

**A REVIEW OF LITERATURE ON TIMBER EXTRACTION
COMPONENTS FOR ALTERNATIVE TIMBER EXTRACTION
ON STEEP SLOPES AND THEIR SUITABILITY FOR SMALL-
SCALE TIMBER FARMING IN SOUTH AFRICA**

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LITERATURE REVIEW AND PROJECT PROPOSAL

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1. INTRODUCTION

Timber production has grown in rural areas to encourage industrial development ,encouraging economic growth and job creation (Fath, 2001). This trend has been noticed worldwide and has seen developing countries migrating from commercial forestry toward landowner-based timber farming and management. This has resulted in a growing number of small-scale timber farmers emerging in an attempt to increase personal and community wealth (Harrison *et al.*, 2002).

Of the 1 200 000 ha of land in South Africa currently under commercial forestry plantations, 83 % belong to private growers and only a small area of approximately 3.5 % (45 000 ha), belonging to small-scale timber growers (Smit, 2015). A small-scale timber operation can vary in size from between 1 and 10 ha, and is owned/managed by the growers. There are approximately 25 000 small-scale timber growers in South Africa, of which 24 170 are linked to Forestry South Africa (FSA) (Smit, 2015). Of these growers, 95 % of them are African and further 79 % of these growers, being female (Smit, 2015). What is surprising of these statistics is that with the small percentage of land owned by the small-scale growers, they produce an estimated R 950 million worth of timber (Smit, 2015). According to Mamba (2013), of the main pulp wood buyers, small-scale timber growers were responsible for contributing 243 000 tons to Sappi's timber supply in 2013. NCT (2012) states that it receives 11.5 % of its annual wattle timber supply, valued at R 14.2 million, from small-scale growers. Furthermore, Mondi purchases about 5 % of their fibre timber from small-scale growers (Smit, 2015).

The income received from the small timber farms provides relief from debt for the land owners (Forestry South Africa, 2013). This income is not received often enough for sustainability, but is often used to pay for education fees or other essentials which may be used to improve the growers' quality of life (Forestry South Africa, 2013). The reason for the large periods between substantial incomes from these plantations is that main harvests only occur approximately every eight years, depending on the species grown (Forestry South Africa, 2013). Only a small amount of timber from thinnings or coppice reductions is harvested between major harvests for use in structural improvements to homes or other structures (Forestry South Africa, 2013).

The small-scale timber growers of South Africa face many challenges which inhibit their ability to grow timber effectively and to efficiently process their timber (Harrison *et al.*, 2002; Forestry

South Africa, 2013; Smit, 2015). The result of the dependence of small communities and small-scale farmers on the forestry industry in rural areas is the desire for the felling and processing of timber to be made as efficient as possible (Upfold *et al.*, 2015). A possible solution to improving timber extraction efficiency is the use of equipment, which may reduce the physical demands of the job, decrease costs and increase production rates (Spinelli *et al.*, 2010). Cable yarding components such as highleads, slacklines, skylines and continuous mainlines are frequently used solutions as alternatives to the manual extraction problem (Ackerman *et al.*, 2017). These are however, very costly systems due to the components used (Food and Agriculture Organisation, 1981) and associated capital expenditure required, that are often not suitable for small-scale farmers because of the costs involved (WorkSafeBC, 2013).

Due to the costs associated with the abovementioned systems which elevate logs on extraction, as well as the associated substandard ergonomics, poor safety and low productivity of current timber extraction systems in rural forestry, it was proposed to the University of KwaZulu-Natal (UKZN), by the Institute for Commercial Forestry Research (ICFR), NCT, Sappi and FSA to provide a solution to the problem. The solution proposed was that of a mobile, mechanical timber winch be designed, built and tested which will improve extraction efficiencies on steep slopes. The first such component designed by Hadebe and Nduli (2015) did not satisfy the project specifications and a new design of the component was required. The redesign of which was carried out by Moloko and Mokou (2016) and operated successfully, but challenges were still evident when tested and operated infield.

Based on the challenges discussed, the aim of this project was to design, construct and assess the performance of a timber extraction unit. The winch should improve extraction rates, reduce overall extraction costs and improve the ease with which the extraction process is completed. Many objectives have been identified for this project, namely:

- a) to refine and test the unit designed and constructed by Moloko and Mokou (2016),
- b) to design, construct and test a new extraction component,
- c) to collect operator feedback for each of the different component from the respective testing periods,
- d) to perform a productivity assessment and comparison of the performance of the current manual component, the component refined in 2016, and the new component designed in 2017/2018, and
- e) to finalise designs for machines suitable for commercial use.

2. A REVIEW OF TIMBER EXTRACTION SYSTEMS FOR USE ON STEEP SLOPES

The forestry industry plays an important role in stimulating South Africa's economy (Smit, 2015). The efficiencies of many extraction practices have been affected by the lack of affordable technologies to aid in the associated timber extraction processes (Gingras *et al.*, 2015). South Africa is a developing country and, as such, still relies largely on manual labour for most of the post-felling processes encountered with timber felling and processing. Most modern technologies for timber extraction are extremely expensive and thus only a few farmers, companies and contractors working for farmers and companies can afford them (Gingras *et al.*, 2015). This chapter contains a review of the technical aspects of post-felling timber processes, the effects of the manual nature of timber processing on human resources and the effects of the different processes on the environment.










2.1 The Timber Extraction Process

There are several different timber harvesting systems in practice to improve extraction efficiencies and reduce the number of workers required to perform the required tasks (Langin *et al.*, 2010). Foresters in South Africa typically use three different extraction methods, namely full-tree, tree-length and cut-to-length methods (Langin *et al.*, 2010). The full-tree method is not included in the scope of this project and, as such, only the tree-length and cut-to-length methods will be reviewed. Langin *et al.* (2010) refers to the extraction method used as the form the timber is in when delivered from a stand to the roadside. Using the tree-length method, a tree is felled, debranched, topped and debarked, and then delivered to the roadside still in full tree lengths. Using the cut-to-length method, the same steps are followed as in the tree-length method with the tree being cross-cut into logs prior to being delivered to the roadside (Langin *et al.*, 2010).

A timber extraction system refers to all the different tools, machines, equipment and people involved in the process, from felling through to delivery at a depot. The individual components of a system depends on the extraction method used, the terrain in the harvesting area, and the capital available for the farmer or contractor (Langin *et al.*, 2010). These components refer to the individual tools or machines which are used within a system and will change depending on

the extraction method used. Table 2.1 is a matrix displaying a timber extraction system and the relationships between activities, the components required to complete each of the activities and the location of the different activities. The dark borders represent the activity flow and where they occur.

Table 2.1 Timber extraction system matrix

Activity	Location	
	Stand	Roadside
Fell		
Debranch		
Top		
Cross-cut		
Debark		
Windrow		
Extract		
Stack		

For this project, only the different types of extraction components will be reviewed. The other components will have an influence on the type of extraction component used but, given the lack of alternative extraction components which are affordable and available to small-scale timber growers in South Africa, the extraction component can be considered the limiting factor within the system. Only ground-based systems are reviewed as the costs associated with aerial systems are not affordable by small scale timber growers. Of the available ground-based components there are a number which are also considered unsuitable for use by small-scale growers.

Components such as ground leads and skidders require large initial capital investments and have high operational costs (WorkSafeBC, 2013). Whilst tractor-mounted winches are cheaper than the two previously mentioned components, many small-scale growers cannot afford to buy tractors which makes this component unsuitable for consideration (Upfold *et al.*, 2015).

All the components that have been considered have an environmental impact on the area in which they are operated and these impacts need to be considered (Langin *et al.*, 2010). The most obvious and concerning impact is the skidding trail, which is cleared as the logs/trees are extracted from the stand (Akbarimehr and Naghdi, 2012). These trails pose a serious threat in that they are easily eroded and as such the aspect of soil erosion will later be discussed in Section 2.4.

2.1.1 Suitable alternate ground-based timber extraction system components

The different types of ground-based timber extraction system components which already exist and are considered accessible and affordable for small-scale growers. These components include manual extraction, animal skidding, All-Terrain Vehicles (ATVs) and capstan winches (Russell and Mortimer, 2005; Langin *et al.*, 2010). To allow for improved extraction efficiencies on small-scale farms in South Africa, components must be easy to transport using a traditional farm pickup truck, lightweight, manoeuvrable, cheap to buy and maintain, and easily maintainable (Russell and Mortimer, 2005).

