27.50	US\$/n
Statutory Leave Days				13		Maintenance Cost			19.55 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost			37 171 US\$s	1		
Productive Days Lost to Weather	Mill Stops			0		2.3 RELOCATION COSTS	2	-		4.1 WORK STUDY ANALYSIS		_
Total Annual Production Days				300	Davs	Number of moves per annu	m		4 #	Truck Volume		m3
Shift length				8	Hours	Cost per Move			1 300 USSS	ave log volume		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 1/5\$5	Slash & Load	1	min
Machine Availability				100.0%		Relocation Cost per Machin	a Hour		2 74 US\$/mhr	other		min
Machine I Itilization				30 6%		5 1 Machine Requirement			and o'samin	other		min
Machine boure per Day				6.3	Hours	Annual Volume			142 500 m2	other		min
Machine hours per Day				1 901	Hours	Hourly Volume Required		1	74.96 m3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Bagu	inad		1.00 #	athor		min
Machine Life Hours				15 000	Vear	Flast Decenter	ared .		094	other		min
Machine Life Years				1.69	rears	Fleet Reserve	Desident	1000	0%	other		min
A CONCONCADO						Exact Number of Machines	Required		1.00 #	other	0.00	ma
1.4 OVERHEADS						Rounded number of vehicle	is Required	0.000	1 #	cycle time	0.00	min
and the second se					lune					cycle time	0.000	nrs
Annual Licence Fees & insurance	3			4 889	US\$s					Machine Output per Hour	75.000	m3/ml
					Line .					Machine Output per Day	475	m3/da
1.5 Overheads	_		10.00%	22160	US\$s					Machine Output per Annum	142 571	m3/ye
6.1 SUMMARY	-			-		0.2 FLEET SUMMARY						
	P	ER MACHIN	UE III	FLEET	76			4 10 4				
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	USS per m3		1.71				
OVERHEADS	11.66	1 847	22 160	22 160	9.09%	Number of Machines	1000					
FIXED COSTS	66.18	10 484	125 809	125 809	51.6%	Number of Operators	-	2				
Hp	36.11	5721	68 652	68 652	28.2%	a second	-					
Crew	27 50	4 356	52 269	52 269	21.4%	Machine Hours		1 901				
Licence	2.57	407	4 889	4 889	2.0%	Capital Employed	3	25 900				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1	65 180				
VARIABLE COSTS	50.39	7 983	95 793	95 793	39.3%	Total Revenue	2	43 763				
Fuel	20.24	3 206	38 477	38 477	15.8%							
Lubrication	3.04	481	5 772	5772	2.4%							
Tyres	4.83	764	9 173	9173	3.8%							
Relocation	19.55	3 098	5 200	3/1/1	2.104	-						
Nelocation1	2.74	100	0 200	5200	6.170							



## DHP System – Tree volume 0.25m<sup>3</sup>



SYSTEM DESCRIPTION	:	
OPERATION	:	
STUDY FOR	:	
PREPARED BY		
	1.1	

DHP Stump to Mill MSc McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)		6				\$1.46	232 500	1	2	2	300
Grapple Skidder (Tigercat 630D)		1				\$2.53	232 500	2	2	4.4	300
DHP (Hitachi ZAxis200 with SP 591)						\$3.42	232 500	2	2	4.4	300
Tracked loader (Tigercat T234 with slasher)						\$1.18	3 232 500	1	2	2.2	300
				Total		\$8.60		6		13.2	
				TOTAL		\$0.00	<u>)</u>	0	-	0	
				TOTAL		\$8.60	=	6	-	13.2	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTE	N : N : N : N D ARE ESTIMA	Wheeled F Felling an MSc McEwan TES,SITE SI	Feller Bunch d bunching PECIFIC & ASS	ner (Tigerca Euc full tre SUME FULLY 1	t 720E) es	OPERATORS				TORE	ITRY SOLUTION	KS (PTY) LTD
1.1 CAPITAL EMPLOYED				-	-	2.1 VEHICLE OPERATING COSTS		-	-	3.1 LABOUR COSTS	-	-
Machine Price Exc. VAT				315 717	US\$s	Fuel Consumption		15.2 L	Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rid	aina			0	US\$s	Fuel Cost		1.17 0	5.\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil % Fuel Consumption		15%		Labour Wage	5.68	US\$/hour
, internetine equipation	combican			0	USSS	Oil Cost		U	S\$/L	No.Labourers/Shift	1.2	#
	other			0	USSS	Tyres/Tracks/Rigging				Contributions	0.0%	
	other		1.2.2	0	USSS	Otv	Cost	Life		Operating Davs/Week	6.0	davs
	other			0	USSS	Tyres 1	9 300	2 500		Operating Hours/Week	96.0	davs
Sub total additional equipment	nt			0	US\$s	Cutting disk 0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				315 717	US\$s	Cutting teeth 0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				66 507	USSS	Other 0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						Other 0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	63 143	US\$s	Fuel,Cost		17.78 U	s\$/mhr	Shift or Other Allowance	0.00	US\$/dav
Interest per annum				8.00%		Oil, Cost	N	2.67 1	ss/mhr	Annual Normal Time	84 461	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		3.72 1/3	s\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				5 542	USSS	Annual Fuel Costs		54 376 US	SSS	Annual Double Time	300	US\$s
Internally polyment			-			Annual Lube Cost	10	8 156 US	SSS	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging Cost		11 374 US	22.5	Annual Shift or Other Allowance	0	USSS
Total Days				365		2.2 VEHICLE MAINTENANCE COSTS	S			Annual Contributions	0	USSS
Weekend Days				52		Maint % Cap Cost/machine life (mhr/s	0	100%		Total Annual Crew Cost	84 986	US\$s
Statutory Leave Days				13		Maintenance Cost		21.05 US	ss/mhr	Total Crew Cost per Machine Hr	27.79	US\$/mhr
Sick Leave Days				0		Annual Maintenance Cost		64 356 US	222			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	and a second			300	Davs	Number of moves per annum		4 #		Average Tree Volume	1	m3
Shift length				8	Hours	Cost per Move		1 300 U	222	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost		5 200 //	225	bunch		min
Machine Availability				100.0%		Relocation Cost per Machine Hour		1.70 US	s/mhr	place		min
Machine Utilisation				63.7%		5.1 Machine Requirements		1110100		move		min
Machine hours per Day				10.2	Hours	Annual Volume		232 500 m	3	other		min
Machine hours per Annum				3 058	Hours	Hourly Volume Required		76.04 m	3/mhr	other		min
Machine Life Hours				15 000	Hours	Number Of Machines Required		1.00 #		other		min
Machine Life Years				4.91	Years	Fleet Reserve		0%		other		min
			_			Exact Number of Machines Required	1	1.00 #		other	-	min
1 4 OVERHEADS						Rounded number of vehicles Required	-	1 #		cycle time	0.00	min
1.4 OVERILLEDO						Internet of Venices Required		1 17		cycle time	0.000	hre
Annual Licence Fees & insuran	100			14 207	11580					Machine Output per Hour	76.1	m3/mhr
			_	1.1 801	0000					Machine Output per Flour	776	m3/day
1.5 Overheads		Γ	10.00%	30916	11555					Machine Output per Day	232 683	m3/vear
6.1 SUMMARY			10.00 /01	00010	0.040	6.2 FLEET SUMMARY				machine output per Annum	EOE OOO	marjour
	Р	ER MACHIN	F	FLEET	96	1						
	USS/hr I	IS\$/month	USS/vear	USSVear	of Total	US\$ per m3	1.46					
OVERHEADS	10 11	2 576	30.016	30.016	0.00%	Number of Machines						
FIXED COSTS	54.10	13 808	165 700	165 700	48.7%	Number of Operators	2					
Ho	21.75	5 542	66 507	66 507	19 6%							
Crew	27 79	7 082	84 986	84 986	25.0%	Machine Hours	3.058					
Licence	4.65	1 184	14 207	14 207	4 204	Capital Employed	315 717					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	63 143					
VARIABLE COSTS	46.92	11 955	143 463	143 463	42 2%	Total Revenue	340 079					
Fuel	17.78	4 531	54 376	54 376	16.0%							
Lubrication	267	680	8 156	8 156	2 404							
Tyres	3.72	948	11 374	11 374	3.3%							
Maintenance	21.05	5 363	64 356	64 356	18.9%							
Relocation	1.70	433	5 200	5 200	1.5%							
TOTAL COST / REVENUE	111.22	28 340	340 079	340 079	100.0%	1		_	_			



MACHINE DESCRIPTION OPERATION STUDY FOR		Grapple S Tree leng MSc	Skidder (Tig th extractio	ercat 630D) n						- CORE	STRY SOLUTION	NA (PTY) LTD
NOTE ALL EIGURES OUOTE	ADE ESTIMA	TEC CITE C	DECIEIC & AS	SUME EULI V TR		ERATORS						offee man
NOTE ALL PIGORES GOOTEL	ARE ESTIMA	120,0112 0	FEOINO & AS	SOME FOLLY IN	ANEDOF	ENATORS					-	
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATING COSTS	5		-	3.1 LABOUR COSTS		
Machine Price, Exc. VAT				381 224	US\$s	Fuel Consumption		20.8 LA	Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rig	ging			0	US\$s	Fuel Cost		1.17 U	5\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Consumption		15%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost		U	S\$A	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	US\$s	Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	front 0	0	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	US\$s	rear 0	0	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				381 224	US\$s	tracks Eco 0	0	0		Total Overtime per week	6.0	Hrs
Annual Hp's				80 306	US\$s	other 0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation					1	other 0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	76 245	US\$s	Fuel,Cost		24.34 US	S\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		3.65 U	S\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		0.00 US	S\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				6 692	US\$s	Annual Fuel Costs		50 897 US	5 <b>\$</b> 5	Annual Double Time	2 940	US\$s
					_	Annual Lube Cost		7 635 US	5\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigging Cost		0 US	5 <b>\$</b> 5	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENANCE CO	STS			Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine life (mh	nr's)	90%		Total Crew Cost per Machine Hr	27.20	US\$/mhr
Statutory Leave Days				13		Maintenance Cost		22.87 US	\$\$/mhr	(*************************************		
Sick Leave Days				0		Annual Maintenance Cost		47 838 US	\$\$5			
Productive Days Lost to Weather	er/Mill Stops			0	A	2.3 RELOCATION COSTS				4.1 WORK STUDY ANALYSIS	_	1
Total Annual Production Days				300	Days	Number of moves per annum		4 #		Lead Distance		km
Shift length				8	Hours	Cost per Move		1 300 US	5\$s	Volume per Load		<i>m</i> 3
Number of Shifts per day				2	#	Annual Relocation Cost		5 200 US	5\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per Machine Hour		2.49 US	\$\$/mhr	Load		min
Machine Utilisation				43.6%		5.1 Machine Requirements	-			travel loaded		km/hr
Machine hours per Day				7.0	Hours	Annual Volume		232 500 m	3	Off Load	_	min
Machine hours per Annum				2 091	Hours	Hourly Volume Required		111.17 m	3/mhr	Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines Required		2.00 #		Travel time loaded	#DIV/0!	min
Machine Life Years				7.17	Years	Fleet Reserve		0%		Load	0.00	min
						Exact Number of Machines Require	d	2.00 #		Off Load	0.00	min
1.4 OVERHEADS						Rounded number of vehicles Requi	red	2 #		cycle time	#DIV/0!	min
			-							cycle time	#DIV/0!	hrs
Annual Licence Fees				19 061	US\$s					Machine Output per Hour	55.6	m3/mhr
					1.0					Machine Output per Day	388	m3/day
1.5 Overheads			10.00%	26783	US\$s					Machine Output per Annum	116 284	m3/year
6.1 SUMMARY	-				_	6.2 FLEET SUMMARY						
	P	ER MACHIN	NE	FLEET	%							
	US\$/hr U	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	2.53					
OVERHEADS	12.81	2 232	26 783	53 565	9.09%	Number of Machines	2					
FIXED COSTS	74.71	13 021	156 256	312 513	53.0%	Number of Operators	- 4					
Hp's	38.40	6 692	80 306	160 612	27.3%							
Crew	27.20	4 741	56 889	113 778	19.3%	Machine Hours	4 183					
Licence	9.11	1 588	19 061	38 122	6.5%	Capital Employed	762 448					
Permit & Toll fees	0.0	1	0	0	0.0%	Residual Value	152 490					
VARIABLE COSTS	53.35	9 297	111 570	223 140	37.9%	Total Revenue	589 217					
Fuel	24.34	4 241	50 897	101 794	17.3%							
Lubrication	3.65	636	7 635	15 269	2.6%							
Tyres	0.00	0	0	0	0.0%							
Maintenance	22.87	3 987	4/ 838	95 676	10.2%							
Relocation					1 1102							



OPERATION	: 1	Debranch	ing and deb	arking Euc	pulp (ful	I trees)					L.		
STUDY FOR		MSc									A State of the sta	TRY SOLUTION	A INTRACTO
PREPARED BY	: 1	-orestry S	solutions										F1288 2141
NOTE: ALL FIGURES QUOTEL	O ARE ESTIMAT	TES, SITE SP	PECIFIC & ASS	UME FULLY	TRAINED C	PERATORS						-	
1.1 CAPITAL EMPLOYED					-	2.1 VEHICLE OPERATING CO	OSTS				3.1 LABOUR COSTS		_
Machine Price Exc VAT				428 571	US\$s	Fuel Consumption			19	L/Hr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	aina			0	USSS	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio		1	0	US\$s	Oil,% Fuel Consumption			20%		Labour Wage	0.00	US\$/hou
Conservation of A state	other			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging			-		Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400	200		Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$s	Chain	1	145	50		Basic Hours/week	90.0	Hrs
Total Capital Employed				428 571	US\$s	Tracks	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				90 280	US\$s	Head	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @			20.00%	85 714	US\$s	Fuel,Cost			22.23	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
nterest per annum				8.00%		Oil, Cost			4.45	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost			4.90	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment			1	7 523	US\$s	Annual Fuel Costs			69 358	US\$s	Annual Double Time	300	US\$s
					_	Annual Lube Cost			13 872	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Rigging Co.	st		15 288	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENANCE	COSTS	_			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine life	(mhr's)		110%		Total Crew Cost per Machine Hr	17	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			31.43	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost		2	98 057	US\$s			
Productive Days Lost to Weathe	er/Mill Stops			0		2.3 RELOCATION COSTS		_			4.1 WORK STUDY ANALYSIS		-
Total Annual Production Days				300	Days	Number of moves per annum			4	#	Average Tree Volume	_	m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	US\$s	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Machine H	lour		1.67	US\$/mhr	crosscut		min
Machine Utilisation				65.0%		5.1 Machine Requirements		_			place		min
Machine hours per Day				10.4	Hours	Annual Volume			232 500	<i>m</i> 3	bunch		min
Machine hours per Annum				3 120	Hours	Hourly Volume Required			74.52	m3/hr	move		min
Machine Life Hours				15 000	Hours	Number Of Machines Required			2.00	#	other		min
Machine Life Years			1.00	4.81	Years	Fleet Reserve			0%		other		min
						Exact Number of Machines Re	quired		2.00	#	other	_	min
						Rounded number of vehicles R	equired		2	#	cycle time	0.00	min
1.4 OVERHEADS			_								cycle time	0.000	hrs
Annual Licence Fees & insurance	e			17 143	US\$s						Machine Output per Machine Hr	37.3	m3/mhr
											Machine Output per Day	388	m3/day
1.5 Overheads			10.00%	36147	US\$s						Machine Output per Annum	116 376	m3/year
5.1 SUMMARY	_		-	121 2 5 3		6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%								
	US\$/hr L	/S\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1.000	3.42					
OVERHEADS	11.59	3 012	36 147	72 293	9.09%	Number of Machines		2					
IXED COSTS	51.18	13 308	159 692	319 384	40.2%	Number of Operators	10	4					
lp	28.94	7 523	90 280	180 560	22.7%		-						
Crew	16.75	4 356	52 269	104 538	13.19	Machine Hours		6 240					
icence	5.49	1 429	17 143	34 286	4.3%	Capital Employed	85	7 142					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	17	1 428					
ARIABLE COSTS	64.67	16 815	201 774	403 548	50.7%	Total Revenue	79	5 225					
Fuel	22.23	5 780	69 358	138 715	17.4%								
ubrication	4.45	1 156	13 872	27 743	3.5%								
Maintenance	31 43	8 171	98 057	196 114	24 79								
Relocation	1.67	433	5 200	10 400	1.3%	3							
and a second second second second	127 44	33 134	397 613	795 225	100.0%								