Manual timber extraction typically involves teams of people working together to extract timber from the place it was grown to the nearest road. In this system the chainsaw operator will cross-cut a row of felled trees at a time to a specified length and the two other workers will extract the logs to a stacking position. The manual extractors will use either an axe or lifting hooks to grip a log and will continue to pull the log to the stacking position on a road or path. This system is limited to extracting timber on slopes of less than 50 % downhill and 27 % uphill, and can only move approximately 95 Eucalyptus logs 2.4 m long and having an average volume of 0.033 m³ on a 60 m (approximately 3 m³.day⁻¹) hauling distance per shift (Shuttleworth, 2007). The two most commonly used methods of pulling the logs are further explained in Section 2.3.2.

Animal skidding is a very simple and primitive component which was used extensively prior to the invention of the tractor (Russell and Mortimer, 2005) This method involves using animals

such as horses, mules or oxen to pull logs up hills to the desired location for processing (Li-hai, 2000). There is a low initial investment required for this component, soil disturbance is reduced and fewer access roads are required. However, this component is limited to hauling downhill on slopes of less than 33 % and uphill on slopes of less than 18 %, meaning that the skidding of an area still requires substantial time to complete (Russell and Mortimer, 2005). For these given limitations, animals can haul up to 150 logs over a 60 m hauling distance, hauling the same size logs as those specified for manual extraction (approximately $5 \text{ m}^3 \cdot \text{day}^{-1}$) (Shuttleworth, 2011). The animals used to haul the logs struggle to find traction under foot when slopes become too steep or muddy which is a limitation (Alex and Ciobanu, 2013). Another limitation of this extraction method is that animals should not work on two successive days. This influences the overall cost of the component type as two animals are needed to extract continuously (Shuttleworth, 2011). This results in two sets of harnesses having to be bought, as each animal grows into its own harness, and the use of a harness on an animal to which the harness was not fitted could result in injury to the animal (Shuttleworth, 2011).

ATVs are motorised, four-wheeled vehicles that use petrol as fuel and can be bought in two or four-wheel drive. These vehicles are designed to be operated off-road by one person and can access areas where other vehicles, especially standard pickup trucks, cannot, including those which are narrower or on slopes of up to 30 % inclines (Schwark *et al.*, 2015). ATVs vehicles are very light, weighing only 300 to 400 kg, which is the main contributor to both its advantages and disadvantages in timber extraction (Russell and Mortimer, 2005). Whilst the small mass saves costs on fuel due to the efficient fuel consumption and reduces the compaction of soil in the area on which the vehicle operates, it also reduces the pulling capacity related to the mass of the vehicle, which increases the risk of rolling/falling and reduces traction in unfavourable terrain (Russell and Mortimer, 2005). The use of ATVs poses another problem in that they are generally used in conjunction with other tools or accessories like skidding arches which can increase project costs (Russell and Mortimer, 2005).

Capstan winches are defined by Cronin and Gleeson (2013) to be vertical or horizontal rotating axes designed to pull ropes. These winches are not only limited to use in forestry but can be used to move or lift heavy industrial equipment which was previously considered “back breaking” work (Hubbell, 2013). The component is a mono-cable (single cable) that hauls in a load and requires a single operator to drag the line back to the next load manually (Bechmann, 1987). These components are small and light, but pose many safety risks and require that the

operator be well trained regarding the machine (Hubbell, 2013). The machine is securely anchored to a strong support such as a tree, stump or pickup truck, and operated off the structure on which it is mounted (Russell and Mortimer, 2005). An example of a capstan winch is shown in Figure 2.1.

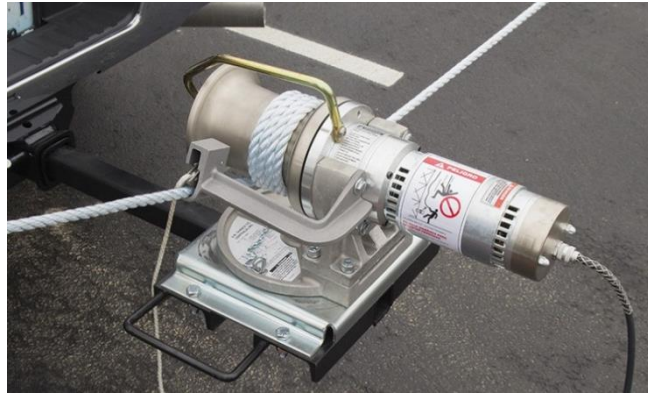


Figure 2.1 Capstan winch (after Hubbell, 2013)

2.1.2 Previous design of a ground-based timber extraction winch

The winch designed by Moloko and Mokou (2016) managed to extract four logs at a time extracting in excess of 10 tons of timber per day with an operation team of four members, which is more than double the amount that a manual extraction team of the same size could achieve (Moloko and Mokou, 2016). During the testing of the machine, it was found that design flaws were present which resulted in the component not working in the desired manner and the machine breaking down repeatedly. The major problem with the machine was that the chain which drives the drum shafts was not correctly selected and was subsequently too loose for the selected gears (Moloko and Mokou, 2016). This resulted in the chain oscillating violently at times when in operation, forcing the entire machine to bounce. The jumping machine generated large forces which pushed the drum shafts out of alignment and prevented the dog clutches from correctly aligning and engaging. The engagement system for the dog clutches also proved to be inadequate as there was too much movement in the join between the engagement bar and the clutches, resulting in too small a force being transferred to the clutches to correctly engage.

The friction reduction skidding cone designed and tested did not always operate successfully during testing. When the logs being hauled did pull correctly into the cone, the cone served its purpose of reducing the environmental effects of soil erosion on the operating site. However,

most of the time the logs could not pull into the skidding cone as the sliders on the haul-back line got stuck on the lip of the cone, thus rendering the skidding cone useless. The overall mass of the machine was another concern. The machine was intended to be light enough for two people to carry off a pickup truck and roll on wheels to the desired point of operation. This was not the case as the machine was too heavy and required at least four people to offload and move the machine around (Moloko and Mokou, 2016).

2.1.3 Landing design on steep slopes

The design and location of a landing used during extraction operations has a crucial impact on the environmental and economic effectiveness of the operation. A landing is the area onto which cut logs or full length trees are extracted and stacked to await merchandising and transportation away from the felling site (FITEC, 2005). There are many safety considerations which need to be understood and extensive planning needs to be done in the design and selection of the location of the landings in different areas (Safe Work Australia, 2013).

There are two main types of landings which are typically used in South Africa, i.e. centralised and continuous landings (Ackerman *et al.*, 2017). However, given that a centralised landing requires an extraction component that operates on a central boom that is then able to swivel 360°, this makes it unsuitable for use by small-scale farmers, and so will not be explored further. Continuous landings employ a parallel harvesting corridor pattern, which can be seen in Figure 2.2, and increases the size of the corridors yarded between rows at each interval, although this requires the yarder to be moved at each new interval (Ackerman *et al.*, 2017).

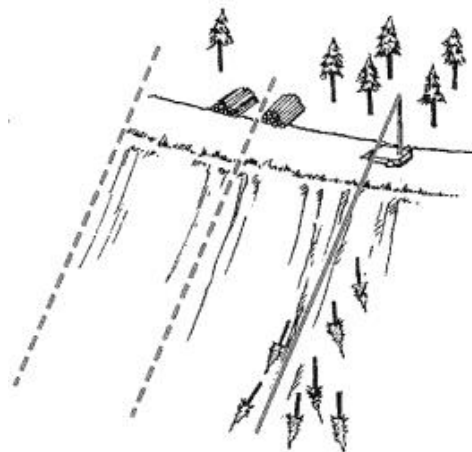


Figure 2.2 Example of a continuous landing (after Ackerman *et al.*, 2017)

The terrain of the landing must be made as level as possible to ensure that stacked logs cannot slide or roll off it and potentially collide with workers who are choking and de-choking downslope from the landing (FITEC, 2005; Safe Work Australia, 2013; Ackerman *et al.*, 2017). It is also necessary to ensure that the landing drains effectively and, as such, it is suggested that landings are sloped between 3 – 6 % (Ackerman *et al.*, 2017).

When determining the size of a landing, WorkSafeBC (2013) indicates it is important to take a number of aspects into consideration, including:

- a) log size,
- b) component size,
- c) transport size and type,
- d) log volume to be stored, and
- e) space for machinery and other vehicles to move about safely.

The environmental impact of the landing being designed is important and any negative impacts must be reduced/removed where possible. All landings should be situated as far away from streamside management zones as possible and all water draining from the landing must be diverted into the surrounding vegetation and not directly into a nearby watercourse (FITEC, 2005).

2.2 General Health and Safety Considerations

The forestry industry is viewed as a 3-D industry for the manual labourers that work within it. According to the Department of Labour (DOL) in South Africa, a 3-D industry is one which is dangerous, dirty and difficult. Considering the nature of the work forestry labourers are required to do along with the equipment which is used to do this and the working environment in which it is done, this definition is widely accepted around the world (Ramutloa, 2013). Worksites are sometimes situated in remote, rural areas where cell phone signals are poor and evacuation is difficult. The result of this dangerous work, when coupled with the problems related to treating accidents, is that there are strict and vigorous safety laws and regulations in place to protect the workers in the forestry industry.

2.2.1 Risks and hazards

The primary occupational health and safety risks and hazards associated with forestry activities can be categorised as either physical, chemical, biological or machine safety (Ramutloa, 2013). Biological hazards do not play a role in the design of a timber extraction component and therefore these hazards are not reviewed in this section.

The physical risks associated with forestry practices tend to be the most apparent of the health and safety risks and hazards given their immediate threat to workers' physical wellbeing. Falling trees and branches are among the common sources of injury for manual workers (WorkSafeNZ, 2014). Extreme care must be taken when selecting which trees to fell and the risks associated with "hung-ups" and "wind-blows" should be assessed (WorkSafeNZ, 2014). Hung-ups are trees or parts of broken trees which are lodged against or suspended in another tree, and attempting to bring these down is a leading cause of fatal injuries in tree felling (WorkSafeNZ, 2014). Wind blows, also known as wind throws, are defined by the European Agency for Health and Safety at Work (EU-OSHA) to be trees which have been blown over or bent by extreme winds such that they lay fallen on the ground or hook onto nearby trees (European Agency for Occupational Health and Safety, 2008). The clearing of wind blows is viewed as one of the most hazardous operations in the forestry industry (International Labour Organisation, 1998).

The chemical risks that are encountered in forestry practices are not experienced as often as physical risks. Chemical hazards consist of spills from portable machinery and chemical plant treatments (Ramutloa, 2013). Petrol used to power portable machinery and some of the oils used for lubrication within the machines are highly flammable. Spillages of any of these substances are therefore fire hazards and, if sparked, could result in runaway fires and human casualties. Apart from the fire risks, skin contact with these substances can cause extreme irritation and may lead to blindness if contact is made with the eyes. Ingestion of these substances is also of major concern and may result in regurgitating and even multiple organ failure (Janssen *et al.*, 1988).

Machine safety is an important factor in forestry for ensuring good health and safety amongst workers. The heavy and potentially dangerous machines used in forestry operations create immediate hazards which collectively result in the most serious injuries in the industry, which

are often debilitating or fatal (European Agency for Occupational Health and Safety, 2008). The moving parts found on these machines and the high temperatures of some of these parts are hazards which usually result in injury when workers place their limbs into these moving parts or stand in unsafe positions near operating vehicles (Ramutloa, 2013).

Careful attention must be paid when anchoring a road based or semi-permanent extraction component like a cable yarder, before operation. It is important that the correct regulations are followed to ensure that there no accidents occur or people get hurt because of poor anchoring. This includes the rigging of the shackles and preparation of the stumps or trees onto which the yarders are to be anchored (WorkSafeBC, 2013). Langin *et al.* (2010), Safe Work Australia (2013), WorkSafeBC (2013) and Ackerman *et al.* (2017) list a series of possible incidents and accidents that can occur if a yarder is not correctly and which could result in injuries and even death.

For the timber extraction process to run safely it is important to choose the correct type of cable for the application. There are two types of cables which are commonly used in industry, i.e. wire cables and synthetic rope. The selection of synthetic ropes is straight forward, with the lifespan and load capacity being the only two factors which need to be considered (Ackerman *et al.*, 2017). The selection of wire cables is slightly more complex with many different properties and applications having to be considered. If a cable or rope were to break or snap when in operation there could be serious implications for the workers operating the extraction system (WorkSafeBC, 2013). An extraction cable in tension which breaks could result in the load being hauled rolling downslope and injuring workers or the workers in the immediate vicinity being struck by the broken cable.

2.2.2 Solutions to health and safety risks and hazards in the forestry industry

Given that the small-scale forestry industry in South Africa has the potential to be a highly exploitative one, the country's Occupational Health and Safety Act (OHSA) must be considered/adhered to at all times to ensure that employers fulfil their legislated duties to their employees to ensure a safe working environment (Republic of South Africa, 1993; Ramutloa, 2008). Langin *et al.* (2010) identifies the OHSA, Basic Conditions of Employment Act (BCEA) and Compensation for Occupational Injuries and Diseases Act (COIDA) as the fundamental legislative guides to use when assessing the health and safety risks of forestry operations, and

thus provide solutions to the risks and hazards that may encountered (Republic of South Africa, 1997b; Republic of South Africa, 1997a).

Risk assessments play a core role in any safety and health management system. The first and most critical step in managing risks in forestry is to identify hazards in the working environment (Langin *et al.*, 2010). A Critical Task Analysis (CTA) is a tool which can be used to assess the potential and criticality of a task for causing an injury or loss, and which adds further value to the risk assessment process (Langin *et al.*, 2010). A CTA is performed after the risk assessment has been completed and all the activities which were identified in the risk assessment are included in the CTA. The results from the CTA will pinpoint tasks of a dangerous nature which may require more regular supervision or focused training interventions (Langin *et al.*, 2010).

The most important solution to improving safety at the work place is to ensure that all employees are adequately trained in their correct operations (Liu *et al.*, 2013). An employee's lack of skill or knowledge is one of the simplest causes of accidents in the forestry industry (Langin *et al.*, 2010). This vocational education should be the primary step in developing a safety strategy as it supplies workers with a knowledge base of how systems should be operating and allows them to identify unsafe working conditions if a malfunction has occurred (Liu *et al.*, 2013). This training not only helps workers to operate more safely, but also increases trainees' willingness and self-confidence to make effective health and safety improvements in the workplace (Becker and Morawetz, 2004). Training can also be considered as a behavioural mechanism which can be used to improve the attitudes of workers towards safety procedures (Yovi and Yamada, 2015). This practical training can help to avoid many of the physical risks associated with forestry, although total avoidance is not guaranteed. All employees using timber extraction equipment should thus be given the required information regarding the specific equipment being used and should be provided with stringent supervision during operation if they have not yet attained the desired level of competency (Langin *et al.*, 2010). All employees should be made aware of the possible dangers associated with the timber extraction profession as well as all the safety precautions which should be taken to keep them safe. Documentation of an operator's accreditation and certification should be kept at all times, along with the names of the people who provided the training, the names of the people who were trained together, the nature of the training and the date the training was given (Langin *et al.*, 2010).

Personal Protective Equipment (PPE) plays a vital role in creating a protective barrier between a hazard and an employee, and can prevent bodily injuries from being fatal (Gandaseca and Yoshimura, 2001). This includes any device, item of clothing, or other work accessories which are designed to protect an individual when exposed to any number of hazards (Myers, 2006). If a PPE fails or is incorrectly used, the user will be directly exposed to possible hazards (Langin *et al.*, 2010). The Food and Agriculture Organisation (1992) proved that the compulsory wearing of PPE and the strict enforcement of this resulted in a large decrease in the number of reported injuries at work. Myers (2006) provides a list of hazards and the PPE which can be used to prevent the given hazards. This list indicates that many of the chemical and biological hazards which may be experienced in forestry practices can be prevented by using the correct forms of PPE. It must, however, be remembered that PPE is the “last line of defence” in preventing accidents and should merely be used to supplement good health and safety management practices (Langin *et al.*, 2010).