Rounded number of vehicles Required

6.2 FLEET SUMMARY

Number of Machines

Number of Operators

US\$ per m3

Machine Hours

Capital Employed

Residual Value

Total Revenue

1.1 CAPITAL EMPLOYED				2.1 VEHICLE OPERA	ATING COSTS				3.1 LABOUR COSTS
Machine Price.Exc.VAT		325 900	US\$s	Fuel Consumption			17.3	L/Hr	Driver Wage
Less Cost of Tyres/Tracks/Rig	aging	0	US\$s	Fuel Cost			1.17	USSAL	No.Drivers/Shift
Plus additional equipment	slasher	0	US\$s	Oil,% Fuel Consumpt	tion		15%		Labour Wage
The state of the s	Truck 2ns hand	0	US\$s	Oil Cost				USSAL	No.Labourers/Shift
	trailer	0	US\$s	Tyres/Tracks/Rigging					Contributions
	other	0	US\$s		Qty	Cost	Life		Operating Days/Week
	other	0	US\$s	Bar	1	714	350		Operating Hours/Week
Sub total additional equipment	nt	0	US\$s	Sprocket	0	0	0		Basic Hours/week/driver
Total Capital Employed		325 900	US\$s	Tracks	0	0	0		Total Overtime per week
Annual HP payment		68 652	US\$s	Chain	1	195	70		Time and a Half per week
1.2 HP Calculation				other	0	0	0		Double Time per Week
Residual Value @	20.00%	65 180	US\$s	Fuel,Cost			20.24	US\$/mhr	Shift or Other Allowance
Interest per annum		8.00%		Oil, Cost			3.04	US\$/mhr	Annual Normal Time
Payment period		60	months	Tyres/Tracks/Rigging	Cost		4.83	US\$/mhr	Annual Time and a Half
Monthly payment		5 721	US\$s	Annual Fuel Costs			50 176	US\$s	Annual Double Time
				Annual Lube Cost			7 526	US\$s	Annual Bonus
1.3 OPERATING HOURS				Annual Tyre/Track/Rig	gging Cost		11 963	US\$s	Annual Shift or Other Allowance
Total Days		365	3	2.2 VEHICLE MAINT	ENANCE COSTS	_			Total Annual Crew Cost
Weekend Days		52		Maint,% Cap.Cost/ma	achine life (mhr's)		90%		Total Crew Cost per Machine Hr
Statutory Leave Days		13		Maintenance Cost			19.55	US\$/mhr	
Sick Leave Days		0		Annual Maintenance	Cost		48 473	US\$s	
Productive Days Lost to Weath	ner/Mill Stops	0		2.3 RELOCATION CO	OSTS	_			4.1 WORK STUDY ANALYSIS
Total Annual Production Days		300	Days	Number of moves per	r annum		4	#	Truck Volume
Shift length		8	Hours	Cost per Move			1 300	US\$s	ave log volume
Number of Shifts per day		2	#	Annual Relocation Co	ost		5 200	US\$s	Slash & Load
Machine Availability		100.0%		Relocation Cost per M	Machine Hour		2.10	US\$/mhr	other
Machine Utilisation		51.6%		5.1 Machine Require	ements	-			other
Machine hours per Day		8.3	Hours	Annual Volume		-	232 500	m3	other
Machine hours per Annum		2 479	Hours	Hourly Volume Requi	red	1	93.79	m3/mhr	other
Machine Life Hours		15 000	Hours	Number Of Machines	Required		1.00	#	other
Machine Life Years		6.05	Years	Fleet Reserve			0%		other
				Exact Number of Mac	chines Required		1.00	#	other

4 889 US\$s

24915 US\$s

%

of Total 9.09%

45.99 25.09 19.19 1.89

**45.0%** 18.3%

2.79 1.99

FLEET

US\$/year 24 915

125 809

68 652 52 269

4 889

123 338

5 200 274 063

10.00%

24 915

125 80

4 88

123 338

50 17

274 063

PER MACHINE

10 278

433 22 839

US\$/h

10.05

50.75

27.69

21.09 1.97

49.75

20.24

3.04 4.83 19.55

110.56

US\$/month US\$/yea 2 076 24 9

MACHINE DESCRIPTION : Tracked loader (Tigercat T234 with slasher)

1.4 OVERHEADS

1.5 Overheads

6.1 SUMMARY

OVERHEADS

FIXED COSTS

Permit & Toll fees VARIABLE COSTS

Fuel Lubrication Tyres Maintenance Relocation TOTAL COST / REVENUE

Hp

Crew

Fuel

Licence

Annual Licence Fees & insurance



9.80 US\$/hour

1.1 # 0.00 US\$/hour

0.0 #

0.0% 6.0 days

96.0 days 90.0 Hrs 6.0 Hrs 3.0 Hrs

3.0 Hrs 0.00 US\$/day 51 744 US\$s

225 US\$s

300 US\$s

0 US\$s 0 US\$s 52 269 US\$s 21.09 US\$/mhr

m3

min min

min min min min min

min m3

m3/mhr

775 m3/day

232 525 m3/year

0.00 min

0.000 hrs

1.00 #

1.18

274 063

1

cycle time

cycle time

Machine Output per Hour

Machine Output per Day

Machine Output per Annum



### DHP System – Tree volume 0.40m<sup>3</sup>



SYSTEM DESCRIPTION		DHP
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

FORESTRY SOLUTIONS (PTY) LTD

Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Wheeled Feller Buncher (Tigercat 720E)	-0	6				\$1.67	324 000	2	2	4	300
Grapple Skidder (Tigercat 630D)		4				\$1.91	324 000	2	2	4.4	300
DHP (Hitachi ZAxis200 with SP 591)						\$2.45	324 000	2	2	4.4	300
Tracked loader (Tigercat T234 with slasher)						\$0.88	324 000	1	2	2.2	300
				Total		\$6.91		7		15.4	
				ΤΟΤΑΙ		\$0.00		0		0	•



INS (PTY) LTD

# MACHINE DESCRIPTION : Wheeled Feller Buncher (Tigercat 720E) OPERATION : Felling and bunching Euc full trees STUDY FOR : MSc PREPARED BY : McEwan











#### MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY DHP (Hitachi ZAxis200 with SP 591) Debranching and debarking Euc pulp (full trees) MSc Forestry Solutions NOT