User manuals are another effective way of preventing machinery-related accidents as they provide operators with information that is readily available and which compliments their practical training. Writing user manuals is seen as an essential part of the design process and one of the most important project activities (Shand, 1994). These manuals must be written in a language that users understand and which convey the expectations of the developers to the users (Shand, 1994). As a result of this, machine operators in the forestry industry who have access to user manuals have immediate access to information which describes what needs to be done to ensure a machine is working safely. These manuals include Written Safe Work Procedures (WSWP), Best Operating Practices (BOP) and Standard Operating Practices (SOP) (Langin *et al.*, 2010). WSWPs, BOPs and SPOs provide step-by-step guidelines regarding what hazards may be encountered when performing the task, how each task is correctly performed and what PPE devices are required to perform the task (Langin *et al.*, 2010). If the workers consult these manuals when in doubt of any safety procedure or hazard, the risks and hazards associated with the machine should be avoided.

It is critical that communication during harvesting operations is clear and consistent. This is not only between operators of different tasks, but also between operators, managers and emergency services. As previously mentioned, cell phone signal in many operation sites is extremely poor, so it is important that there be a good and reliable communication channel available at all times (Langin *et al.*, 2010).

In order to make harvesting risk control strategies more effective it is important that these strategies are monitored, measured and planned (Ackerman *et al.*, 2017). Three possible methods of monitoring harvesting operations are inspections, checklists and Planned Job Observations (PJO). All of which should ideally be implemented together (Langin *et al.*, 2010). Thorough and regular inspections of equipment which are conducted on a set schedule are an effective way to identify hazards before they result in accidents (Langin *et al.*, 2010). Checklists are a complimentary way of improving the efficiencies of these inspections, although a professional with adequate technical knowledge should compile the checklist to ensure that all required checks are covered (Ackerman *et al.*, 2017). A PJO is a technique which allows harvesting supervisors to assess whether an employee executes a given task to the same standard he/she was trained to do (Langin *et al.*, 2010). According to Langin *et al.* (2010), a PJO can either take place on an informal or formal basis. A formal PJO is conducted such that the supervisor observes the way the employee is executing the task and non-compliance to BOPs means that further training is required. An informal PJO is conducted daily whilst the harvesting supervisor is conducting his/her daily routines. The supervisor will naturally assess how an employee conducts their task, will easily notice if mistakes are being made and will immediately rectify them.

Nutritional plans may also assist to improve safety at work. Ensuring food and nutrient security and enforcing regular water breaks during the long forestry working hours can reduce the effect that poor living conditions, low daily nutritional intake at home and lack of fresh drinking water can have on workers' physical limitations (Scott *et al.*, 2004). Food and nutrition security encompasses meeting the nutrient, energy and protein needs required to meet the demands of a physically taxing profession (Capone *et al.*, 2016). The increased daily nutritional intake and hydration can improve a worker's overall productivity whilst reducing the effect of inadequate vigilance and focus which results from malnutrition and high physical demands of forestry work (Scott *et al.*, 2004). These nutrition plans will also help workers who are affected by HIV and AIDS to continue to perform their jobs effectively by ensuring that their dietary requirements are met and sufficient energy sources supplied. This will assist to ensure that individuals, households and organisations are not stripped of their assets as a result of the impacts of HIV and AIDS because infected workers can continue to work (Mikwamba and Mthinda, 2014).

2.3 Ergonomic Machine Design

Ergonomics is, as defined by the International Ergonomics Association (2003), the scientific discipline concerned with the study of interactions between human operators and the individual elements of an operating system, ensuring that the operators' wellbeing is looked after whilst also ensuring that the system performs as desired. The purpose of ergonomic design is to improve system performance by improving human-machine interaction (Phairah *et al.*, 2016). If the interactions between the two elements, i.e. people and systems, are effectively managed and controlled, the working environment can be made more comfortable, thereby reducing worker fatigue and improving safety on the job (Iqbal *et al.*, 2011; Karwowski, 2012). By planning the ergonomic relationships before production begins, a company can save large amounts of money and enhance certain desirable human values (Iqbal *et al.*, 2011). In doing this, the company essentially undergoes a process to try fit the job to the worker and thereby improve the physical, aesthetic, rational and moral perception the worker has of the job (Karwowski, 2012).

2.3.1 Safety in ergonomic machine design

Machinery safety is of critical importance to ergonomic machine design, as many serious injuries occur each year due to inadequate guarding of machines and the areas around them. The Ministry of Business, Innovation and Employment (MBIE), New Zealand, states that all machines should be guarded at all times to ensure that employees and the company are always fully protected (Ministry of Business Innovation and Employment, 2013). Bridger (2009) states that occupational hazards are defined as the sum of the individual hazards to which employees are exposed at work. The most critical aspect is to ensure that workers cannot reach past the guards and into the machine while it is in operation, therefore reducing the number of hazards to which workers are exposed. The guarding needs to be designed per the general actions of an employee when operating the machine.

Some typical ergonomic principles include:

- a) the movements and postures of operators,
- b) the physical ease with which operators use the machine,
- c) the implications of noise and temperature on the user,
- d) the clarity and location of controls,

- e) the design of displays, dials, and markings, and
- f) the presence of warning features.

All of these aspects need to be carefully considered along with the tasks being performed and the skills of the operators performing them (Ministry of Business Innovation and Employment, 2013). The process of guarding a machine can be simplified by studying information regarding human body measurements. This information helps when making decisions about the dimensions of the access points to the machine for different activities.

There are many standards in place which provide good guidance towards choosing the type and size of access points in guards. One of these is provided by the Ministry of Business Innovation and Employment (2013) and the publication gives recommended access sizes for slots, squares and holes for given safe distances between the guard and dangerous area.

2.3.2 Ergonomic problems for manual timber extraction

The responsibilities of extractors in the forestry harvesting process is to move merchandised and usually debarked logs from where the trees were felled to a desired location and then stack them in a neat manner such that they are easily accessible for further transport to the market place. The nature of this work forces the extractors to assume very awkward working postures when conducting this physically demanding work, the results of which are musculoskeletal strain and the potential overtaxing of the cardiorespiratory and metabolic systems (Scott *et al.*, 2004; James, 2006).

Extractors are required to move many logs each day and each extractor will usually stick to one style which they know to move the logs out of the compartment (Scott *et al.*, 2004). The observed manners of moving the logs are either by pulling the logs behind them with one arm or by pulling the logs with both arms between their legs (Scott *et al.*, 2004). This becomes a problem as the nature of these movements can generate extremely large stresses on the necks, shoulders, elbows, hands and backs of the workers, all of which is further compounded by the repetitive movements (Hagen *et al.*, 1998; James, 2006). This strain on the musculoskeletal system was confirmed in a report by the Department of Labour on Health and Safety in Forestry, which further outlined the seriousness of the repetitive strain injuries (Ramutloa, 2013).

Accident reporting systems are problematic in the forestry industry. Workers in the forestry industry, especially extractors, are seen as “easily replaceable” due to the simple nature of the work and the little education which is required to do the job (Scott *et al.*, 2004). As a result of this, workers tend not to report injuries or rest when they are injured for fear of being seen as ‘complaining’ or simply because the ‘work hardening’ of the daily involvement of the task has conditioned them that feeling tired or sore is normal. Job insecurity forces the workers to rather push through the pain so that they can help provide for their families whose lives depend on the money (Estruch *et al.*, 2013).

Bad labour practices are influential in many of the problems associated with forestry. The nature of the competitive independent contract work which is employed in the industry has resulted in four major areas of concern being identified by Scott *et al.* (2004), namely:

- a) provision and maintenance the tools required for the jobs,
- b) training levels,
- c) supervision of work practices, and
- d) overall organisation and control of the workers.

The failure by some contractors to adhere to acceptable operating standards is often a cause of many injuries, despite being easily manageable and one of the company’s core responsibilities. The PPE which are issued to workers is another area of concern. Although the equipment serves its purpose very well, the extreme heat and humidity sometimes experienced in KZN, which is only amplified when working under the canopy of a forest, tends to make workers want to remove some items of clothing to allow them to cool down (Scott *et al.*, 2004). Hard hats, for example, tend to be uncomfortable and hence are often removed. Long-sleeved shirts are also often removed as they inhibit the ability of the sweat on a person’s body to evaporate and cool the skin. These ergonomic problems associated with PPE need to be considered together with the safety importance of the PPE issued to workers as discussed in Section 2.2.2

2.3.3 Consequences of ergonomic problems

The nature of the work performed by stackers on any normal work day can be trauma-inducing and can cause Cumulative Trauma Disorders (CTDs) in the back and upper limbs (Hagen *et al.*, 1998; Scott *et al.*, 2004). These are not the only injuries that have been recorded from the

occupation, and further explanations into a few of the injuries and consequences associated with ergonomic problems will be further explained in the following section.

Scott *et al.* (2004) states that Work-related Musculoskeletal Disorders (WMSDs) account for approximately 40 – 50 % of all occupational illnesses and injuries in the forestry industry. A common feature of these musculoskeletal problems are very high forces experienced in the lower back (International Labour Organisation, 2010). When exerting such forces externally, forces are created internally which are just as large. Shear and compressive forces are experienced on the lumbar disks and tensile forces on the lumbar musculature (Hagen *et al.*, 1998). Forest harvesting is particularly hazardous, with it being responsible for anywhere between 38 and 90 % of all accidents recorded in the industry depending on where in the world the operation is taking place (International Labour Organisation, 1998). Trip, fall and slip accidents are extremely common for extractors because of the presence of stripped bark and the untidy way the debarked logs are left in the compartment. The moment any of this stripped material gets wet, it becomes extremely slippery and this problem is further compounded by the presence of mud in the area which gathers on the workers' boots. The study done by Scott *et al.* (2004) indicates that the forces experienced by the stackers when pulling and stacking logs are often well above the acceptable limits established by the National Institute for Occupational Safety and Health (NIOSH). They found that the compressive forces experienced in the spine were approximately 2.5 times higher than the acceptable limit (Scott *et al.*, 2004). In fact, per the standards set out by NIOSH, less than 50 % of the population would be able to generate and sustain such high forces as those required of the extractors (Scott *et al.*, 2004). The pulling of logs using a single arm behind the body twists the arm and spine, which is the most taxing strain on the spine (Scott *et al.*, 2004). Using both arms and pulling logs between the legs does not twist the spine, but the awkward posture and nature of the movement places more shear pressure on the spine (Scott *et al.*, 2004).

The lack of water, PPE-associated cooling problems, and the extreme physical demands of the extraction occupation also has a large impact on the cardiovascular system. Scott *et al.* (2004) found that the average heart rate of a worker when operating was at 66 % of the age-predicted maximum for the average age of workers in the test sample. The risk of heart disease and attacks is increased with such activity and dehydration becomes a risk. No management strategies were put in place in the system studied by Scott *et al.* (2004) to ensure that workers had scheduled rest times or that water was readily available to be consumed during scheduled breaks.

The inadequate pay of the workers and long working hours results in poor nutritional intake and little time for them to rest their bodies between work days. As a result their bodies are not being allowed to recover adequately from the physical work (Estruch *et al.*, 2013). This is a problem as not only a person's physical, but also their mental state, can begin to deteriorate, as is noticed in extreme athletes who have recorded similar heart rates over similar length periods during extreme events. Scott *et al.* (2004) found that the average protein intake of a stacker was only 56 % of the Recommended Daily Allowance (RDA) and that this is only 21–35 % of that recommended for athletes who have similar demands placed on their bodies (Scott *et al.*, 2004). The mental deterioration which can occur from such eating and working habits can be the most severe consequence (Lilley *et al.*, 2002; James, 2006). If a worker is not focused or mentally capable of working, the chance of making mistakes increases dramatically. Slips, trips and falls become common place and the workers begin to make errors using the dangerous tools they are given. Less attention is also paid to their immediate surroundings and, as such, accidents involving falling trees and branches become more common (Scott *et al.*, 2004).

2.4 Soil Erosion

Soil erosion is a naturally occurring process which influences all landforms and which has been largely accelerated by agricultural practices in recent years (Ritter, 2012). For agricultural purposes, this process is loosely defined as the wearing of a field or land's topsoil by the natural forces of wind or water, or through forces created by some farming activities such as tillage (Ritter, 2012; FESA and ICFR, 2014). Erosion, regardless of what is responsible for the application of the forces, involves three different actions, viz. soil detachment, movement and deposition (Ritter, 2012).

2.4.1 Causes of water erosion in ground-based timber harvesting

There are many causes of soil erosion by water which need to be considered, including rainfall, runoff, soil erodibility, slope gradient and length, and vegetation cover (Ritter, 2012; Roşca *et al.*, 2012). These are however, not included in this review as the focus is on the causes and effects of timber extraction components on soil erosion. For more information regarding rainfall, runoff, soil erodibility, slope gradient and length, and vegetation cover, see publications by Arrow *et al.* (1995), Mohamoud (2013) and Spalevic *et al.* (2015).

Skid trails are widely used in ground-based skidding extraction components and are considered a major cause of erosion (Jusoff *et al.*, 1986; Akbarimehr and Naghdi, 2012). Through the compaction of the soil in areas where skidding extraction components are used, increased runoff rates, and subsequent deep rill formation, are observed (Ampoorter *et al.*, 2010). These skidding trails have the ability to cause increased soil detachment from the area, which can result in increased sedimentation and siltation of nearby surface waterbodies and courses (Akbarimehr and Naghdi, 2012). As these skidding trails are more frequently or intensively used, so these problems become more apparent and their effects on landforms more severe.

Another aspect associated with erosion is the amount of timber residue, or slash, left on a slope post-processing and the time at which the slash obtained from harvesting is removed. Leaving as much of the offcuts and slash from harvesting on the ground for as long as possible will allow some of this to decompose back into the soil which will return some nutrients to the soil, as well as protect the soil from erosion (FESA and ICFR, 2014). Planning harvesting and planting times is therefore important in preserving the landscape which is being farmed and can largely improve yields if done correctly.

2.4.2 Effects of water erosion

On-site, there are many implications associated with water erosion. These implications extend far beyond those related to top soil removal, but crop emergence, plant growth, and yield can all be effected (Arrow *et al.*, 1995; Ritter, 2012; Spalevic *et al.*, 2015). As soil is lost from the area, so are the naturally occurring nutrients and applied fertilisers (Arrow *et al.*, 1995; FESA and ICFR, 2014; Spalevic *et al.*, 2015). Pesticides are another expensive loss which can also occur if erosion is not controlled and all the losses together can have a significant financial impact on farmers (Ritter, 2012).

The off-site effects of erosion are not always as clear. Eroded soil which gets deposited down slope of the working site can accumulate on roads. This accumulation of sediment and its creep under some road surfaces can damage the roads and have large cost implications (Ritter, 2012). Sediment which settles in streams or water courses can increase bank erosion, obstruct flow through drainage channels, fill reservoirs, shallow out dams, and reduce water quality (Ritter, 2012). The pesticides and fertilisers which are sometimes removed with the soils can pollute water resources. It is thus important to control non-point pollution, from forestry practices given

the damage that can be caused and the subsequent cost implications (Arrow *et al.*, 1995; Mohamoud, 2013).

2.5 Productivity Assessments of Forestry Activities

Improving the efficiencies of operations is an on-going challenge in all industries around the world, including forestry (Bjorheden *et al.*, 1995). The South African forestry industry faces a unique set of challenges which complicates the process of addressing these inefficiencies. A tool which is commonly used to address these challenges is the discipline of work science which entails studying work and productivity (Bjorheden *et al.*, 1995). Work science involves studying work and its associated measurement of human elements, equipment used, methods of work, time and the organisation of work (Bjorheden *et al.*, 1995). It is important that a clear objective is developed before any of the studies in this process are completed (Ackerman *et al.*, 2014). A clear and concise objective ensures that the efficiencies of the use of resources and time are maximised when developing the final set of results. A sound experimental design helps to further simplify the process of achieving the experimental objectives mentioned above (Ackerman *et al.*, 2014). The process of conducting a productivity assessment can be done by multiple methods, but is typically reduced to two for simplification. These two methods include observational studies and experimental studies (Ackerman *et al.*, 2014). The scope of this section will not cover experimental studies due to the large relative cost of this type of study and its consequent unsuitability for use in small-scale timber operations.