	[	20.00%	428 571 0 0 0 0 0 0 0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s US\$s US\$s US\$s	2.1 VEHICLE OPERATING COST Fuel Consumption Fuel Cost Oll % Fuel Consumption Oll Cost Tyres/Tracks/Rigging Day Bar 1 Chain 1 Tracks 0 Head 0 other 0 Fuel Cost	Cost 400 145 0	19 L 1.17 U 20% U Life 200 50 0 0	/Hr S\$/L S\$/L	3.1 LABOUR COSTS Driver Wage No.Drivers/Shift Labour Wage No.Labourers/Shift Contributions Operating Days/Week Operating Hours/Week Basic Hours/Week Basic Hours/Week	9.80 1.1 0.00 0.0% 6.0 96.0 90.0 6.0	US\$/hou # US\$/hou # days days Hrs Hrs Hrs
	[	20.00%	428 571 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	US\$5 US\$5 US\$5 US\$5 US\$5 US\$5 US\$5 US\$5	Fuel Consumption Fuel Cost Oil % Fuel Consumption Oil Cost Tyres/Tracks/Rigging Bar 1 Chain 1 Tracks 0 Head 0 other 0 Fuel Cost	Cost 400 145 0	19 L 1.17 U 20% U Life 200 50 0 0	/Hr \$\$/L \$\$/L	Driver Wage No Drivers/Shift Labour Wage No Labourers/Shift Contributions Operating Days/Week Operating Hours/Week Basic Hours/Week Basic Hours/Week	9.80 1.1 0.00 0.0% 6.0 96.0 90.0 6.0	US\$/hou # US\$/hou # days days Hrs Hrs Hrs
	[	20.00%	0 0 0 0 0 0 0 428 571 90 280 65 714 8.00% 60 0 7 523	US\$s US\$s US\$s US\$s US\$s US\$s US\$s US\$s	Fuel Cost Oil % Fuel Consumption Oil Cost Tyres/Tracks/Rigging Oty Bar 1 Chain 1 Tracks 0 Head 0 other 0 Fuel Cost	Cost 400 145 0 0	1.17 20% Life 200 50 0 0	5\$/L 5\$/L	No.Drivers/Shift Labour Wage No.Labourers/Shift Contributions Operating Days/Week Operating Hours/Week Basic Hours/Week Basic Hours/Week	1.1 0.00 0.0% 6.0 96.0 90.0 6.0	# US\$/hou # days days Hrs Hrs Hrs
	[	20.00%	0 0 0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s US\$s US\$s US\$s	Oll,% Fuel Consumption Oll Cost Tyres/Tracks/Rigging Bar 1 Chain 1 Tracks 0 Head 0 other 0 Fuel Cost	Cost 400 145 0 0	20% Life 200 50 0 0	S\$/L	Labour Wage No. Labourers/Shift Contributions Operating Davs/Week Operating Hours/Week Basic Hours/Week Basic Hours/Week	0.00 0.0% 6.0 96.0 90.0	US\$/hou # days days Hrs Hrs Hrs
	[	20.00%	0 0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s US\$s US\$s US\$s	Oil Cost         Oil Cost           Tyres/Tracks/Rigging         Oty           Bar         1           Chain         1           Tracks         0           Head         0           other         0           Fuel Cost         0	Cost 400 145 0 0	Life 200 50 0 0	S\$/L	No Labourers/Shift Contributions Operating Days/Week Operating Hours/Week Basic Hours/Week Total Overtime per week	0.0 0.0% 6.0 96.0 90.0 6.0	# days days Hrs Hrs Hrs
	[	20.00%	0 0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s US\$s US\$s	Tyres/Tracks/Rigging         Oty           Bar         1           Chain         1           Tracks         0           Head         0           other         0           Fuel Cost         0	Cost 400 145 0 0	Life 200 50 0 0		Contributions Operating Days/Week Operating Hours/Week Basic Hours/Week Total Overtime per week	0.0% 6.0 96.0 90.0 6.0	days days Hrs Hrs Hrs
-	[	20.00%	0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s US\$s	Oty           Bar         1           Chain         1           Tracks         0           Head         0           other         0           Fuel Cost         0	Cost 400 145 0 0	Life 200 50 0 0		Operating Days/Week Operating Hours/Week Basic Hours/Week Total Overtime per week	6.0 96.0 90.0 6.0	days days Hrs Hrs Hrs
		20.00%	0 0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s US\$s	Bar         1           Chain         1           Tracks         0           Head         0           other         0           Fuel Cost         0	400 145 0 0	200 50 0 0		Operating Hours/Week Basic Hours/Week Total Overtime per week	96.0 90.0 6.0	days Hrs Hrs Hrs
	[	20.00%	0 428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s US\$s	Chain         1           Tracks         0           Head         0           other         0           Fuel Cost         0	145 0 0	50 0 0		Basic Hours/week Total Overtime per week	90.0 6.0	Hrs Hrs Hrs
	[	20.00%	428 571 90 280 85 714 8.00% 60 7 523	US\$s US\$s US\$s	Tracks         0           Head         0           other         0           Fuel.Cost         0	0	0		Total Overtime per week	6.0	Hrs
	[	20.00%	90 280 85 714 8.00% 60 7 523	US\$s US\$s	Head 0 other 0 Fuel Cost	0	0			22	Hrs
	[	20.00%	85 714 8.00% 60 7 523	US\$s	other 0 Fuel Cost	.0			Time and a Half per week	3.0	a set of
	[	20.00%	85 714 8.00% 60 7 523	US\$s	Fuel Cost	0	0		Double Time per Week	3.0	Hrs
			8.00% 60 7 523			1	22.23	S\$/mhr	Shift or Other Allowance	0.00	US\$/day
			60 7 523		Oil. Cost		4.45	S\$/mhr	Annual Normal Time	51 744	USSS
			7 523	months	Tyres/Tracks/Rigging Cost		4.90 (	S\$/mhr	Annual Time and a Half	225	USSS
				US\$s	Annual Fuel Costs		69 358	SES	Annual Double Time	300	USSE
				0000	Annual Lube Cost		13 872	580	Annual Bonus	0	115.50
				-	Annual Tyre/Track/Rigging Cost		15 288 (	SSS	Annual Shift or Other Allowance	0	USSS
			365		2.2 VEHICLE MAINTENANCE CO	STS	10 400 0	0.00	Total Annual Crew Cost	52 269	11580
			52		Maint % Can Cost/machine life (m)	ur's)	110%		Total Crew Cost per Machine Hr	17	US\$/mhr
			13		Maintenance Cost		34 43 /	Ct/mhr	Total crew cost per machine rit		Josannin
			0		Annual Maintenance Cost		98.057	Ste			
			0		2 3 PELOCATION COSTS		30 007 0	345	A A WODK STUDY ANALYSIS		
ops			300	Davie	Number of maries per applier		4 4		Autorean Tree Volume		
		-	900	Hours	Cost per Meno		4 200		Average free volume		mo
			0	Hours	Annual Polosetion Cost		F 200	535	tell		min
			100.00		Annual Relocation Cost		5 200 0	0.000	debranch / debark		min
			100.0%		Relocation Cost per Machine Hour		1.6/ 0	Savmnr	crosscut		min
			65.0%	Marine	5.1 Machine Requirements		204 000		piace		min
			10.4	Hours	Annuai Volume		324 000 m	3	bunch		min
		-	3 120	Hours	Houriy Volume Required		103.85 m	3/hr	move		min
		-	15 000	Hours	Number Of Machines Required		2.00 #		other		min
			4,81	Years	Fleet Reserve		0%		other		min
					Exact Number of Machines Require	d	2.00 #		other		min
					Rounded number of vehicles Requi	red	2 #		cycle time	0.00	min
			10.110						cycle time	0.000	hrs
			17 143	US\$s					Machine Output per Machine Hr	52.0	m3/mhr
				1000					Machine Output per Day	541	m3/day
_		10.00%	36147	US\$S	A A FI FET CUMMARY			-	Machine Output per Annum	162 240	m3/year
			-		0.2 FLEET SUMMART						
PE	RMACHIN	E	FLEET	%							
s/hr Us	\$/month	US\$/year	US\$/year	of Total	US\$ per m3	2.45					
11.59	3 012	36 147	72 293	9.09%	Number of Machines	2					
51.18	13 308	159 692	319 384	40.2%	Number of Operators	4					
28.94	7 523	90 280	180 560	22.7%	in a start in the						
16.75	4 356	52 269	104 538	13.1%	Machine Hours	6 240					
5.49	1 429	17 143	34 286	4.3%	Capital Employed	857 142					
0.0		0	0	0.0%	Residual Value	171 428					
54.67	16 815	201 774	403 548	50.7%	Total Revenue	795 225					
22.23	5 780	69 358	138 715	17.4%							
4.45	1 156	13 872	27 743	3.5%							
4.90	1 274	15 288	30 576	3.8%							
167	8 171	98 057	196 114	24 7%							
27.44	33 134	397 613	795 225	100.0%							
	PE 5/hr US 1.59 1.18 6.75 5.49 4.67 2.23 4.46 1.67 1.67 7.74	PER MACHIN Vhr US Month 1.56 3012 1.18 13 308 8.94 7 523 6.75 4 356 5.46 1.420 0.0 4.67 16.615 5.23 5.780 4.46 1.156 4.90 1.274 1.43 6.171 1.67 4.33 134	10.00%           PER MACHINE           Uhr         US\$/year           156         3.012         35.147           1.18         13.308         159.692           8.94         7.523         90.280           6.75         4.356         52.280           5.4         1.420         17.143           0.0         0         4.67           4.67         16.815         201.774           223         5.780         63.358           4.90         1.274         15.285           14.35         6.71         1.99.057           167         4.33         5.200           744         33         13.4	300         8           100.0%         2           100.0%         65.0%,           100.0%         65.0%,           100.0%         3120           15000         4.81           10.00%         36147           10.00%         36147           159         3012         35 147           159         3012         35 147           159         3012         35 147           159         3012         35 147           159         3012         35 147           159         3012         35 147           159         3012         35 147           159         3013         195 692           16         13 306         195 692           16         13 306         195 692           16         15         201774           420         17 143         34 286           00         0         0           445         1 156         13 872         27 743           400         1 274         15 286         136 71           13         617         957         106 114           167         435         5 200         1	300         Days           8         Hours           2         #           100.0%         65.0%           104. Hours         3.120           3.320         Hours           3.320         Hours           3.320         Hours           3.320         Hours           15.000         Hours           4.81         Years           17.143         USSs           10.00%         36147           USSyear         of Total           1.59         3.012         36.147           72.293         9.09%           1.8         13.06         159.692           1.8         3.06         10         0.27%           6.75         4.365         52.265         104.538         13.1%           6.46         1.426         17.14.3         34.426         4.3%           0.0         0         0         0.0%         0.0%           4.45         1.86         13.872         27.743         3.5%           1.45         13.872         27.743         3.5%           1.87         14.36         13.672         27.743         3.5% <t< td=""><td>300         Days         Number of moves per annum Cost per Move           2 #         Annual Relocation Cost 100.0%         Annual Relocation Cost Relocation Cost per Machine Hour 5.1 Machine Requirements           104. Hours         3.120         Hours         S.1 Machine Requirements           104. Hours         15.000         Hours         Annual Relocation Cost per Machine Hour           104. Hours         3.120         Hours         Annual Volume Required           105.000         Hours         Number of Machines Required           115.000         Hours         Number of Machines Required           10.00%         36147         US\$s           10.00%         36147         US\$s           10.00%         36147         US\$s per m3           1.59         3.012         36.147         72.293         9.09%           Number of Machines         1.59         1.59         machines           1.18         13.06         159.692         319.364         40.2%           6.7         4.365         52.269         104.588         13.1%         Machine Hours           6.40         2.0         0.0%         Residual Value         1.46         1.420         1.7.44           2.23         57.80         69.356</td><td>300         Days         Number of moves per annum           2         #         Annual Relocation Cost           100.0%         65.0%         Annual Relocation Cost per Machine Hour           65.0%         104.0%         65.0%           100.0%         65.0%         Annual Relocation Cost per Machine Hour           61.00         65.0%         Annual Volume Requirements           104.1%         Hours         Annual Volume Required           115.000         Hours         Number of Machines Required           115.0%         Lexat Number of Vehicles Required         Rounded number of Vehicles Required           100.0%         36147         US\$s         6.2 FLEET SUMMARY           1158         30012         36 147         US\$s         6.2 FLEET SUMMARY           1158         10.00%         36147         US\$s         6.2 FLEET SUMMARY           126         30.06         50.09%         Number of Machines         2.4</td><td>300         Days         Number of moves per annum         4           8         Hours         Cost per Move         1300 U           2 #         Annual Relocation Cost         500 U           100.0%         65.0%         Annual Relocation Cost         187 U           104. Hours         Annual Relocation Cost         187 U         187 U           104. Hours         Annual Volume Required         103.85 m         103.85 m           15000 Hours         Hours         Hours         Number of Machines Required         2.00 #           4.85 Years         Fleet Reserve         00%         2.00 #         2.00 #         2.00 #           17 143         US\$s         6.2 FLEET SUMMARY         2.00 #         2.00 #         2.00 #           1.86 13 0.06 159 692         36147         US\$s per m3         2.45         2.45           1.86 13 0.06 159 692         39.90%         Number of Machines         2.00 #         2           1.86 13 0.06 159 692         39.90%         Number of Operators         4         2           6.47 7 523         90.280         180.680         22.7%         Number of Operators         4           8.94 7 523         90.280         180.680         22.7%         A         32406</td><td>300         Days         Number of moves per annum         4 #           2         #         Annual Relocation Cost         5 200         US\$s           100.0%         Relocation Cost per Machine Hour         1.51         US\$s         1.52         0.05           100.0%         Relocation Cost per Machine Hour         1.61         US\$s         1.62         0.05           100.0%         Relocation Cost per Machine Hour         1.61         US\$s         1.62         0.05           10.4         Hours         Annual Volume         Annual Volume         324 000         m3           115 000         Hours         Number of Machines Required         10.03.85         m3/nr           115 000         Hours         Number of Machines Required         2.00         #           4.81         Years         Fleet Reserve         0%         2.00         #           10.00%         38147         US\$s         0.2 FLEET SUMMARY         2.00         #           116         13 30.81         10.90%         Number of Machines         2         4           116         3.012         36 147         72 23         9.09%         Number of Machines         2           116         3.013.05         5.05<td>300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5200         USS:         debranch / debark           100.0%         Relocation Cost per Machine Hour         157         USS:mhr         crossout           3120         Hours         Annual Volume         324 000         move           1100.0%         S1 Machine Requirements         place         place           1100.0%         Asti Years         Fleet Reserve         0%         other           111         USS:         Cycle time         cycle time         cycle time           111         USS:         00.0%         36147         USS:         0%           111         USS:         0         0%         dther         cycle time           111         USS:         0.00%         36147         USS:         0%         dther           112         USS:         of Total         USS per m3         2.45         Machine Output per Annum           113         USS 1160         0.00%         S2400         5240         5240         5240           113         USS per m3         2.45         S240         5240</td><td>300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5.200         USSs         delranch / debark           100.0%         Relocation Cost per Machine Hour         1.57         USSmhr         crosscut           65.0%         5.1 Machine Requirements         molul Volume         324 000         m3           100.0%         3.120         Hours         Hourly Volume Required         103.85         m3/hr         move           15.00         Hours         Hourly Volume Required         2.00         #         other         bunch           4.8.5         Years         File Reserve         0.0%         #         other         other           4.8.5         Years         File Reserve         0.0%         #         other         0.00           10.00%         36147         USSs         6.2 FLEET SUMMARY         2.00         #         other         0.00           11.8         13.302         150.00         USSs         Variance of Machines         2.45         Machine Output per Machine Hr         52.240           10.00%         36147         USSs         0.2         FLEET         Machine Of Operators</td></td></t<>	300         Days         Number of moves per annum Cost per Move           2 #         Annual Relocation Cost 100.0%         Annual Relocation Cost Relocation Cost per Machine Hour 5.1 Machine Requirements           104. Hours         3.120         Hours         S.1 Machine Requirements           104. Hours         15.000         Hours         Annual Relocation Cost per Machine Hour           104. Hours         3.120         Hours         Annual Volume Required           105.000         Hours         Number of Machines Required           115.000         Hours         Number of Machines Required           10.00%         36147         US\$s           10.00%         36147         US\$s           10.00%         36147         US\$s per m3           1.59         3.012         36.147         72.293         9.09%           Number of Machines         1.59         1.59         machines           1.18         13.06         159.692         319.364         40.2%           6.7         4.365         52.269         104.588         13.1%         Machine Hours           6.40         2.0         0.0%         Residual Value         1.46         1.420         1.7.44           2.23         57.80         69.356	300         Days         Number of moves per annum           2         #         Annual Relocation Cost           100.0%         65.0%         Annual Relocation Cost per Machine Hour           65.0%         104.0%         65.0%           100.0%         65.0%         Annual Relocation Cost per Machine Hour           61.00         65.0%         Annual Volume Requirements           104.1%         Hours         Annual Volume Required           115.000         Hours         Number of Machines Required           115.0%         Lexat Number of Vehicles Required         Rounded number of Vehicles Required           100.0%         36147         US\$s         6.2 FLEET SUMMARY           1158         30012         36 147         US\$s         6.2 FLEET SUMMARY           1158         10.00%         36147         US\$s         6.2 FLEET SUMMARY           126         30.06         50.09%         Number of Machines         2.4	300         Days         Number of moves per annum         4           8         Hours         Cost per Move         1300 U           2 #         Annual Relocation Cost         500 U           100.0%         65.0%         Annual Relocation Cost         187 U           104. Hours         Annual Relocation Cost         187 U         187 U           104. Hours         Annual Volume Required         103.85 m         103.85 m           15000 Hours         Hours         Hours         Number of Machines Required         2.00 #           4.85 Years         Fleet Reserve         00%         2.00 #         2.00 #         2.00 #           17 143         US\$s         6.2 FLEET SUMMARY         2.00 #         2.00 #         2.00 #           1.86 13 0.06 159 692         36147         US\$s per m3         2.45         2.45           1.86 13 0.06 159 692         39.90%         Number of Machines         2.00 #         2           1.86 13 0.06 159 692         39.90%         Number of Operators         4         2           6.47 7 523         90.280         180.680         22.7%         Number of Operators         4           8.94 7 523         90.280         180.680         22.7%         A         32406	300         Days         Number of moves per annum         4 #           2         #         Annual Relocation Cost         5 200         US\$s           100.0%         Relocation Cost per Machine Hour         1.51         US\$s         1.52         0.05           100.0%         Relocation Cost per Machine Hour         1.61         US\$s         1.62         0.05           100.0%         Relocation Cost per Machine Hour         1.61         US\$s         1.62         0.05           10.4         Hours         Annual Volume         Annual Volume         324 000         m3           115 000         Hours         Number of Machines Required         10.03.85         m3/nr           115 000         Hours         Number of Machines Required         2.00         #           4.81         Years         Fleet Reserve         0%         2.00         #           10.00%         38147         US\$s         0.2 FLEET SUMMARY         2.00         #           116         13 30.81         10.90%         Number of Machines         2         4           116         3.012         36 147         72 23         9.09%         Number of Machines         2           116         3.013.05         5.05 <td>300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5200         USS:         debranch / debark           100.0%         Relocation Cost per Machine Hour         157         USS:mhr         crossout           3120         Hours         Annual Volume         324 000         move           1100.0%         S1 Machine Requirements         place         place           1100.0%         Asti Years         Fleet Reserve         0%         other           111         USS:         Cycle time         cycle time         cycle time           111         USS:         00.0%         36147         USS:         0%           111         USS:         0         0%         dther         cycle time           111         USS:         0.00%         36147         USS:         0%         dther           112         USS:         of Total         USS per m3         2.45         Machine Output per Annum           113         USS 1160         0.00%         S2400         5240         5240         5240           113         USS per m3         2.45         S240         5240</td> <td>300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5.200         USSs         delranch / debark           100.0%         Relocation Cost per Machine Hour         1.57         USSmhr         crosscut           65.0%         5.1 Machine Requirements         molul Volume         324 000         m3           100.0%         3.120         Hours         Hourly Volume Required         103.85         m3/hr         move           15.00         Hours         Hourly Volume Required         2.00         #         other         bunch           4.8.5         Years         File Reserve         0.0%         #         other         other           4.8.5         Years         File Reserve         0.0%         #         other         0.00           10.00%         36147         USSs         6.2 FLEET SUMMARY         2.00         #         other         0.00           11.8         13.302         150.00         USSs         Variance of Machines         2.45         Machine Output per Machine Hr         52.240           10.00%         36147         USSs         0.2         FLEET         Machine Of Operators</td>	300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5200         USS:         debranch / debark           100.0%         Relocation Cost per Machine Hour         157         USS:mhr         crossout           3120         Hours         Annual Volume         324 000         move           1100.0%         S1 Machine Requirements         place         place           1100.0%         Asti Years         Fleet Reserve         0%         other           111         USS:         Cycle time         cycle time         cycle time           111         USS:         00.0%         36147         USS:         0%           111         USS:         0         0%         dther         cycle time           111         USS:         0.00%         36147         USS:         0%         dther           112         USS:         of Total         USS per m3         2.45         Machine Output per Annum           113         USS 1160         0.00%         S2400         5240         5240         5240           113         USS per m3         2.45         S240         5240	300         Days         Number of moves per annum         4         #         Average Tree Volume           2         #         Annual Relocation Cost         5.200         USSs         delranch / debark           100.0%         Relocation Cost per Machine Hour         1.57         USSmhr         crosscut           65.0%         5.1 Machine Requirements         molul Volume         324 000         m3           100.0%         3.120         Hours         Hourly Volume Required         103.85         m3/hr         move           15.00         Hours         Hourly Volume Required         2.00         #         other         bunch           4.8.5         Years         File Reserve         0.0%         #         other         other           4.8.5         Years         File Reserve         0.0%         #         other         0.00           10.00%         36147         USSs         6.2 FLEET SUMMARY         2.00         #         other         0.00           11.8         13.302         150.00         USSs         Variance of Machines         2.45         Machine Output per Machine Hr         52.240           10.00%         36147         USSs         0.2         FLEET         Machine Of Operators



FORESTRY SOLUTIONS (PTY) LTD

## MACHINE DESCRIPTION : Tracked loader (Tigercat T234 with slasher) OPERATION : Slash STUDY FOR : MSc PREPARED BY : McEwan







### Harvester (CTL) System – Tree volume 0.075m<sup>3</sup>



SYSTEM DESCRIPT	ION	:	Harvester s	system IIII							L
STUDY FOR			MSc								FORESTRY
PREPARED BY		;	McEwan							3	Contraction of the statements
Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$23.01	78 500	5	2	11	300
Forwarder (Tigercat 1075)						\$5.83	78 500	1	2	2.2	300
				Total		\$28.84		6		13.2	
				TOTAL		\$28.84		6		13.2	



STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: N : N ARE ESTIMAT	ISc IcEwan ES, SITE SP	PECIFIC & AS	SUME FULLY TR	RAINED O	PERATORS						OLUTIONS
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATING	COSTS			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				357 143	US\$s	Fuel Consumption			19 L/Hr	Driver Wage	9.80	US\$/ho
Less Cost of Tyres/Tracks/Rigg	aing			0	US\$s	Fuel Cost			1.17 US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			20%	Labour Wage	0.00	US\$/ho
	other			0	US\$s	Oil Cost			US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life	Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400	200	Operating Hours/Week	96.0	days
Sub total additional equipment	-			0	US\$s	Chain	1	145	50	Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres	0	0	0	Total Overtime per week	6,0	Hrs
Annual HP payment				75 233	US\$s	other	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation					1	other	0	0	0	Double Time per Week	3,0	Hrs
Residual Value @		[	20.00%	71 429	US\$s	Fuel,Cost			22.23 US\$/mhr	Shift or Other Allowance	0.00	US\$/da
Interest per annum				8.00%		Oil, Cost			4.45 US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost			4.90 US\$/mhr	Annual Time and a Half	225	USSS
Monthly payment				6 269	US\$s	Annual Fuel Costs			69 804 US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			13 961 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigging C	ost	-	15 386 US\$s	Annual Shift or Other Allowance	0	USSS
Total Days				365		2.2 VEHICLE MAINTENANO	E COSTS			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine I	ife (mhr's)		110%	Total Crew Cost per Machine Hr	17	USS/m
Statutory Leave Days				13		Maintenance Cost	10 81000 EX	1	26,19 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost		1	82 240 US\$s			
Productive Days Lost to Weather	r/Mill Stops			0		2.3 RELOCATION COSTS		-		4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				.300	Davs	Number of moves per annun	1		4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300 US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 US\$s	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Machine	Hour		1.66 US\$/mhr	crosscut		min
Machine Utilisation				65.4%		5.1 Machine Requirements		-		place		min
Machine hours per Day				10.5	Hours	Annual Volume			78 500 m3	bunch		min
Machine hours per Annum				3 140	Hours	Hourly Volume Required			25.00 m3/hr	move		min
Machine Life Hours				15 000	Hours	Number Of Machines Requir	ed		5.00 #	other		min
Machine Life Years				4.78	Years	Fleet Reserve			0%	other		min
			-			Exact Number of Machines F	equired		5.00 #	other		min
						Rounded number of vehicles	Required		5	cycle time	0.00	min
A OVERHEADS							required	-		cycle time	0.000	hrs
Annual Licence Fees & insurance	e			14 286	USSS					Machine Output per Machine Hr	5.0	m3/mh
terrest shoring i goo a disciglio			L	14 200						Machine Output per Day	52	m3/day
1.5 Overheads		E C	10.00%	32838	USSS					Machine Output per Annum	15 700	m3/vas
3.1 SUMMARY			10100 /0	01000		6.2 FLEET SUMMARY		_		Subar bar survey		
	PE	R MACHIN	E	FLEET	%							
	US\$/hr U	S\$/month	US\$/vear	US\$/vear	of Total	US\$ per m3		23.01				
OVERHEADS	10.46	2 736	32 838	164 189	9.09%	Number of Machines		5		1		
FIXED COSTS	45.15	11 816	141 788	708 941	39.3%	Number of Operators	· · · · · · ·	11				
Hp	23.95	6.269	75 233	376 167	20.8%							
Crew	16.65	4 356	52 269	261 345	14 5%	Machine Hours	8	5 700				
Licence Insurance	4.55	1 190	14 286	71 429	4.0%	Capital Employed	1.78	35 715				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	34	57 143				
VARIABLE COSTS	59.42	15 549	186 591	932 954	51.7%	Total Revenue	1.80	06 084				
Fuel	22.23	5.817	69 804	349 019	19 3%							
Lubrication	4.45	1 163	13 961	69 804	3.9%							
Tyres	4.90	1 282	15 386	76 932	4.3%							
Maintenance	26.19	6 853	82 240	411 200	22.8%							
Relocation	1 66	433	5 200	26 000	1.4%							
ICITAL COST / REVENUE	115 03	50 101	301 217	1 806 084	100.0%							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED A	: : RE ESTIMA	Forwarder Extraction MSc McEwan TES, SITE SF	r (Tigercat 1 of logs to r PECIFIC & ASS	075) oadside UME FULLY TR	AINED OP	ERATORS							Ather COREST
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATI	NG COSTS			-	3.1 LABOUR COSTS		
Machine Price, Exc. VAT				571 139	US\$s	Fuel Consumption			22 L	Hr	Driver Wage	9.80	USS
Less Cost of Tyres/Tracks/Riggin	9			Ő	USSS	Fuel Cost			1.17 0	S\$/L	No.Drivers/Shift	1.1	1 #
Plus additional equipment	radio	-		0	US\$s	Oil.% Fuel Cost			15%		Labour Wage	0.00	USS
	other			0	US\$s	Oil Cost			U	SSA	No.Labourers/Shift	0.0	0 #
	other			0	USSS	Tyres/Tracks/Rigging					Contributions	0.0%	6
	other			0	USSS		Qtv	Cost	Life		Operating Days/Week	6.0	dava
	other		-	0	USSS	front	4	7 200	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	USSS	rear	4	7 200	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				571 139	USSS	tracks Eco	1	19 500	0		Total Overtime per week	6.0	Hrs
Annual Ho's				120 312	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		Г	20.00%	114 228	US\$s	Fuel.Cost			25.74	S\$/mhr	Shift or Other Allowance	0.00	USS
Interest per annum				8.00%		Oil Cost			3.86 1	S\$/mhr	Annual Normal Time	51 744	USS
Payment period				60	months	Tyres/Tracks/Rigging Co	st		0.00	S\$/mhr	Annual Time and a Half	2 20	5 US
Monthly navment				10.026	USSe	Annual Fuel Costs			80 309 //	SSe	Annual Double Time	2 940	USS
, juliant			_			Annual Lube Cost			12 046	SSS	Annual Bonus	(	US
13 OPERATING HOURS						Annual Tyre/Track/Ricci	na Cost		0 1	SSS	Annual Shift or Other Allowance		USS
Total Dave				365		2.2 VEHICLE MAINTEN	ANCE COSTS			000	Total Annual Crew Cost	56 889	115
Neekend Davs				52		Maint % Can Cost/mach	ine life (mhr's)		100%		Total Crew Cost per Machine Hr	18.23	US
Statutory Leave Days				13	1.1	Maintenance Cost	ine me (min e)	1	38.08	S\$/mhr		10.11	1000
Sick Leave Days				0	1.1	Annual Maintenance Cos	t	1 m	118 797	SSs			
Productive Days Lost to Weather/M	till Stops			0		2.3 RELOCATION COS	TS	-			4.1 WORK STUDY ANALYSIS		
Total Annual Production Days	un stake			300	Davs	Number of moves per an	num		4 #		Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300 U	222	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 U	SSS	travel empty		km/
Machine Availability				100.0%		Relocation Cost per Mac	hine Hour		1.67 /	S\$/mhr	Load		min
Machine Utilisation				65.0%	1.1.1	5.1 Machine Requireme	ents				travel loaded		km/
Machine hours per Day				10.4	Hours	Annual Volume			78 500 m	3	Off Load		min
Machine hours per Annum				3 120	Hours	Hourly Volume Required			25.16	3/mhr	Travel time empty	#DIV/01	min
Machine Life Hours				15 000	Hours	Number Of Machines Re	quired		1.00 #		Travel time loaded	#DIV/01	min
Machine Life Years				4.81	Years	Fleet Reserve	44.00		0%		Load	0.00	min
			_			Exact Number of Machin	es Required		1.00 #		OffLoad	0.00	min
4 OVERHEADS						Rounded number of vehi	cles Required		1 #		cycle time	#DIV/01	min
of entremented							ondo recipined	-			cycle time	#DIV/01	hrs
Annual Licence Insurance Fees				22 846	USSS						Machine Output per Hour	25.2	m3/
			-								Machine Output per Day	262	2 m3/
.5 Overheads		[	10.00%	41640	US\$s	and a contraction					Machine Output per Annum	78 624	m3/
.1 SUMMARY	-					6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%	Concernant of the	_		_	_			
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		5.83		_			
OVERHEADS	13.35	3 470	41 640	41 640	9.09%	Number of Machines	6 S.	1					
IXED COSTS	64.12	16 671	200 047	200 047	43.7%	Number of Operators	-	2					
lp's	38.56	10 026	120 312	120 312	26.3%	The second se	-						
Crew	18.23	4 741	56 889	56 889	12.4%	Machine Hours	1.000	3 120					
icence Insurance	7.32	1 904	22 846	22.846	5.0%	Capital Employed		571 139					
Permit & Toll fees	0.0		D	0	0.0%	Residual Value		114 228					
ARIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	Total Revenue	6	458 039					
Fuel	25.74	6 692	80 309	80 309	17.5%								
ubrication	3.86	1.004	12 046	12 046	2.6%								
yres faistenance	0.00	0 000	119 707	149 707	0.0%								
Relocation	1.67	433	5 200	5 200	1.1%								
	the second se		-		1 10								

Harvester (CTL) System – Tree volume 0.15m<sup>3</sup>



SYSTEM DESCRIPTION	:	Harvester system
OPERATION		Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$12.45	111 000	4	2	8.8	300
Forwarder (Tigercat 1075)						\$4.13	111 000	1	2	2.2	300
				Total		\$16.57		5		11	
						\$0.00		0		0	
				TOTAL		\$16.57		5		11	

FORESTRY

MACHINE DESCRIPTION	- 21	Harvester (Hitachi ZAxis200 with SP591)
OPERATION	:	Fell, delimb, debarking, crosscut and stack Euc pulp
STUDY FOR	-	MSc
PREPARED BY		McEwan



1 1 CADITAL EMPLOYED						2 1 VEHICI E OPERATI	NG COSTS			- 1	3 1 LABOUR COSTS		_
Machina Drice Evo VAT				357 143	11550	Fuel Consumption	10 00010		19 //Hr		Driver Wage	9.80	USSMOU
Loss Cost of Turge/Tracke/Ring	ina			007 140	11580	Fuel Cost			1 17 1158		No Drivers/Shift	11	#
Due additional equipment	fadio			0	11550	Oil % Fuel Cost			20%		abour Wage	0.00	USShou
Plus additional equipment	ather			0	11000	Oil Cost			1/50	, 1	No Labourers/Shift	0.00	#
	other				11000	Turse/Tracks/Disains			034	٠ I	Contributions	0.0%	-
	other			0	110535	Tyres/Tracks/Rigging	Otu	Cost	Life		Operating Days Meak	6.0	daue
	other			0	10335	Des	Gity	400	200		Operating Daysreveek	06.0	days
	other			0	11084	Chair		400	200		Desig Hourshweek	90.0	Lies
Sub total additional equipment					0348	Times		140	50		Basic Hours/week	50.0	lis
Total Capital Employed				35/ 143	0535	Tyres	U	0	0		Total Overtime per week	0.0	rirs
Annual HP payment				75 233	US\$S	other	0	0	0		Time and a Hair per week	3.0	HIS
1.2 HP Calculation		T I			Lui a	lother	0	0	0		Double Time per week	3.0	HIS
Residual Value @		L	20.00%	71 429	US\$s	<b>*</b>			22.23 US\$	mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%	1		VAN PRETOR		4.45 US\$	mhr /	Annual Normal Time	51 744	US\$s
Payment period			-	60	months	YUNIBESITHI	YA PRETOR	IA	4.90 US\$/	mhr /	Annual Time and a Half	225	US\$s
Monthly payment				6 269	US\$s	Annual Fuel Costs			64 260 US\$	1	Annual Double Time	300	US\$s
					_	Annual Lube Cost			12 852 US\$s		Annual Bonus	0	US\$s
1.3 OPERATING HOURS			0			Annual Tyre/Track/Rigg	ng Cost		14 164 US\$s	/	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTEN	ANCE COSTS	_			Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/mach	ine life (mhr's)		110%		Total Crew Cost per Machine Hr	18	US\$/mhr
Statutory Leave Days				13		Maintenance Cost			26.19 US\$	mhr			
Sick Leave Days				0		Annual Maintenance Co	st		75 709 US\$s			_	
Productive Days Lost to Weather	r/Mill Stops			0		2.3 RELOCATION COS	TS			4	4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per a	num		4 #		Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300 US\$	1	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200 US\$s		debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Mar	hine Hour		1.80 US\$	mhr	crosscut		min
Machine Utilisation				60.2%		5.1 Machine Requirem	ents				place		min
Machine hours per Day				9.6	Hours	Annual Volume			111 000 m3		bunch		min
Machine hours per Annum				2 891	Hours	Hourly Volume Required			38.40 m3/h		move		min
Machine Life Hours				15 000	Hours	Number Of Machines Re	benuired		4 00 #		other		min
Machina Life Veare				5 19	Voare	Fleet Reserve	quirea		0%		other		min
indenine che rears			-		10010	Exact Number of Machin	as Required		4.00 #		other		min
1.						Rounded number of web	icles Required		4 #	t,	cucle time	0.00	min
1 1 OVERHEADS						Rounded number of ven	icies required				nucle time	0.000	hre
Annual Licence Face & insurance			E	14 286	luce					l,	Machine Output per Machine Hr	9.6	m3/mhr
Annual Licence Fees & Insurance	e			14 200	10.949						Machine Output per Machine In	03	m 2/day
		Г	10.000	24207	luce						Machine Output per Day	27 764	mahaar
1.5 Overneads			10.00%	21241	0535	6 2 ELEET SUMMARY				- 1'	Machine Output per Annum	21 131	moryear
0.1 SUMMART	-	DHACHIN				O.2 FEEL SOMMART							
	PE	RMACHIN	LIDAL	FLEET	70	1100		40.40	1				
	US\$/nr U	S\$/month	USsyear	USavyear	of lotal	US\$ per m3		12.40					
OVERHEADS	10.86	2 616	31 397	125 589	9.099	Number of Machines	1	4					
FIXED COSTS	49.05	11 816	141 788	567 152	41.19	Number of Operators		9					
Нр	26.03	6 269	75 233	300 934	21.89	i main				- 1			
Crew	18.08	4 356	52 269	209 078	15,19	Machine Hours	100	11 563					
Licence Insurance	4.94	1 190	14 286	57 143	4.19	Capital Employed	1	428 572					
Permit & Toll fees	0.0		0	0	0.09	Residual Value		285 714					
VARIABLE COSTS	59.57	14 349	172 185	688 740	49.9%	Total Revenue		381 482					
Fuel	22.23	5 355	64 260	257 040	18.69	1							
Lubrication	4.45	1 071	12 852	51 408	3,79								
Tyres	4.90	1 180	14 164	56 658	4.19								
Maintenance	26,19	6 309	75 709	302 834	21.99								
and the second states	1.00	400	5200	20 800	1.07								





Harvester (CTL) System – Tree volume 0.25m<sup>3</sup>



SYSTEM DESCRIPTION	1	Harvester system
OPERATION		Stump to Mill
STUDY FOR		MSc
PREPARED BY	:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$8.03	126 000	3	2	6.6	300
Forwarder (Tigercat 1075)						\$3.64	126 000	1	2	2.2	300
				Total		\$11.67		4		8.8	
						\$0.00		0		0	
				TOTAL		\$11.67		4		8.8	



MACHINE DESCRIPTION OPERATION		larvester ell, delim	(Hitachi ZA b, debarkir	xis200 with ng, crosscut	SP591) and sta	ck Euc pulp						ANT	
STUDY FOR	: N	ISc											OPESTRY
PREPARED BY	: N	AcEwan											OLUTIONS
NOTE: ALL FIGURES QUOTED	D ARE ESTIMAT	ES, SITE SI	PECIFIC & AS	SUME FULLY T	RAINED C	PERATORS						No. A.	and the second
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERAT	TING COSTS	-			3.1 LABOUR COSTS		
Machine Price, Exc. VAT				357 143	US\$s	Fuel Consumption			19	UHr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	ging		1	0	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			20%		Labour Wage	0.00	US\$/hou
	other			0	US\$s	Oil Cost			_	US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400	200		Operating Hours/Week	96.0	days
Sub total additional equipment	t			0	US\$s	Chain	1	145	50		Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres	0	0	0	1	Total Overtime per week	6.0	Hrs
Annual HP payment				75 233	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	71 429	US\$s	Fuel,Cost		1	22.23	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%	-	Oil, Cost			4.45	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period	ent period 60 months				Tyres/Tracks/Rigging (	Cost	1	4.90	US\$/mhr	Annual Time and a Half	225	US\$s	
Monthly payment				6 269	US\$s	Annual Fuel Costs			61 425	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			12 285	US\$s	Annual Bonus	0	USSS
1.3 OPERATING HOURS	-					Annual Tyre/Track/Rig	ging Cost		13 540	US\$s	Annual Shift or Other Allowance	0	US\$s
tal Davs 385				2.2 VEHICLE MAINTE	NANCE COSTS	(			Total Annual Crew Cost	52 269	US\$s		
Weekend Davs				52		Maint,% Cap.Cost/machine life (mhr's) 110%					Total Crew Cost per Machine Hr	19	US\$/mhr
Statutory Leave Days				13		Maintenance Cost 26,19 US\$/mhr							
Sick Leave Days				0		Annual Maintenance C	ost		72 369	US\$s			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION CO	STS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per	munne		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cos	t		5 200	US\$s	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Ma	achine Hour		1.88	US\$/mhr	crosscut		min
Machine Utilisation				57.6%		5.1 Machine Requirer	nents	_			place		min
Machine hours per Day				9.2	Hours	Annual Volume			126 000	m3	bunch		min
Machine hours per Annum				2 763	Hours	Hourly Volume Require	d		45.60	m3/hr	move		min
Machine Life Hours				15 000	Hours	Number Of Machines F	Required		3.00	#	other		min
Machine Life Years				5.43	Years	Fleet Reserve			0%		other		min
			-			Exact Number of Mach	ines Required		3.00	#	other		min
						Rounded number of ve	hicles Required		3	#	cycle time	0.00	min
1.4 OVERHEADS										-	cycle time	0.000	hrs
Annual Licence Fees & insurance	ce		1	14 286	USSS						Machine Output per Machine Hr	15.2	m3/mhr
			-								Machine Output per Day	140	m3/dav
1.5 Overheads		[	10.00%	30661	US\$s						Machine Output per Annum	42 000	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY							
	PE	R MACHIN	E	FLEET	%								
	US\$/hr U	S\$/month	US\$/year	US\$/year	of Total	US\$ per m3		8.03		100			
OVERHEADS	11.10	2 555	30 661	91 982	9.09%	Number of Machines		3					
FIXED COSTS	51.31	11 816	141 788	425 364	42.0%	Number of Operators		7					
Hp	27.23	6 269	75 233	225 700	22.39	6							
Crew	18.92	4 356	52 269	156 807	15.59	Machine Hours		8 289					
Licence Insurance	5.17	1 190	14 286	42 857	4.2%	Capital Employed	1	071 429					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		214 286					
VARIABLE COSTS	59.65	13 735	164 818	494 455	48.9%	Total Revenue	7	011 801					
Fuel	22.23	5 119	61 425	184 276	18.2%		_						
Lubrication	4.45	1 024	12 285	36 855	3.69	5							
Tyres	4.90	1 128	13 540	40 619	4.0%	b							
Maintenance	26.19	6 031	72 369	217 106	21.5%								
Relocation	1.88	433	337 267	15 600	1.5%								
TOTAL COST / REVENUE	122.00	20 100	331 201	1011601	100.0%	-					-		