2.5.1 Observational studies

In observational studies, no variables are controlled by external factors (Kanawaty, 1992; Spinelli *et al.*, 2010). A machine, operation or system is simply assessed to determine the current state and learn more about what is being observed (Kanawaty, 1992; Spinelli *et al.*, 2010). The system, machine or operation must be allowed to operate as it was before any modifications were made so that the results of the study serve as a good control against which alternatives can be compared. Two key elements of an observational study are a work study and a time study, both of which form a part of an accurate productivity assessment (Spinelli *et al.*, 2010).

2.5.2 Work studies

A work study can be defined as the “systematic examination of the methods of carrying on activities to improve the effective use of resources and to set up standards of performance for the activities being carried out” (Kanawaty, 1992). These studies are then typically broken down into two parts, namely a method study and a work measurement (Ackerman *et al.*, 2014). A method study is usually the first step in determining the optimal method which should be followed to complete a task (Kanawaty, 1992; Bjorheden *et al.*, 1995). It is defined by Kanawaty (1992) as “a study where the task is systematically recorded and critically examined to find ways to make improvements to the task completion”. After establishing a method, the work measurement can begin (Ackerman *et al.*, 2014).

Work measurement includes applying different techniques such as time studies to establish the amount of time it should take a qualified worker to perform a specific job at a defined level of performance (Mundel, 1978). This aids in the determination of the efficiency of new forest equipment or already studied equipment in new conditions (Muşat *et al.*, 2016). The models developed from work studies can be used to either emphasise differences between alternatives or provide the required support for decision making.

2.5.3 Time studies

Time is an extremely important resource in business and is a crucial element of production. It is therefore essential that this resource be effectively managed and controlled during all forestry activities (Ackerman *et al.*, 2014). Time studies provide a means by which a skill can be transferred from management to workers in the simplest way, as they provide the standard amount of time a task should take a worker to complete under a certain set of conditions (Barnes and Orlandi, 1963).

These studies are particularly useful when comparing or testing the performance metrics of different equipment or systems which serve a similar purpose (Muşat *et al.*, 2016). The time obtained when recording in the field as the task is being performed is the observed time (Bjorheden *et al.*, 1995). This observed time is then “corrected” to determine the standard time and ensure that direct comparisons can be made between the time taken by two different workers. Standard time accounts for differences in working rate and skill of the worker by rating the performance of the worker relative to the expected rate of working as well as providing for

rest and meal breaks (Bjorheden *et al.*, 1995). The results of a time study, which are usually empirical models, often have the capability of predicting performance of the different equipment or systems under the tested operational conditions (Visser and Spinelli, 2012). A full set of results from one such study, which require large time and monetary investments, essentially aim to classify and quantify inputs to the system to relate them to outputs or to eliminate time which does not contribute to the completion of given task (Acuna *et al.*, 2012). One of the simpler time study techniques is one in which time and production are accounted for and compared on different levels (Ackerman *et al.*, 2014). The observation levels can vary from an element level study to a shift level study (Ackerman *et al.*, 2014). In this review, elemental studies will not be considered due to the amount of time they require to complete.

A cycle level study is the next largest scale study which examines the production output of the machine against time input for one full work cycle (Kanawaty, 1992). In this level of study, it is easy to isolate unscheduled, small breaks in work or “useless” time which negatively affect the productivity of a machine (Olsen *et al.*, 1998). Delays of any amount of time are recorded and, as such, the study typically also requires fairly large monetary and time inputs although not as large as that for the element level study (Olsen *et al.*, 1998). The units of output for such studies is typically time per cycle and output per cycle.

3. DISCUSSION AND CONCLUSIONS

As discussed in Section 1, the forestry industry in South Africa is well-established and profitable. This has resulted in different technologies being designed and developed to improve efficiencies in the industry and increase the net profit received from operations. However, many of these are extremely expensive and are not suited for use by small-scale timber growers, meaning that there are few systems in place to help small-scale timber growers. Therefore, a component for use in small-scale operations is needed which satisfies the criteria mentioned in Section 2.1.1 and is capable of extracting timber in a more efficient manner than manual stackers.

Whilst animal skidding is the cheapest alternative component to manual extraction that can be used for small-scale growers, it can still be a costly option should conditions not be favourable. Both animal systems and ATVs are limited by the amount of wood that can be extracted at a time and the gradient of the slopes on which they can operate. A standard farm pickup truck can operate legally on similar gradients, so the slight increase in efficiency from these two alternatives cannot justify the capital investment required for purchasing the components.

Capstan winches are an alternative that could satisfy the needs of small-scale growers. They are small, light, easy to move around, and can be mounted to almost anything that can withstand the pressure applied by hauling logs. However, they are expensive to buy and maintain, and spare parts are not easily available, making them unsuitable for small-scale timber farmers.

The component designed and tested by Moloko and Mokou (2016) did not fully satisfy the needs of a small-scale timber farmer as it was too heavy for its application and thus could not easily be moved around. The skidding cone which was aimed at reducing the environmental effects of erosion on the landform was successful when the logs were inserted into the cone but, when the component was left to operate on its own, the logs caught on the lip of the cone and the cone ceased to operate effectively. The sliding system which allowed individual logs to be choked in different areas was the cause of the problem.

To identify where time can be made up in the system and where improvements can be made, cycle level studies will be carried out. This information will help to determine the ideal cycle

time for the system and allow farmers to judge the quality of the work done by the operators. The cost comparison between the tested system and manual extraction will require information from these assessments, so it will be important that these are done accurately and correctly.

It can be concluded from the literature that there is a need to develop and redesign the component built by Moloko and Mokou (2016) as it is the component which comes closest to satisfying the needs of the small-scale timber farmers in South Africa. The friction reduction system and mass of the component are the two main features that need to be addressed and which will improve the desirability of the machine for small-scale timber farmers. This will be done throughout the thorough testing periods which will be undertaken and through the redesign of the component, all of which will take place in 2017/2018. The data collected and the results of the data will be used as the main source of knowledge for the design of the final component.

4. PROJECT PROPOSAL

The project proposal focuses on the, re-design, construction and testing of a timber extraction winch. This winch must satisfy the needs of small-scale timber growers and the operators who will use the component in-field.

4.1 Methodology

The research for this study will be conducted in two system phases. The first phase will focus on the development, testing and assessment of the component constructed in 2016, and the comparison of this component to the manual extraction component already in place. The second phase will focus on the design, testing and assessment of the component which is to be designed in 2017 and 2018, and the comparison of this component to the manual extraction component already in place.

Both phases of the study will follow the same methodology with the exception that the first phase simply involves the further development and assessment of an existing design and the second phase requires a completely new design. The actions for the first phase will include the following:

- a) develop improved components of the existing component, where necessary,
- b) test the improved components to ensure they are operational,
- c) test the existing manual extraction component,
- d) test the improved extraction component in-field,
- e) conduct a productivity assessment,
- f) conduct an operator survey,
- g) analyse the feedback from (c), (d), and (e),
- h) use operator feedback from (f) to improve the design in the second phase, and
- i) draw conclusions regarding the performance of the improved existing component.

The second phase will include the following actions:

- a) re-design and construct a new extraction component, based on the lessons learnt and feedback obtained in the first phase,
- b) test the new component internally to ensure it is operational,

- c) test the existing manual extraction component,
- d) test the new component in-field,
- e) conduct a productivity assessment of the new extraction component,
- f) conduct an operator survey of the new extraction component,
- g) analyse the feedback from (c), (d), and (e),
- h) draw conclusions regarding the reliability and productivity of the new extraction component,
- i) use operator feedback from (f) to further revise and finalise the new design, and
- j) prepare designs for final machines for distribution.

4.2 Resources Required for the Project

The nature of this projects is such that it is very resource intensive. Many different resources will be required to undergo the two phases of testing listed in Section 4.1.

The set of resources required includes:

- a) workshop space, motors and materials to construct the machines and extraction component,
- b) technical assistance with construction,
- c) vehicles for transport to sites,
- d) test sites and operators,
- e) equipment for productivity assessments, and
- f) materials to prepare operator surveys.