MACHINE DESCRIPTION	:	Forwarde	r (Tigercat	1075) roadside							4	2
STUDY FOR	-	MSc	in or logs to	rouusiue							X	*
PREPARED BY		McEwan									1	SOLUTIONS
NOTE: ALL FIGURES QUOTED	ARE ESTIM	ATES, SITE S	PECIFIC & AS	SUME FULLY TR	RAINED OP	ERATORS						
1 1 CAPITAL EMPLOYED					_	2.1 VEHICLE OPERATING COSTS			-	3 1 LABOUR COSTS	-	100
Machine Price Exc VAT			Г	571 139	11550	Fuel Consumption	Г	22 1	Hr	Driver Wage	9.80	USSMOU
Lass Cost of Tures/Tracks/Ringin	00			571158	lisse	Fuel Cost		1 17 /	58/1	No Drivers/Shift	1.1	#
Dive additional equipment	Iradio			0	lisse	Oil % Euel Cost		15%	OWE	Labour Wage	0.00	USEMOU
Fius additional equipment	other			0	11580	Oil Cost	C.C.A	No Labourare/Shift	0.00	#		
	other			0	11000	Turas/Tracks/Bigging	L	0	SAL	Contributions	0.0%	-
	other			0	10535	Tyres/Tracks/Rigging	Cast	1.14.0		Contributions	0.0%	dava
	other			0	0535	City	COSI	Life		Operating Days/week	0.0	days
C. b. state and different and incoments	other			0	USAS	front	7 200	0		Operating Hours/week	96.0	HIS
Sub total additional equipment				0	USSS	rear 4	7 200	0		Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				571 139	0535	Tracks Eco 1	19 500	0		Total Overtime per week	6.0	Hrs
Annual Hp's				120 312	US\$s	other 0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation					1	other 0	0	0	1.1.1.1	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	114 228	US\$s	Fuel,Cost		25.74 0	S\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		3.86 0	S\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		0.00 U	S\$/mhr	Annual Time and a Half	2 205	US\$s
Monthly payment				10 026	US\$s	Annual Fuel Costs		80 309 U	S\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost		12 046 U	S\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigging Cost	L	0 0	S\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENANCE COST	s			Total Annual Crew Cost	56 889	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine life (mhr's		Total Crew Cost per Machine Hr	18.23	US\$/mhr		
Statutory Leave Days			1	13		Maintenance Cost		38.08 0	S\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost		118 797 U	S\$s	1		
Productive Days Lost to Weather/	Mill Stops			0		2.3 RELOCATION COSTS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Days	Number of moves per annum		4 #		Lead Distance		km
Shift length				8	Hours	Cost per Move 1 300 US\$			S\$s	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Cost	1	5 200 U	S\$s	travel empty		km/hr
Machine Availability			1	100.0%		Relocation Cost per Machine Hour		1.67 1	S\$/mhr	Load		min
Machine Utilisation				65.0%		5.1 Machine Requirements				travel loaded		km/hr
Machine hours per Day				10.4	Hours	Annual Volume		126 000 m	3	OffLoad		min
Machine hours per Annum				3 120	Hours	Hourly Volume Required		40.38 0	3/mhr	Travel time empty	#DIV/01	min
Machine Life Hours				15 000	Hours	Number Of Machines Required		1.00 #	Contra la	Travel time loaded	#DIV/01	min
Machine Life Years				4.81	Veare	Float Reserve		0%		Load	0.00	min
Machine Life reals			-	4.01	Tears	Field Reserve		1.00		Load	0.00	min
1.4.00/50015400						Exact Number of Machines Required		1.00 #			0.00	min
1.4 OVERHEADS						Rounded number of vehicles Required		1 #		cycle time	#DIV/01	min
			E		1					cycle time	#DIV/0!	hrs
Annual Licence Insurance Fees			L	22 846	US\$s					Machine Output per Hour	40.5	m3/mhr
					Luna					Machine Output per Day	421	m3/day
1.5 Overheads			10.00%	41640	US\$s				_	Machine Output per Annum	126 360	m3/year
0.1 SUMMART	_	DED MACHI	UE I	FIEFT	8/	0.2 FLEET SUMMART						
	US\$/hr	US\$/month	US\$/vear	US\$/vear	of Total	US\$ per m3	3.64		-			
OVERHEADS	43.95	3 470	41 640	44 840	0.004	Number of Machines	0.54	_		1		
EIVED COSTS	13.00	10 074	200.047	200 047	42 100	Number of Operators						
Line COSTS	20.50	10 071	100.04/	100 047	43.7%	reamber of Operators	Z					
Create	30.50	10 020	50 000	120 312	20.3%	Machine Maure	2 100					
Urew Income	18.23	4 /41	698.90	50 889	12.4%	Conital Employed	3 120					
Describe Tall face	1.32	1 804	22 846	22 846	5.0%	Desidual Value	5/1 139					
Permit & Ioli tees	0.0	10.010	0	0	0.0%	Residual Value	114 228					
VARIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	I otal Revenue	458 039					
Fuel	25.74	6 692	80 309	80 309	17.5%							
Lubrication	3.86	1 004	12 046	12 046	2.6%							
Maintenance	38.08	0000	118 797	118 707	25.0%							
Relocation	1.67	433	5 200	5 200	1,1%							
the state of the s	440.04	38 170	458 039	458 039	100.0%							



Harvester (CTL) System – Tree volume 0.40m<sup>3</sup>


SYSTEM DESCRIPTION		Harvester system
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan

	4
X	
Grown	FORESTRY
A LHAM	1
P.A.	ormerships

Locality	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$5.87	161 500	3	2	6.6	300
Forwarder (Tigercat 1075)			EXTENSION OF			\$2.84	161 500	1	2	2.2	300
				Total		\$8.70		4		8.8	
				-		\$0.00		0		0	
				TOTAL		\$8.70		4		8.8	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY	: H : F : N	larvester ( fell, delimi ISc IcEwan	Hitachi ZA) o, debarkin	kis200 with g, crosscut	SP591) and stac	k Euc pulp						ORESTRY
NOTE: ALL FIGURES QUOTED	ARE ESTIMAT	ES, SITE SP	ECIFIC & ASS	UME FULLY T	RAINED O	PERATORS					Sol and	
1.1 CAPITAL EMPLOYED			_			2.1 VEHICLE OPERATING	COSTS		_	3.1 LABOUR COSTS		-
Machine Price, Exc. VAT				357 143	US\$s	Fuel Consumption			19 L/Hr	Driver Wage	9.80	US\$/ho
Less Cost of Tyres/Tracks/Rigg	ng			0	US\$s	Fuel Cost		1	17 US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio		-	0	US\$s	Oil,% Fuel Cost		2	1%	Labour Wage	0.00	US\$/hou
	other			0	US\$s	Oil Cost			US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
	other			0	US\$s		Qty	Cost I	ife	Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400 3	00	Operating Hours/Week	96.0	days
Sub total additional equipment			8	0	US\$s	Chain	1	145	50	Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres	0	0	0	Total Overtime per week	6.0	Hrs
Annual HP payment			1	75 233	US\$s	other	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @		L	20.00%	71 429	US\$s	Fuel,Cost		22	23 USS/mh	Shift of Other Allowance	0.00	USS/day
nterest per annum				8.00%		OII, COST		4	45 US\$/mh	Annual Normal Time	51 744	0535
Payment period				60	months	Tyres/Tracks/Rigging Cost		4	90 USS/mh	Annual Time and a Hait	225	USAS
Monthly payment				6 269	US\$s	Annual Fuel Costs		53 5	18 0535	Annual Double Time	300	0535
						Annual Lube Cost		10 /	84 US38	Annual Bonus		USAS
1.3 OPERATING HOURS				205		Annual Tyre/Track/Rigging	CECOETE	110	85 0535	Tatal Annual Crew Cost	62.260	11580
Total Days				385		2.2 VEHICLE MAINTENAN	GE COSIS	14	10/	Total Annual Crew Cost	DZ 208	USAS
weekend Days				52		Maint, % Cap.Costmachine	me (mnrs)	26	10 11C C/mb	Total Crew Cost per Machine Hr	44	Jusamin
Statutory Leave Days				13	1.1.1.1	Annual Maintenance Cost		62 6	18 035/111			
SICK Leave Days	Mill Stops			0		2 3 PELOCATION COSTS		00 :	2010335	A 1 WORK STUDY ANALYSIS		
Froductive Days Lost to vveather	Mill Stops			300	Dave	Number of moves per sonu	m		4 #	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move		1 2	11580	fell	-	min
Shift engin				2	#	Annual Palacation Cost		5.7	11580	debranch / debark		min
Machine Availability				100.0%		Relocation Cost ner Machin	e Hour	2	14 US\$/mh	crossout		min
Machine I Itilisation				50.5%		5.1 Machine Requirement		-	000	place		min
Machine hours ner Day				81	Hours	Annual Volume		161.6	00 m3	bunch		min
Machine hours per Annum				2 425	Hours	Hourly Volume Required		66	58 m3/hr	move		min
Machine Life Hours				15 000	Hours	Number Of Machines Requi	red	3	00 #	other		min
Machine Life Years				6.18	Years	Fleet Reserve			%	other		min
			-			Exact Number of Machines	Required	3	00 #	other		min
						Rounded number of vehicle	s Required		3 #	cycle time	0.00	min
1.4 OVERHEADS								-		cycle time	0.000	hrs
Annual Licence Fees & insurance				14 286	US\$s					Machine Output per Machine Hr	22.2	m3/mhr
		-								Machine Output per Day	179	m3/day
1.5 Overheads			10.00%	28710	US\$s	and the second s			_	Machine Output per Annum	53 846	m3/year
5.1 SUMMARY						6.2 FLEET SUMMARY						
	PE	R MACHINE		FLEET	%	1000	-		_			
	US\$/hr U	S\$/month	US\$/year	US\$/year	of Total	US\$ per m3		5.87				
OVERHEADS	11.84	2 392	28 710	86 130	9.09%	Number of Machines		3				
FIXED COSTS	58,46	11 816	141 788	425 364	44.9%	Number of Operators		7				
Hp	31.02	6 269	75 233	225 700	23.8%	and the second		-				
Crew	21.55	4 356	52 269	156 807	16.6%	Machine Hours	1	7 276				
Licence Insurance	5,89	1 190	14 286	42 857	4.5%	Capital Employed	1 07	1 429				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	21	4 286				
VARIABLE COSTS	59.91	12 109	145 311	435 934	46.0%	Total Revenue	94	7 429				
Fuel	22.23	4 493	53 918	161 755	17.1%							
Lubrication	4.45	899	10 784	32 351	3.4%							
Vaintenance	4.90	5 294	63 525	35 655	3.8%							
Relocation	2 14	433	5 200	15 600	1.6%							
	100.00	26 247	345 840	047 420	100.00/							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY		Forwarder Extraction MSc McEwan	(Tigercat 1 of logs to i	075) roadside									ORESTRY
NOTE: ALL FIGURES QUOTED /	ARE ESTIMAT	res, site sp	ECIFIC & ASS	SUME FULLY TR	AINED OP	ERATORS						1	The state of the s
1.1 CAPITAL EMPLOYED Machine Price,Exc.VAT Less Cost of Tyres/Tracks/Riggin	ng		F	571 139	US\$s US\$s	2.1 VEHICLE OPERAT Fuel Consumption Fuel Cost	ING COSTS		22	L/Hr US\$/L	3.1 LABOUR COSTS Driver Wage No.Drivers/Shift	9.80	US\$/hour
Plus additional equipment	radio other			0	US\$s US\$s	Oil,% Fuel Cost Oil Cost			15%	US\$1	Labour Wage No.Labourers/Shift	0.00	US\$/hour #
	other			0	US\$s US\$s	front	Qty 4	Cost 7 200	Life 0	1	Operating Days/Week Operating Hours/Week	6.0 96.0	days Hrs
Sub total additional equipment Total Capital Employed Annual Hp's				0 571 139 120 312	US\$s US\$s US\$s	rear tracks Eco other	4 1 0	7 200 19 500 0	0		Basic Hours/week/driver Total Overtime per week Time and a Half per week	90.0 6.0 3.0	Hrs Hrs Hrs
1.2 HP Calculation				10000000	Lines	other	0	0	0		Double Time per Week	3.0	Hrs
Residual Value @ Interest per annum Payment period Monthly payment			20.00%	114 228 8.00% 60 10 026	months US\$s	Fuel,Cost Oil, Cost Tyres/Tracks/Rigging C Annual Fuel Costs	ost		25.74 3.86 0.00 80 309	US\$/mhr US\$/mhr US\$/mhr US\$s	Shift or Other Allowance Annual Normal Time Annual Time and a Half Annual Double Time	51 744 2 205 2 940	US\$s US\$s US\$s US\$s
1.3 OPERATING HOURS Total Days Weekend Days			F	365 52		Annual Lube Cost Annual Tyre/Track/Rigg 2.2 VEHICLE MAINTEN Maint,% Cap.Cost/mac	ing Cost. IANCE COSTS nine life (mhr's)		12 046 0 100%	US\$\$	Annual Bonus Annual Shift or Other Allowance Total Annual Crew Cost Total Crew Cost per Machine Hr	0 56 889 18.23	US\$s US\$s US\$s US\$/mhr
Statutory Leave Days Sick Leave Days Productive Days Lost to Weather/	Mill Stops			13 0 0		Maintenance Cost Annual Maintenance Co 2.3 RELOCATION COS	st		38.08 118 797	US\$/mhr US\$s	4.1 WORK STUDY ANALYSIS	_	
Total Annual Production Days Shift length Number of Shifts per day				300 8 2 100.0%	Days Hours #	Number of moves per a Cost per Move Annual Relocation Cost Relocation Cost per Ma	nnum		4 1 300 5 200	# US\$s US\$s	Lead Distance Volume per Load travel empty		km m3 km/hr min
Machine Utilisation Machine hours per Day Machine hours per Annum				65.0% 10.4 3 120	Hours Hours	5.1 Machine Requirem Annual Volume Hourly Volume Require	ents	-	161 500 51.76	m3 m3/mhr	travel loaded Off Load Travel time empty	#DIV/0!	km/ħr min min
Machine Life Hours Machine Life Years				<u>15 000</u> 4.81	Hours Years	Number Of Machines R Fleet Reserve Exact Number of Machi	equired		1.00 0% 1.00	#	Travel time loaded Load Off Load	#DIV/01 0.00 0.00	min min min
1.4 OVERHEADS Annual Licence Insurance Fees				22 846	US\$s	Rounded number of veh	icles Required		1	#	cycle time cycle time Machine Output per Hour	#DIV/01 #DIV/01 51.8	min hrs m3/mhr
1.5 Overheads		Г	10.00%	41640	115\$\$	1					Machine Output per Day Machine Output per Annum	539	m3/day m3/vear
6.1 SUMMARY						6.2 FLEET SUMMARY							
	P	ER MACHIN	E	FLEET	%	and the second second				_	-		
	US\$/hr L	IS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1	2.84		10.000			
EIXED COSTS	64.12	16 671	200 047	200 047	43.7%	Number of Operators	S	2					
Ho's	38.56	10 026	120 312	120 312	26.3%	and a special of a							
Crew	18.23	4 741	56 889	56 889	12.4%	Machine Hours		3 120					
Licence Insurance	7.32	1 904	22 846	22 846	5.0%	Capital Employed		571 139					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value		114 228					
VARIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	Total Revenue		458 039					
Fuel	25.74	6 692	80 309	80 309	17.5%								
Lubrication Tyres Maintenance	3.86 0.00 38.08	1 004 0 9 900	12 046 0 118 797	12 046 0 118 797	2.6% 0.0% 25.9%								
Relocation TOTAL COST / REVENUE	1.67 146.81	433 38 170	5 200 458 039	5 200 458 039	1.1%					_			-