The budget in Table 4.1 gives a summary of the overall budgeted costs for the years 2017 and 2018 and is funded from The Department of Science and Technology – Forestry Sector Innovation Fund, administered by FSA.

Table 4.1 Proposed overall project budget including supervisor and travel fees

	Description	Purchases	Travel	Total Cost
2017	Project costs Year 1	R 274 240	R 24 900	R 299 140
2018	Project costs Year 2	R 371 907	R 25 388	R 397 295
		R 646 147.00	R 50 288.00	R 696 435.00

4.3 Safety Considerations

Section 2.2 of this document gives background, considerations and recommendations regarding the health and safety of operators involved in timber extraction processes. This contains summarised information regarding the possible effects of disregard for safety rules and procedures, possible risks and hazards and solutions to the listed risks and hazards.

All the recommendations and publications mentioned above must not be used as the only source of safety rules at the workplace. It must be noted that all forestry companies must, by law, follow the rules and procedures stated in the Occupational Safety and Health Act (OSHA). Commercial timber companies will also have their own set of health and safety rules which must be followed in conjunction with OSHA for the company to remain responsible for an employee's wellbeing.

4.4 Project Plan

A summary of the proposed plan for the dates on which activities will be carried out can be found on the Gantt chart in Figure 4.1. This figure gives a short description of each of the activities to be conducted, the length of each activity and the dates over which these activities will be conducted.

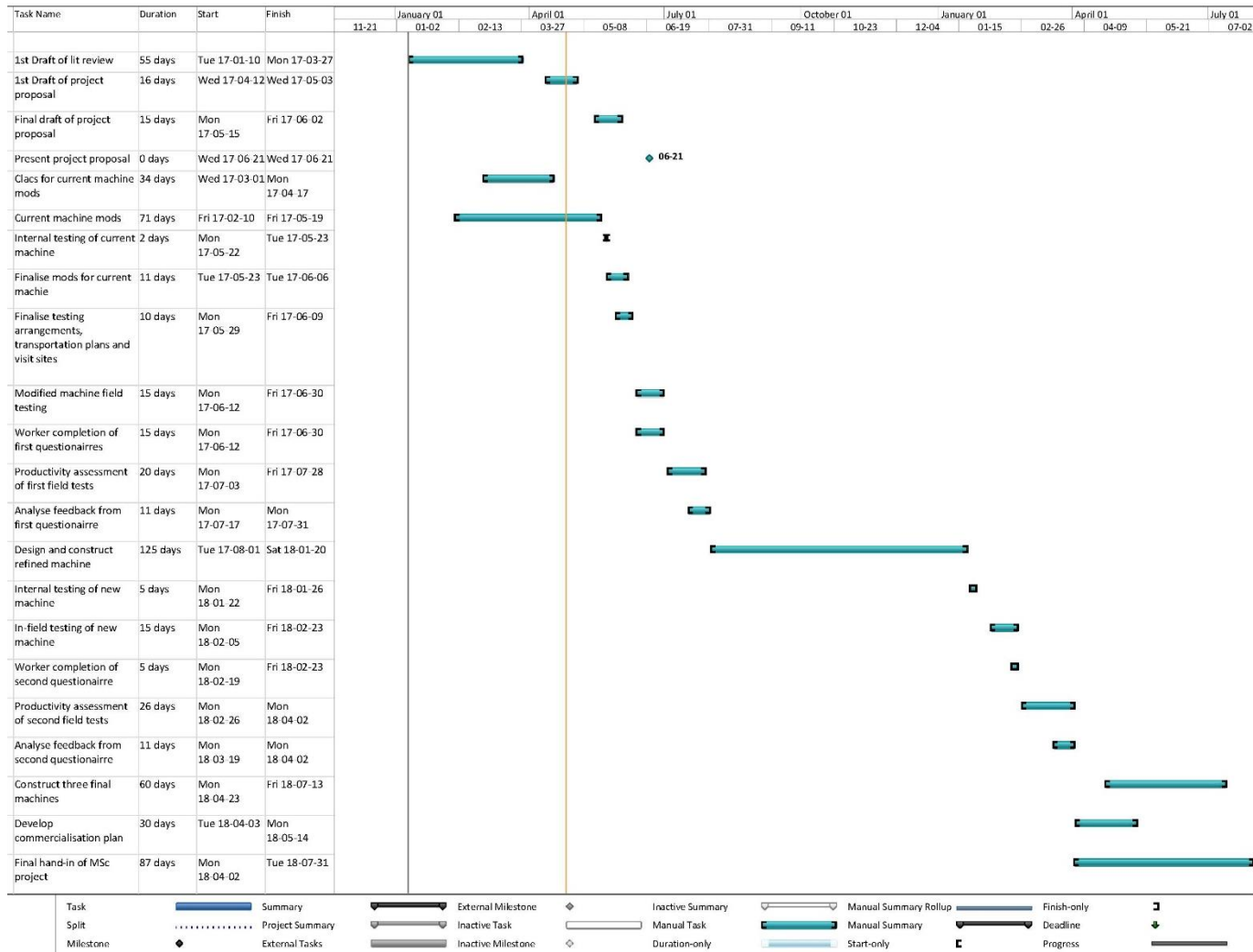


Figure 4.1 Summary of proposed project deadlines

5. REFERENCES

- Ackerman, P, Gleasure, E, Ackerman, S and Shuttleworth, B. 2014. *Standards for time studies for the South African forest industry*. ICFR, FESA, Pietermaritzburg, South Africa.
- Ackerman, S, Immelmann, A, McEwan, A, Upfold, S and Naidoo, S. 2017. *South African cable yarding safety and operating handbook*. ICFR, FESA, Pretoria, South Africa.
- Acuna, M, Bigot, M, Guerra, S, Hartsough, B, Kanzian, C, Kärhä, K, Lindroos, O, Magagnotti, N, Roux, S and Spinelli, R. 2012. *Good practice guidelines for biomass production studies*. CNR IVALSIA, Florence, Italy.
- Akbarimehr, M and Naghdi, R. 2012. Reducing erosion from forest roads and skid trails by management practices. *Journal of Forest Science* 58 (4): 165-169.
- Alex, S and Ciobanu, V. 2013. Efficiency of motor-manual felling and horse logging in small-scale firewood production. *African Journal of Agricultural Research* 8 (24): 3126-3135.
- Ampoorter, E, Van Nevel, L, De Vos, B, Hermy, M and Verheyen, K. 2010. Assessing the effects of initial soil characteristics, machine mass and traffic intensity on forest soil compaction. *Forest Ecology and Management* 260 (10): 1664-1676.
- Arrow, K, Bolin, B, Costanza, R, Dasgupta, P, Folke, C, Holling, CS, Jansson, B-O, Levin, S, Mäler, K-G and Perrings, C. 1995. Economic growth, carrying capacity, and the environment. *Ecological economics* 15 (2): 91-95.
- Barnes, R and Orlandi, B. 1963. *Motion and time study: Design and measurement of work*. John Wiley & Sons Inc., London, England.
- Bechmann, P. 1987. Single head capstan winch. USA Patent No. 4666128
- Becker, P and Morawetz, J. 2004. Impacts of health and safety education: Comparison of worker activities before and after training. *AJIM American Journal of Industrial Medicine* 46 (1): 63-70.
- Bjorheden, R, Thompson, M, Apel, K and Shiba, M. 1995. An international nomenclature for forest work study. *Forest Work Study Nomenclature*, 16. The Swedish University of Agricultural Sciences Department of Operational Efficiency Tampere, Finland.
- Bridger, R. 2009. Human-system dis-integration : management of stress, strain and fatigue in the workplace. *ergosa Ergonomics SA : Journal of the Ergonomics Society of South Africa* 21 (2): 2-29.
- Capone, R, El-Bilali, H, Debs, P and Bottalico, F. 2016. Relations between food and nutrition security, diets and food systems. *Agriculture and Forestry* 62 (1): 49-58.
- Cronin, K and Gleeson, J. 2013. Variability in output torque of capstan and wrap spring elements. *Mechanism and Machine Theory* 68 49-66.
- Estruch, E, Rapone, C and De Rivas, C. 2013. *Promoting decent employment in forestry for improved nutrition and food security*. FAO, Rome, Italy.
- European Agency for Occupational Health and Safety. 2008. *Occupational safety and health in Europe's forestry industry*. European Agency for Occupational Health and Safety, Rome, Italy.
- Fath, H. 2001. *Commercial timber harvesting in the natural forests of Mozambique*. Food and Agriculture Organization of the United Nations, Rome, Italy.
- FESA and ICFR. 2014. *Guidelines for forest engineering practices in South Africa*. ICFR/FESA, Pietermaritzburg, South Africa.
- FITEC. 2005. *Best practice guidelines for road and landing construction*. 0-9582261-2-1. FITEC, Auckland, New Zealand.
- Food and Agriculture Organisation. 1981. *Cable logging systems*. FAO, Rome, Italy.
- Food and Agriculture Organisation. 1992. *Introduction to ergonomics in forestry in developing countries*. FAO, Rome, Italy.