Harvester (CTL) System – Tree volume 0.075m<sup>3</sup>



SYSTEM DESCRIPTION	1	Harvester system
OPERATION	:	Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$23.01	78 500	5	2	11	300
Forwarder (Tigercat 1075)						\$5.83	78 500	1	2	2.2	300
				Total		\$28.84		6		13.2	
						\$0.00		0		0	
				TOTAL		\$28.84		6		13.2	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTEI	D ARE ESTIMA	Harvester Fell, delin MSc McEwan TES, SITE S	(Hitachi ZA hb, debarkin PECIFIC & ASS	xis200 with ig, crosscut SUME FULLY 1	SP591) and stat	ck Euc pulp					DRESTAY
		-		_							made
1.1 CAPITAL EMPLOYED				257 442	11000	2.1 VEHICLE OPERATING COSTS		10 1 /14	S.1 LABOUR COSTS	0.00	licehour
Machine Price, Exc. VA1			-	357 143	0535	Fuel Cost		19 047	Driver wage	9.60	-US\$mour
Less Cost of Tyres/Tracks/Rig	ging			0	0535	Oil & Fuel Cost		1.17 USAL	No. Drivers/Snitt	0.00	"
Plus additional equipment	radio			0	11000	Oil Cost		11000	No Labourare/Shift	0.00	#
	other			0	11080	Tures/Tracks/Pigging		0342	Contributions	0.0%	
	other			0	11580	City	Cost	Life	Operating Days Meek	6.0	dave
	other			0	11555	Bar 1	400	200	Operating Hours/Week	96.0	days
Sub total additional equipment	t			0	US\$s	Chain 1	145	50	Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres 0	0	0	Total Overtime per week	6.0	Hrs
Annual HP payment				75 233	US\$s	other 0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other 0	0	0	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	71 429	US\$s	Fuel,Cost		22.23 US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		4.45 US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		4.90 US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				6 269	US\$s	Annual Fuel Costs		69 804 US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost		13 961 US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS			-			Annual Tyre/Track/Rigging Cost		15 386 US\$s	Annual Shift or Other Allowance	0	US\$s
Total Days				365		2.2 VEHICLE MAINTENANCE COST	s		Total Annual Crew Cost	52 269	US\$s
Weekend Days				52		Maint,% Cap.Cost/machine life (mhr/s	s)	110%	Total Crew Cost per Machine Hr	17	US\$/mhr
Statutory Leave Days				13		Maintenance Cost		26.19 US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cost		82 240 US\$s			
Productive Days Lost to Weath	er/Mill Stops			0		2.3 RELOCATION COSTS	-		4.1 WORK STUDY ANALYSIS		1
Total Annual Production Days				300	Days	Number of moves per annum		4 #	Average Tree Volume		<i>m</i> 3
Shift length				8	Hours	Cost per Move	-	1 300 US\$s	fell		min
Number of Shifts per day				2	#	Annual Relocation Cost		5 200 US\$s	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Machine Hour	-	1,66 US\$/mhr	crosscut		min
Machine Utilisation				65.4%		5.1 Machine Requirements			place		min
Machine hours per Day				10.5	Hours	Annual Volume	-	78 500 m3	bunch		min
Machine hours per Annum			-	3 140	Hours	Houriy Volume Required		25.00 m3/hr	move		min
Machine Life Hours				15 000	Vent	Floet Recence	-	0%	other		min
Machine Life Years				4.70	rears	Event Number of Machines Dequired		5.00 #	other		min
						Rounded number of vehicles Required		5.00 #	cycle time	0.00	min
1 4 OVERHEADS						Rounded number of venicles Require	- L		cycle time	0.000	bre
Annual Licence Fees & insuran	ca			14 286	USSS				Machine Output per Machine Hr	5.0	m3/mhr
			-		10000				Machine Output per Day	52	m3/day
1.5 Overheads			10.00%	32838	US\$s				Machine Output per Annum	15 700	m3/year
6.1 SUMMARY						6.2 FLEET SUMMARY					
	P	ER MACHIN	NE	FLEET	%	_					
and the second second	US\$/hr	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	23.01	100			
OVERHEADS	10.46	2 736	32 838	164 189	9.09%	Number of Machines	5				
FIXED COSTS	45.15	11 816	141 788	708 941	39.3%	Number of Operators	11				
Нр	23.96	6 269	75 233	376 167	20.8%	6					
Crew	18.65	4 356	52 269	261 345	14.59	Machine Hours	15 700				
Licence Insurance	4.55	1 190	14 286	71 429	4.0%	Capital Employed	1 785 715				
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value	357 143				
VARIABLE COSTS	59.42	15 549	186 591	932 954	51.7%	Total Revenue	1 806 084				
Fuel	22.23	5 817	69 804	349.019	19.3%						
Lubrication	4.45	1 163	13 961	69 804	3.9%	b.					
Maintenance	4.90	6 853	82 240	411 200	4.3%						
Relocation	1.66	433	5 200	26 000	1.4%						
TOTAL COST / REVENUE	115.03	30 101	361 217	1 806 084	100.0%						



MACHINE DESCRIPTION	N : 1	Forwarde	r (Tigercat 1	075)							1	4
STUDY FOR		Asc	t or logs to i	oadside							4	1
DREDARED BY	: :	McEwan									10	FORESTRY
NOTE: ALL EIGURES OUDTE	D ARE ESTIMA	TES SITE S				ERATORS						
NOTE. ALL PIGURES QUOTE	DAREESTINA	ES,SHE S	PECIFIC & ASS	OME FOLLT IN	CANNED OF	ENATORS					-4	ates
1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERA	TING COSTS			3.1 LABOUR COSTS		_
Machine Price Exc. VAT				571 139	US\$s	Fuel Consumption			22 L/Hr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	aging		1	0	USSS	Fuel Cost			1.17 USS/L	No. Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil.% Fuel Cost			15%	Labour Wage	0.00	US\$/hou
and the second s	other			0	USSS	Oil Cost			USSA	No.Labourers/Shift	0.0	#
	other			0	USSS	Tyres/Tracks/Rigging		_	-	Contributions	0.0%	
	other			0	USSS		Otv	Cost	Life	Operating Days/Week	6.0	davs
	other			0	USSS	front	4	7 200	0	Operating Hours/Week	96.0	Hrs
Sub total additional equipmen	t			0	USSS	rear	4	7 200	0	Basic Hours/week/driver	90.0	Hrs
Total Capital Employed				571 139	USSS	tracks Eco	1	19 500	0	Total Overtime per week	6.0	Hrs
Annual Ho's				120 312	USSS	other	0	0	0	Time and a Half per week	3.0	Hrs
1.2 HP Calculation					1	other	0	0	0	Double Time per Week	3.0	Hrs
Residual Value @		[	20.00%	114 228	USSS	Fuel.Cost			25.74 USS/n	hr Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			3.86 USS/n	hr Annual Normal Time	51 744	USSS
Payment period				60	months	Tyres/Tracks/Rigging	Cost		0.00 USS/n	hr Annual Time and a Half	2 205	US\$s
Monthly payment				10 026	USSS	Annual Fuel Costs	2271	1	80 309 US\$s	Annual Double Time	2 940	US\$s
functional bulliness			-			Annual Lube Cost			12 046 1/555	Annual Bonus	0	USSS
13 OPERATING HOURS						Annual Tyre/Track/Rig	ing Cost		0 1/585	Annual Shift or Other Allowance		USSS
Total Days				365		2.2 VEHICLE MAINTE	NANCE COSTS	_		Total Annual Crew Cost	56 885	USSS
Weekend Days				52		Maint % Cap Cost/ma	chine life (mhr's)		100%	Total Crew Cost per Machine Hr	18.23	USS/mhr
Statutory Leave Dave				13		Maintenance Cost			38.08 1155/0	thr	10,110	
Sick Leave Dave				0		Annual Maintenance C	Cost		118 797 11585			
Productive Days	er/Mill Stons			0		2 3 RELOCATION CO	ISTS		110 101 0000	4 1 WORK STUDY ANALYSIS		
Total Annual Production Days	Contrained Cooper			300	Davs	Number of moves per	annum		4 #	Lead Distance		km
Shift length				8	Hours	Cost per Move	diritari'		1 300 US\$5	Volume per Load		m3
Number of Shifts per day				2	#	Annual Relocation Co	st	100	5 200 US\$s	travel empty		km/hr
Machine Availability				100.0%		Relocation Cost per M	lachine Hour		1.67 US\$/n	hr Load		min
Machine Utilisation				65.0%		5.1 Machine Require	ments			travel loaded		km/hr
Machine hours per Day				10.4	Hours	Annual Volume		1	78 500 m3	Off Load		min
Machine hours per Annum				3 120	Hours	Hourly Volume Requir	ed	100	25.16 m3/m	r Travel time empty	#DIV/0!	min
Machine Life Hours				15 000	Hours	Number Of Machines	Required		1.00 #	Travel time loaded	#DIV/0!	min
Machine Life Years				4.81	Years	Fleet Reserve			0%	Load	0.00	min
			_			Exact Number of Mach	hines Required		1.00 #	Off Load	0.00	min
14 OVERHEADS						Rounded number of ve	ehicles Required	1	1 #	cycle time	#DIV/0!	min
1								_		cycle time	#DIV/01	hrs
Annual Licence Insurance Fees			1	22 846	USSS					Machine Output per Hour	25.2	m3/mhr
			_							Machine Output per Day	262	m3/day
1.5 Overheads		[	10.00%	41640	USSS					Machine Output per Annum	78 624	m3/vear
6.1 SUMMARY						6.2 FLEET SUMMAR	Y					
and the second sec	P	ER MACHIN	IE .	FLEET	%							
	US\$/hr U	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		5.83				
OVERHEADS	13.35	3 470	41 640	41 640	9.09%	Number of Machines		1				
FIXED COSTS	64.12	16 671	200 047	200 047	43.7%	Number of Operators		2				
Hp's	38.56	10 026	120 312	120 312	26.3%	1		-				
Crew	18.23	4 741	56 889	56 889	12.4%	Machine Hours		3 120				
Licence Insurance	7.32	1 904	22 846	22 846	5.0%	Capital Employed	1.00	571 139				
Permit & Toll fees	0.0	-	0	0	0.0%	Residual Value		114 228				
VARIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	Total Revenue	2.0	458 039				
Fuel	25.74	6 692	80 309	80 309	17.5%		_					
Lubrication	3.86	1 004	12 046	12 046	2.6%							
Tyres	0.00	0	0	0	0.0%	2						
Maintenance	38.08	9 900	118 797	118 797	25.9%	2						
TOTAL COST / REVENUE	146.81	38 170	458 039	458 039	100.0%							
Letter boot the tertor	144/41			100 000	10010/1							



Harvester (CTL) System – Tree volume 0.15m<sup>3</sup>



:	Harvester system
:	Stump to Mill
:	MSc
:	McEwan
	:



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Locality	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$12.45	111 000	4	2	8.8	300
Forwarder (Tigercat 1075)						\$4.13	111 000	1	2	2.2	300
				Total		\$16.57		5		11	
				100 m		\$0.00		0		0	
				TOTAL		\$16.57		5		11	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED /	: F : F : N : N ARE ESTIMAT	Harvester Fell, delim MSc McEwan TES, SITE SP	(Hitachi ZA b, debarkin PECIFIC & AS	Axis200 with ng, crosscut SUME FULLY T	SP591) and stac	e <b>k Euc pulp</b> PERATORS						And Description
11 CAPITAL EMPLOYED				_	-	2.1 VEHICLE OPERATI	G COSTS				3.1 LABOUR COSTS	
Machine Price Exc VAT				357 143	USSS	Fuel Consumption	1.01040		19	Ar	Driver Wage	9.80 US
Less Cost of Turge/Tracks/Riggin	a			007 140	11580	Fuel Cost			1 17	158/1	No Drivers/Shift	11#
Dive additional equipment	radio			0	11550	Oil % Fuel Cost			20%	JOWE	Labour Wage	0.00 US
rius additional equipment	other			0	11580	Oil Cost			2010	158/	No Labourare/Shift	0.0 #
	other			0	11000	Turge Tracks Diaging				JOWL	Costributions	0.0%
	outer			0	10000	Tyres/Tracks/Rigging	Obi	Cost	1160		Contributions	6.0 de
	other			0	0535		City	Cost	Lite		Operating Days/week	6.0 day
	other			0	US\$s	Bar	1	400	200		Operating Hours/Week	96.0 day
Sub total additional equipment				0	US\$s	Chain	1	145	50		Basic Hours/week	90.0 Hrs
Total Capital Employed				357 143	US\$s	Tyres	0	0	0		Total Overtime per week	6.0 Hrs
Annual HP payment				75 233	US\$s	other	0	0	0		Time and a Half per week	3.0 Hrs
1.2 HP Calculation		-				other	0	0	0		Double Time per Week	3.0 Hrs
Residual Value @		L	20.00%	71 429	US\$s	Fuel,Cost		1	22.23	US\$/mhr	Shift or Other Allowance	0.00 US
Interest per annum				8.00%	0	Oil, Cost			4.45	US\$/mhr	Annual Normal Time	51 744 US
Payment period				60	months	Tyres/Tracks/Rigging Co	st		4.90	US\$/mhr	Annual Time and a Half	225 US
Monthly payment				6 269	US\$s	Annual Fuel Costs			64 260	US\$s	Annual Double Time	300 US
			-			Annual Lube Cost			12 852	US\$s	Annual Bonus	0 US
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	na Cost		14 164	US\$s	Annual Shift or Other Allowance	0 US
Total Dave				365		2.2 VEHICLE MAINTEN	ANCE COSTS	_			Total Annual Crew Cost	52 269 US
Mashad Dave			F	62		Maint % Can Cost/mach	na life (mbrie)		110%		Total Crew Cost per Machine Hr	18 115
weekend Days				52		Maint, 70 Cap. Costmach	ne me (nun s)		00.40	in Plantes	Total Crew Cost per machine rir	10 00
Statutory Leave Days				13		Maintenance Cost			20.19	JSSymnr		
Sick Leave Days				0		Annual Maintenance Cos	4		75 709	JS\$S		
Productive Days Lost to Weather/	Mill Stops			0		2.3 RELOCATION COS	S				4.1 WORK STUDY ANALYSIS	
Total Annual Production Days				300	Days	Number of moves per an	num	0	4 4		Average Tree Volume	m3
Shift length				8	Hours	Cost per Move			1 300	JS\$s	fell	min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	JS\$s	debranch / debark	min
Machine Availability				100.0%		Relocation Cost per Mac	hine Hour		1.80	JS\$/mhr	crosscut	min
Machine Utilisation				60.2%		5.1 Machine Requireme	ents	-			place	min
Machine hours per Day				9.6	Hours	Annual Volume			111 000	m3	bunch	min
Machine hours per Annum				2 891	Hours	Hourly Volume Required		1	38.40	m3/hr	move	min
Machine Life Hours				15 000	Hours	Number Of Machines Re	quired		4.00		other	min
Machine Life Years				5 19	Veare	Fleet Reserve	4-0.3-		0%		other	min
Machine che reara			-	0.10	10010	Exact Number of Machin	es Dequired		4.00		other	min
						Deunded number of watching	es Required		4.00		outlet time	0.00
1 CONTRACTOR						Rounded number of vehi	ues required	1	4		cycle une	0.00 min
1.4 OVERHEADS					E.i.e						cycle time	0.000 hrs
Annual Licence Fees & insurance			L	14 286	0555						Machine Output per Machine Hr	9.6 m3
		-									Machine Output per Day	93 m3
1.5 Overheads			10.00%	31397	US\$s					-	Machine Output per Annum	27 751 m3
6.1 SUMMARY					_	6.2 FLEET SUMMARY					the second se	
	PI	ER MACHIN	E	FLEET	%		-					
	US\$/hr L	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	1000	12.45		-	4	
OVERHEADS	10.86	2 615	31 397	125 589	9.09%	Number of Machines		4				
FIXED COSTS	49.05	11 816	141 788	567 152	41.1%	Number of Operators	1	9				
Hp	26.03	6 269	75 233	300 934	21.8%	and the second sec						
Crew	18.0B	4 358	52 269	209 076	15.1%	Machine Hours	1.000	11 563				
Licence Insurance	4.94	1 190	14 286	57 143	4.1%	Capital Employed	14	28 572				
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	2	85 714				
VADIADI E COSTE	50.57	14 240	172 185	699 740	40.0%	Total Revenue	4.2	81 482				
VARIABLE CUSIS	09.07	14 349	1/2 105	000 740	49.3%	rotal Revenue	13	01 402				
Fuel	22.23	5 355	64 260	257 040	18.6%							
Lubrication	4.45	1071	12 852	51 408	3.7%							
l yres Maintenance	9.90	6 300	75 700	302 834	9.1%							
Pelocation	1.80	433	5 200	20 800	1,5%						1	
				0000	10							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: Forw : Extra : MSc : Fore: ARE ESTIMATES,S	varder (Tigercat action of logs to stry Solutions SITE SPECIFIC & AS	1075) roadside sume fully TRA	INED OP	ERATORS							ORESTRY
1.1 CAPITAL EMPLOYED Machine Price,Exc VAT Less Cost of Tyres/Tracks/Rigg Plus additional equipment	radio other other other		571 139 0 0 0 0 0 0 0 0 0 0 0	US\$s US\$s US\$s US\$s US\$s	2.1 VEHICLE OPERATIN Fuel Consumption Fuel Cost Oil % Fuel Cost Oil Cost Tyres/Tracks/Rigging	Qty	Cost	L/Hr US\$/L US\$/L	3.1 LABOUR COSTS Driver Wage No. Drivers/Shift Labour Wage No. Labourers/Shift Contributions Operating Days/Week	9.80 1.1 0.00 0.0 0.0% 6.0	US\$/hour # US\$/hour # days	
Sub total additional equipment Total Capital Employed Annual Hp's 1.2 HP Calculation	other		0 ( 0 ( 571 139 ( 120 312 (	US\$8 US\$8 US\$8 US\$8	front rear tracks Eco other other	4 4 1 0 0	0	000000		Operating Hours/Week Basic Hours/Week/driver Total Overtime per week Time and a Half per week Double Time per Week	96.0 90.0 6.0 3.0 3.0	Hrs Hrs Hrs Hrs Hrs
Residual Value @ Interest per annum Payment period Monthly payment		20.00%	114 228 ( 8.00% 60 r 10 026 (	JS\$s months JS\$s	Fuel, Cost Oil, Cost Tyres/Tracks/Rigging Cos Annual Fuel Costs Annual Lube Cost	st		US\$/mhr US\$/mhr US\$/mhr US\$s US\$s	Shift or Other Allowance Annual Normal Time Annual Time and a Half Annual Double Time Annual Bonus	0.00 51 744 2 205 2 940 0	US\$/day US\$s US\$s US\$s US\$s	
1.3 OPERATING HOURS Total Days Weekend Days Statutory Leave Days Sick Leave Days		365 52 13 0		Annual Tyre/Track/Rigging Cost         0 US\$s           2.2 VEHICLE MAINTENANCE COSTS         100%           Maint,% Cap.Cost/machine life (mhr's)         100%           Maintenance Cost         38.08         US\$r           Annual Maintenance Cost         118.797         118.797					Annual Shift or Other Allowance Total Annual Crew Cost Total Crew Cost per Machine Hr	0 56 889 18.23	US\$s US\$s US\$/mhr	
Productive Days Lost to Weather Total Annual Production Days Shift length Number of Shifts per day Machine Availability	0 300 0 8 / 2 # 100.0%	Days Hours	2.3 RELOCATION COSTS           Number of moves per annum         4           Cost per Move         1 300           Annual Relocation Cost         5 200           Relocation Cost per Machine Hour         1.87					4.1 WORK STUDY ANALYSIS Lead Distance Volume per Load travel empty Load		km m3 km/hr min		
Machine Utilisation Machine hours per Day Machine hours per Annum Machine Life Hours Machine Life Years			65.0% 10.4 3 120 15 000 4.81	Hours Hours Hours Years	5.1 Machine Requirements           Annual Volume         111 000 m3           Hourly Volume Required         35.58 m3/n           Number Of Machines Required         1.00 #           Fleet Reserve         0%				m3 m3/mhr #	travel loaded Off Load Travel time empty Travel time loaded Load	#DIV/01 #DIV/01 0.00	km/hr min min min min
1.4 OVERHEADS Annual Licence Insurance Fees		[	22 846	JS\$s	Exact Number of Machine Rounded number of vehic	es Required		1.00	#	Off Load cycle time cycle time Machine Output per Hour Machine Output per Day	0.00 #DIV/0! #DIV/0! 35.7 371	min min hrs m3/mhr m3/day
1.5 Overheads		10.00%	41640	JS\$s					_	Machine Output per Annum	111 384	m3/year
6.1 SUMMARY	PER M. US\$/hr US\$/m	ACHINE nonth US\$/year	FLEET US\$/year	% of Total	6.2 FLEET SUMMARY		4.13	1	-21			
OVERHEADS FIXED COSTS Hp's	13.35 3 64.12 16 38.56 10	3 470         41 640           6 671         200 047           0 026         120 312	41 640 200 047 120 312	9.09% 43.7% 26.3%	Number of Machines Number of Operators		1 2					
Crew Licence Insurance Permit & Toll fees	18.23 7.32 0.0	4 741 56 889 1 904 22 846 0	56 889 22 846 0	12.4% 5.0% 0.0%	Machine Hours Capital Employed Residual Value		3 120 571 139 114 228					
VARIABLE COSTS Fuel Lubrication Tyres	69.34 18 25.74 6 3.86 1 0.00	8 029 216 352 6 692 80 309 1 004 12 046 0 0	216 352 80 309 12 046 0	47.2% 17.5% 2.6% 0.0%	Total Revenue		458 039					
Maintenance Relocation TOTAL COST / REVENUE	38.08 \$ 1.67 146.81 38	9 900 118 797 433 5 200 8 170 458 039	118 797 5 200 458 039	25.9% 1.1% 100.0%								



Harvester (CTL) System – Tree volume 0.25m<sup>3</sup>



SYSTEM DESCRIPTION	:	Harvester system
OPERATION		Stump to Mill
STUDY FOR	:	MSc
PREPARED BY	:	McEwan



Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$8.03	126 000	3	2	6.6	300
Forwarder (Tigercat 1075)						\$3.64	126 000	1	2	2.2	300
				Total		\$11.67		4		8.8	
						\$0.00		0		0	
				TOTAL		\$11.67		4		8.8	



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED AF	: I : I : I RE ESTIMA	Harvester Fell, delim MSc McEwan TES, SITE SF	(Hitachi ZA b, debarkii PECIFIC & AS	Axis200 with ng, crosscut SUME FULLY T	SP591) and sta	ek Euc pulp					and	DRESTRY
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATING COST	5	-	_	3.1 LABOUR COSTS	1	
Machine Price, Exc. VAT				357 143	US\$s	Fuel Consumption	Г	19	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rigging				0	US\$s	Fuel Cost		1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost		20%	100	Labour Wage	0.00	US\$/hour
c	other			0	US\$s	Oil Cost			US\$/L	No.Labourers/Shift	0.0	#
c	other			0	US\$s	Tyres/Tracks/Rigging				Contributions	0.0%	
q	other			0	US\$s	Qty	Cost	Life		Operating Days/Week	6.0	days
6	other			0	US\$s	Bar 1	400	200	100	Operating Hours/Week	96.0	days
Sub total additional equipment				0	US\$s	Chain 1	145	50		Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres 0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment	_			75 233	US\$s	other 0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other 0	0	0		Double Time per Week	3.0	Hrs
Residual Value @		L	20.00%	71 429	US\$s	Fuel,Cost		22.23	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost		4.45	USS/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Cost		4,90	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment			1	6 269	0535	Annual Fuel Costs		01 425	USSS	Annual Double Time	300	0535
						Annual Lube Cost		12 285	USas	Annual Bonus	0	0535
1.3 OPERATING HOURS				0.05	1	Annual Tyre/Track/Rigging Cost	CTC.	13 540	US\$S	Annual Shift or Other Allowance	0	US\$S
Total Days			-	365		2.2 VEHICLE MAINTENANCE CO	515		1	Total Annual Crew Cost	52 269	USAS
Weekend Days				52		Maint, % Cap.Cost/machine life (mi	nrs)	110%		Total Crew Cost per Machine Hr	19	USSymnr
Statutory Leave Days				13		Maintenance Cost		26,19	USS/mhr			
Sick Leave Days				0		Annual Maintenance Cost		72 369	US\$s			
Productive Days Lost to Weather/Mi	ill Stops			0	0.00	2.3 RELOCATION COSTS	E.		1.	4.1 WORK STUDT ANALTSIS	_	
Total Annual Production Days			-	300	Days	Number of moves per annum		4 200	#	Average Tree Volume		ma
Shift length				0	Hours	Cost per Move		1 300	10535	tell		min
Number of Shifts per day				100.0%	"	Relocation Cost		1 99	US\$S	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Machine Hour		1.00	USUMA	crosscut		min
Machine Utilisation				57.0%	Haura	Annual Valume	E	126 000	-2	busch		min
Machine hours per Day				2 763	Hours	Hourly Volume Required		45 60	m3/hr	movie		min
Machine Life Hours				15 000	Hours	Number Of Machines Required		3.00	#	other		min
Machine Life Vears				5.43	Vaare	Fleet Reserve		0%	-	other		min
machine Life rears			1	0,43	1 roars	Event Number of Machines Require	4	3.00		other		min
						Rounded number of vehicles Require	rad	3.00		cusia time	0.00	min
1 4 OVERHEADS						Rounded number of venicles Requi	L		1	cycle time	0.000	hre
Appual Licence Feet & insurance			E.	14 286	lusse					Machine Output per Machine Hr	15.2	m3/mhr
Annual Licence Pees & Insurance				14 200	10040					Machine Output per Machine Fil	140	m3/day
15 Overheade			10.00%	30661	11580					Machine Output per Day	42 000	m3/vear
6.1 SUMMARY		-	10.00101		0000	6.2 FLEET SUMMARY		-	-			
<b>Г</b>	P	ER MACHIN	E	FLEET	%	1						
	US\$/hr	JS\$/month	US\$/year	US\$/year	of Total	US\$ per m3	8.03					
OVERHEADS	11.10	2 555	30 661	91 982	9.099	Number of Machines	3			1		
FIXED COSTS	51.31	11 816	141 788	425 364	42.09	Number of Operators	7					
Hp	27.23	6 269	75 233	225 700	22.39		_					
Crew	18.92	4 356	52 269	156 807	15.59	Machine Hours	8 289					
Licence Insurance	5.17	1 190	14 286	42 857	4.29	Capital Employed	1 071 429					
Permit & Toll fees	0.0		0	0	0.09	Residual Value	214 286					
VARIABLE COSTS	59.65	13 735	164 818	494 455	48.99	Total Revenue	1 011 801					
Fuel	22.23	5 119	61 425	184 276	18.29							
Lubrication	4.45	1 024	12 285	36 855	3.69							
Tyres	4.90	1 128	13 540	40 619	4.09							
Maintenance	26.19	6.031	72 369	217 106	21.59							
L MAIOCALIÓD	1.89	422	5 200	15 600	1 40							



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY		Forwarder Extraction MSc McEwan	(Tigercat 1 of logs to r	075) roadside									ORESTRY
IOTE: ALL FIGURES QUOTED	ARE ESTIMAT	TES, SITE SP	PECIFIC & ASS	UME FULLY TR	AINED OP	ERATORS	_					-	100
1 CAPITAL EMPLOYED	_		-			2.1 VEHICLE OPERA	TING COSTS	_			3.1 LABOUR COSTS		
fachine Price, Exc. VAT				571 139	US\$s	Fuel Consumption			22	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Rigg	ing			0	US\$s	Fuel Cost			1.17	US\$1L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			15%		Labour Wage	0.00	US\$/hour
	other			0	US\$s	Oil Cost				US\$1L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s	1	Qty	Cost	Life	6 m a 1	Operating Days/Week	6.0	days
	other			0	US\$s	front	4	7 200	0		Operating Hours/Week	96.0	Hrs
Sub total additional equipment				0	US\$s	rear	4	7 200	0		Basic Hours/week/driver	90.0	Hrs
tal Capital Employed				571 139	US\$s	tracks Eco	1	19 500	0		Total Overtime per week	6.0	Hrs
nual Hp's				120 312	US\$s	other	O	0	0		Time and a Half per week	3.0	Hrs
HP Calculation						other	0	0	0		Double Time per Week	3.0	Hrs
sidual Value @			20.00%	114 228	US\$s	Fuel,Cost			25.74	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
erest per annum		1.1		8.00%		Oil, Cost			3.86	US\$/mhr	Annual Normal Time	51 744	US\$s
yment period				60	months	Tyres/Tracks/Rigging (	Cost		0.00	US\$/mhr	Annual Time and a Half	2 205	USSS
onthly payment				10 026	USSS	Annual Fuel Costs			80 309	US\$s	Annual Double Time	2 940	US\$s
						Annual Lube Cost			12 046	USSS	Annual Bonus	0	USSS
OPERATING HOURS						Annual Tyre/Track/Rig	ging Cost		0	US\$s	Annual Shift or Other Allowance	0	US\$s
tal Davs			0	365		2.2 VEHICLE MAINTE	NANCE COSTS	_			Total Annual Crew Cost	56 889	US\$s
ekend Days				52		Maint % Cap.Cost/mac	chine life (mhr's)		100%		Total Crew Cost per Machine Hr	18.23	US\$/mhr
atutory Leave Days				13		Maintenance Cost	and a local state of the set		38.08	US\$/mhr	Company and the second second second		
k Leave Days				0		Annual Maintenance C	ost		118 797	US\$s			
ductive Days Lost to Weather	Mill Stops			0		2.3 RELOCATION CO	STS				4.1 WORK STUDY ANALYSIS		
tal Annual Production Days	and a second			300	Davs	Number of moves per a	annum		4		Lead Distance		km
ft length				8	Hours	Cost per Move			1 300	115.54	Volume per Load		m3
mber of Shifts per day				2	#	Annual Relocation Cos	t		5 200	USSS	travel empty		km/hr
chine Availability				100.0%		Relocation Cost per Ma	achine Hour		1.67	US\$/mhr	Load		min
chine Utilisation				65.0%		5.1 Machine Requirer	nents				travel loaded		km/hr
chine hours per Day				10.4	Hours	Annual Volume			126 000	m3	Offload		min
chine hours per Annum				3 120	Hours	Hourly Volume Require	d		40.38	m3/mhr	Travel time empty	#01/01	min
chine Life Hours				15 000	Hours	Number Of Machines F	Required		1.00	#	Travel time loaded	#DIV/01	min
chine Life Years				4.81	Years	Fleet Reserve	toquirou		0%	-	Load	0.00	min
					, ours	Exact Number of Mach	ines Required		1.00		Offload	0.00	min
OVERHEADS						Rounded number of ve	hicles Required		100		cucle time	#00//01	min
						in a second of the second of the	and a second	_		-	cycle time	#DIV/OI	hrs
nual Licence Insurance Fees				22 846	USSS						Machine Output per Hour	40.5	m3/mhr
			-								Machine Output per Day	424	m3/day
Overheads		Г	10.00%	41640	USSS						Machine Output per Annum	126 360	m3/vear
SUMMARY						6.2 FLEET SUMMARY							
	PI	ER MACHINI	E	FLEET	%								
	US\$/hr L	IS\$/month	US\$/year	US\$/year	of Total	US\$ per m3		3.64	1				
ERHEADS	13.35	3 470	41 640	41 640	9.09%	Number of Machines	1	1					
ED COSTS	64.12	16 671	200 047	200 047	43.7%	Number of Operators		2					
	38.56	10.026	120 312	120 312	28 3%	and a second		-					
N	18.23	4 741	56 889	56 889	12 4%	Machine Hours		3 120					
ance insurance	7.32	1 904	22 846	22 846	5.0%	Capital Employed	100	571 139					
mit & Toll fees	0.0		0	0	0.0%	Residual Value	8	114 228					
RIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	Total Revenue		458 039					
	25.74	6 600	80 300	80 200	57 564	i otor i tovoliue		400 000					
rication	2.00	1.004	12 048	12 046	2.62								
es	0.00	0	0	12 040	0.0%								
intenance	38.08	9 900	118 797	118 797	25.9%								
ocation	1.67	433	5 200	5 200	1.1%								
TAL COST / REVENUE	146.81	38 170	458 039	458 039	100.0%					-			



Harvester (CTL) System – Tree volume 0.40m<sup>3</sup>



SYSTEM DESCRIPT OPERATION STUDY FOR PREPARED BY	TION		Harvester s Stump to M MSc McEwan	system Iill						- ADAVE 51	FORESTRY
Locality Activity	Stand	Extraction route	Roadside Landing	Forest Road	Millyard	Cost (US\$/m3)	Annual System Production	Equip #	# of shifts	Staff #	Working days / annum
Harvester (Hitachi ZAxis200 with SP591)						\$5.87	161 500	3	2	6.6	300
Forwarder (Tigercat 1075)						\$2.84	161 500	1	2	2.2	300
				Total		\$8.70		4		8.8	
				TOTAL		\$8.70		4		8.8	



MACHINE DESCRIPTION OPERATION	N :	Harvester Fell, delin	<ul> <li>Hitachi ZA</li> <li>debarkir</li> </ul>	xis200 with	SP591) and star	ck Euc pulp						人理	
STUDY FOR	: 1	MSc	C. K. C. C. C.									Ĩ	-
PREPARED BY	: 1	McEwan											OLUTIONS
NOTE: ALL FIGURES QUOTE	D ARE ESTIMA	TES, SITE S	PECIFIC & AS	SUME FULLY T	RAINED C	PERATORS						See. A	
1.1 CAPITAL EMPLOYED			-			2.1 VEHICLE OPERATI	NG COSTS	-	_		3.1 LABOUR COSTS		
Machine Price, Exc. VAT				357 143	US\$s	Fuel Consumption			19	L/Hr	Driver Wage	9.80	US\$/hou
Less Cost of Tyres/Tracks/Rig	gging			10	US\$s	Fuel Cost			1.17	US\$/L	No.Drivers/Shift	1.1	#
Plus additional equipment	radio			0	US\$s	Oil,% Fuel Cost			20%		Labour Wage	0.00	US\$/hou
	other			0	US\$s	Oil Cost				US\$/L	No.Labourers/Shift	0.0	#
	other			0	US\$s	Tyres/Tracks/Rigging					Contributions	0.0%	
	other			0	US\$s		Qty	Cost	Life		Operating Days/Week	6.0	days
	other			0	US\$s	Bar	1	400	200		Operating Hours/Week	96.0	days
Sub total additional equipment	nt			0	US\$s	Chain	1	145	50		Basic Hours/week	90.0	Hrs
Total Capital Employed				357 143	US\$s	Tyres	0	0	0		Total Overtime per week	6.0	Hrs
Annual HP payment				75 233	US\$s	other	0	0	0		Time and a Half per week	3.0	Hrs
1.2 HP Calculation						other	0	0	0	_	Double Time per Week	3.0	Hrs
Residual Value @			20.00%	71 429	US\$s	Fuel,Cost			22.23	US\$/mhr	Shift or Other Allowance	0.00	US\$/day
Interest per annum				8.00%		Oil, Cost			4.45	US\$/mhr	Annual Normal Time	51 744	US\$s
Payment period				60	months	Tyres/Tracks/Rigging Co	st		4.90	US\$/mhr	Annual Time and a Half	225	US\$s
Monthly payment				6 269	US\$s	Annual Fuel Costs			53 918	US\$s	Annual Double Time	300	US\$s
						Annual Lube Cost			10 784	US\$s	Annual Bonus	0	US\$s
1.3 OPERATING HOURS						Annual Tyre/Track/Riggi	ng Cost		11 885	US\$s	Annual Shift or Other Allowance	0	US\$s
Total Davs				365		2.2 VEHICLE MAINTEN	ANCE COSTS				Total Annual Crew Cost	52 269	US\$s
Weekend Days			1	52	1	Maint,% Cap.Cost/mach	ine life (mhr's)		110%		Total Crew Cost per Machine Hr	22	US\$/mhr
Statutory Leave Days				13		Maintenance Cost		17	26.19	US\$/mhr			
Sick Leave Days				0		Annual Maintenance Cos	it		63 525	US\$s			
Productive Days Lost to Weath	ner/Mill Stops			0		2.3 RELOCATION COST	TS				4.1 WORK STUDY ANALYSIS		
Total Annual Production Days				300	Davs	Number of moves per an	num		4	#	Average Tree Volume		m3
Shift length				8	Hours	Cost per Move			1 300	USSS	feli		min
Number of Shifts per day				2	#	Annual Relocation Cost			5 200	USSS	debranch / debark		min
Machine Availability				100.0%		Relocation Cost per Mac	hine Hour	1.0	2.14	US\$/mhr	crosscut		min
Machine   Itilisation				50.5%		5 1 Machine Requireme	onte	-		0 Outinin	nlace		min
Machine bours per Day				81	Hours	Annual Volume			161 500	m3	hunch		min
Machine hours per boy				2 425	Hours	Hourly Volume Required			66 58	m3/br	mone		min
Machine Life Hours			F	15 000	Hours	Number Of Machines De	nuired		2.00	#	other		min
Machine Life Veare				6.18	Veare	Fleet Decesso	quired		0.00	~	other		min
Machine Life Years				0,10	rears	Freet Neserve	on Demuired		2.00		other		min
						Exact Number of Machin	es Required		3.00		other		min
LA OUTDUILLES						Rounded number of vehi	cles Required		3	#	cycle time	0.00	min
1.4 OVERHEADS					luni						cycle time	0.000	nrs
Annual Licence Fees & insuran	ce			14 285	US\$s						Machine Output per Machine Hr	22.2	m3/mhr
			10.000		lune						Machine Output per Day	179	m3/day
1.5 Overheads			10.00%	28710	US\$s	A DELEET CUMMADY					Machine Output per Annum	53 846	m3/year
0.1 SUMMART		CD MACHIN		EL CET		0.2 FLEET SUMMART							
	P	ER MACHIN	NE.	FLEET	%						•		
	US\$/hr C	IS\$/month	US\$/year	US\$/year	of lotal	US\$ per m3		5.87					
OVERHEADS	11.84	2 392	28 710	86 130	9.09%	Number of Machines		3					
FIXED COSTS	58.46	11 816	141 788	425 364	44.9%	Number of Operators		7					
нр	31.02	6 269	75 233	225 700	23.8%		-						
Crew	21.55	4 356	52 269	156 807	16.6%	Machine Hours		7 276					
Licence Insurance	5,89	1 190	14 286	42 857	4.5%	Capital Employed	1	071 429					
Permit & Toll fees	0.0	1000	0	0	0.0%	Residual Value		214 286					
VARIABLE COSTS	59.91	12 109	145 311	435 934	48.0%	Total Revenue		947 429					
Fuel	22.23	4 493	53 918	161 755	17.1%	•							
Lubrication	4.45	899	10 784	32 351	3.4%								
Maintenance	4,90	5 294	83 525	35 655	3.8%								
Relocation	2.14	433	5 200	15 600	1.6%								
TOTAL COST / REVENUE	130.20	26 317	315 810	947 429	100.0%								



MACHINE DESCRIPTION OPERATION STUDY FOR PREPARED BY NOTE: ALL FIGURES QUOTED	: F : F : F : F : F : F : F : F : F : F	orwarder Extraction MSc McEwan res, site sp	(Tigercat 1 of logs to r PECIFIC & ASS	075) roadside SUME FULLY TR	AINED OP	ERATORS							ORESTRY
1.1 CAPITAL EMPLOYED						2.1 VEHICLE OPERATING	COSTS				3.1 LABOUR COSTS		
Machine Price Exc VAT				571 139	USSS	Fuel Consumption			22	L/Hr	Driver Wage	9.80	US\$/hour
Less Cost of Tyres/Tracks/Riggi	na			0	USSS	Fuel Cost			1.17	US\$/L	No. Drivers/Shift	1.1	#
Plus additional equipment	radio			0	USSS	Oil % Fuel Cost			15%		Labour Wage	0.00	US\$/hour
The desirent equipment	other			0	USSS	Oil Cost				US\$/L	No Labourers/Shift	0.0	#
	other			0	11550	Tyres/Tracks/Ringing				0000	Contributions	0.0%	
	other			0	11550	i from the one tragging	Otv	Cost	Life		Operating Days/Week	6.0	dave
	other			0	11580	front	4	7 200	0	1	Operating Hours Week	96.0	Hre
Sub total additional equipment	ourier			0	11580	rear		7 200	0		Basic Hours Augek (driver	90.0	Hre
Total Capital Employed				574 430	11540	tracks Eco		10 500	0		Total Quatima par week	6.0	Hre
Annual Hale				120 312	11580	other		0	0		Time and a Half our week	3.0	Hre
1.2 HP Calculation				120 312	0348	other	0	0	0		Double Time per Week	3.0	Hre
Pacidual Value @			20.00%	114 228	11540	Fuel Cost			25 74	11St/mhr	Shift or Other Allowance	0.00	11SE/day
Interest per annum		-	20.0070	8 00%	0.040	Oil Cost			3.86	US\$/mhr	Annual Normal Time	51 744	USSE
Developer annum				60.00%	monthe	Tyres/Tracks/Ringing Cost			0.00	11St/mhr	Annual Time and a Half	2 205	11580
Monthly neumont				10.026	11Ste	Annual Fuel Costs			80 309	115.8e	Annual Double Time	2 940	11580
Monally payment			_	10 010	0043	Annual Lube Cost			12 046	115.80	Annual Bonus		USSe
1 2 OPERATING HOURS	-					Annual Tyre/Track/Ringing	Cost		12 040	11580	Annual Shift or Other Allowance	0	11580
Total Dave				365		2 2 VEHICI E MAINTENAN	CE COSTS	_		0.040	Total Annual Crew Cost	56 880	11580
Maakaad Dava			-	500		Maint % Can Cost/machine	life (mbrie)		100%		Total Crew Cost per Machine Hr	18.23	11Cg/mhr
Statutany Leave Dave				13		Maintenance Cost	me (mm s)		38.08	115¢/mhr	Total Crew Cost per Machine Pi	10.25	034/11/1
Statutory Leave Days						Annual Maintenance Cost			118 707	11580			
Broductive Days	Mill Stone			0		2 3 RELOCATION COSTS			110 / 0/	0.040	A 1 WORK STUDY ANALYSIS		
Total Appual Production Dave	will otopa			300	Dave	Number of moves per appu	m		4	#	Lead Distance		km
Shift length				8	Hours	Cost per Move			1 300	11580	Volume per Load		m3
Number of Shifts ner day				2	#	Annual Relocation Cost			5 200	USSe	travel emoty		km/hr
Machine Availability				100.0%		Relocation Cost per Machin	e Hour		1.67	US\$/mhr	Load		min
Machine I Itilisation				65.0%		5 1 Machine Requirement	he is a second sec		1.67	o o grinni	travel loaded		km/hr
Machine bours per Day				10.4	Hours	Annual Volume			161 500	m3	Offload		min
Machine hours per Annum				3 120	Hours	Hourly Volume Required			51 76	m3/mbr	Travel time emoty	#DIV/01	min
Machine Life Hours				15 000	Hours	Number Of Machines Renu	ired		1.00	#	Travel time loaded	#DIV/01	min
Machine Life Years				4.81	Years	Fleet Reserve			0%		Load	0.00	min
				4.01	100.0	Exact Number of Machines	Required		1.00	#	Offload	0.00	min
1 4 OVERHEADS						Rounded number of vehicle	s Required		1	#	cycle time	#DIV/01	min
							in reduined	_		-	cycle time	#DIV/01	hrs
Annual Licence Insurance Fees				22 846	USSS						Machine Output per Hour	51.8	m3/mhr
			_								Machine Output per Day	539	m3/day
1.5 Overheads		L .	10.00%	41640	USSS	10 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1					Machine Output per Annum	161 616	m3/vear
6.1 SUMMARY						6.2 FLEET SUMMARY							
	PI	R MACHINI	E	FLEET	%								
	US\$/hr L	S\$/month	US\$/year	US\$/year	of Total	US\$ per m3		2.84		-			
OVERHEADS	13.35	3 470	41 640	41 640	9.09%	Number of Machines		1			1		
FIXED COSTS	64.12	16 671	200 047	200 047	43.7%	Number of Operators		2					
Hp's	38.56	10 026	120 312	120 312	26.3%								
Crew	18.23	4 741	56 889	56 889	12.4%	Machine Hours		3 120					
Licence Insurance	7.32	1 904	22 846	22 846	5.0%	Capital Employed		571 139					
Permit & Toll fees	0.0		0	0	0.0%	Residual Value	1	114 228					
VARIABLE COSTS	69.34	18 029	216 352	216 352	47.2%	Total Revenue	1000	458 039					
Fuel	25.74	6 692	80 309	80 309	17.5%								
Lubrication	3.86	1 004	12 046	12 046	2.6%								
Tyres	0.00	0	0	0	0.0%								
	38.08	9 900	118 797	118 797	25.9%								
Relocation	1.67	432	5 200	5 200	1 104								



# Annexure D

# University of Pretoria declaration of originality



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