- Forestry South Africa. 2013. *Small growers planning for bigger things*. Green Forest Media, Hilcrest, South Africa.
- Gandaseca, S and Yoshimura, T. 2001. Occupational safety, health and living conditions of forestry workers in indonesia. *Journal of Forest Research* 6 (4): 281-285.
- Gingras, J, Boswell, B and Lewis, T. 2015. *Steep-slope harvesting initiative: road map, 2015 to 2020*. FPIInnovations, Quebec, Canada.
- Hadebe, T and Nduli, S. 2015. *Design, construction and evaluation of a mechanical winch for timber extraction*. Unpublished Final Year Design Project, School of Engineering, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Hagen, Magnus, P and Vetlesen, K. 1998. Neck/shoulder and low-back disorders in the forestry industry: relationship to work tasks and perceived psychosocial job stress. *Ergonomics* 41 (10): 1510-1518.
- Harrison, S, Herbohn, J and Niskanen, A. 2002. Non-industrial, smallholder, small-scale and family forestry: what's in a name? *Small-Scale Forestry* 1 (1): 1-11.
- Hubbell. 2013. Capstan hoist- ten safety recommendations. [Internet]. Hubbell Incorporated. Available from: <http://www.hubbelpowersystems.com/literature/lineman/BR09023E.pdf>. [Accessed: 21 April 2017].
- International Ergonomics Association. 2003. *IEA triennial report*. IEA Press, Santa Monica, CA, USA.
- International Labour Organisation. 1998. *Safety and health in forestry work*. ILO, Geneva, Switzerland.
- Iqbal, M, Iqbal, S, Rahman, A and Samsuzzoha, A.2011. Ergonomics and design. *International Conference on Industrial Engineering and Operations Management Kuala Lumpur, Malaysia*, 22-24.
- James, G. 2006. *An ergonomic assessment of manual timber extraction*. ICFR, Pietermaritzburg, South Africa.
- Janssen, S, Van der Geest, S, Meijer, S and Uges, D. 1988. Impairment of organ function after oral ingestion of refined petrol. *Intensive care medicine* 14 (3): 238-240.
- Jusoff, K, Majid, N and Muhamad, N. 1986. The impact of skid trails on the physical properties of tropical hill forest soils. *Pertanika* 9 (3): 311-321.
- Kanawaty, G. 1992. *Introduction to work study*. ILO, Geneva, Switzerland.
- Karwowski, W. 2012. The discipline of human factors and ergonomics. *Handbook of human factors and ergonomics* 4 3-37.
- Langin, D, Ackerman, P, Krieg, B, Immelmann, A, Potgieter, C, van Rooyen, J and Upfold, S. 2010. *South African ground based harvesting handbook*. ICFR/FESA, Pietermaritzburg, South Africa.
- Li-hai, W. 2000. Environmentally sound timber extracting techniques for small tree harvesting. *Journal of Forestry Research* 11 (4): 269-272.
- Lilley, R, Feyer, A, Kirk, P and Gander, P. 2002. A survey of forest workers in New Zealand: Do hours of work, rest, and recovery play a role in accidents and injury? *Journal of safety research* 33 (1): 53-71.
- Liu, G, Wang, J, Li, X and Zhang, J. 2013. Research and practice of the construction mode of the practical training base for agriculture and forestry. *Asian Agricultural Research* 5 (1): 70-72.
- Mamba, S. 2013. Evaluation of forestry models for future settlement of forestry plantations under land claims: the case of Jessievale and Roburna forest plantations in Mpumalanga, South Africa. Unpublished thesis, University of Pretoria, Pretoria, South Africa.

- Mikwamba, K and Mthinda, C. 2014. The financial benefits of agroforestry practicing to HIV and AIDS affected households. *International Journal of Agricultural Extension 2* (International Conference): 121-126.
- Ministry of Business Innovation and Employment. Ergonomics of machine guarding guide. 2013. MBIE, Auckland, New Zealand
- Mohamoud, YM. 2013. A method to assess soil erosion from smallholder farmers fields : A case study from Malawi. *Environ Monit Assess Environmental Monitoring and Assessment : An International Journal Devoted to Progress in the Use of Monitoring Data in Assessing Environmental Risks to Man and the Environment* 185 (9): 7195-7203.
- Moloko, K and Mokou, L. 2016. *Design, construction and evaluation of a timber extraction system for timber harvesting on steep slopes*. Unpublished Final Year Design Project, School of Engineering, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Mundel, ME. 1978. *Motion and time study: Improving productivity*. Prentice-Hall, New Jersey, USA.
- Muşat, E, Apahacek~fahacek~ian, A, Ignea, G, Ciobanu, V, Iordache, E, Derczeni, R, Spârchez, G, Vasilescu, M and Borz, S. 2016. Time expenditure in computer aided time studies implemented for highly mechanized forest equipment. *Annals of Forest Research* 59 (1): 129-143.
- Myers, ML. 2006. *National strategy for personal protective technologies: research for the agriculture, forestry, and fishing sector*. NIOSH.
- NCT. 2012. *Project regeneration work at Ozwathini*. NCT, Pietermaritzburg, South Africa.
- Olsen, ED, Hossain, MM and Miller, ME. 1998. *Statistical comparison of methods used in harvesting work studies*. Corvallis, Or.: College of Forestry, Forest Research Laboratory, Oregon State University, Oregon, USA.
- Phairah, K, Brink, M, Chirwa, P and Todd, A. 2016. Operator work-related musculoskeletal disorders during forwarding operations in South Africa: an ergonomic assessment. *Southern Forests: a Journal of Forest Science* 78 (1): 1-9.
- Ramutloa, L. 2008. *Report of the employment conditions commission on the review of sectoral determination 12: forestry sector, South Africa*. Department of Labour, Pretoria, South Africa.
- Ramutloa, L. 2013. *Health and safety in forestry*. DOL, South Africa.
- Republic of South Africa. Occupational Health and Safety Act. 1993. Government Gazette No. 181 of 1993, No. 14918. Cape Town, South Africa
- Republic of South Africa. Basic Conditions of Employment Act. 1997a. Government Gazette No. 75 of 1997, No. 18491. Cape Town, South Africa
- Republic of South Africa. Compensation for Occupational Injuries and Diseases Act. 1997b. Government Gazette No. 130 of 1993, No. 1850. Cape Town, South Africa
- Ritter, J. 2012. Soil erosion-causes and effects. *Ontario Ministry of Agriculture and Rural Affairs* 12-053.
- Roşca, B, Vasiliniuc, I and Topşa, G. 2012. Models for estimating soil erosion in the Middle and Lower Vasluiet Basin. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture* 69 (1): 163-172.
- Russell, F and Mortimer, D. 2005. *A review of small-scale harvesting systems in use worldwide and their potential application in Irish forestry*. COFORD Dublin,
- Safe Work Australia. 2013. Guide to managing risks in cable logging.
- Schwark, J, Fowler, G, Larson, R and Rauschenberger, R. 2015. An investigation of operator performance in All-Terrain Vehicle (ATV) handling and control. *Procedia Manufacturing* 3 4621-4628.

- Scott, PA, Hristie, C, James, G and Todd, A. 2004. *Ergonomics report: forest harvesting*. Rhodes University.
- Shand, RM. 1994. User manuals as project management tools. I. Theoretical background. *IEEE Transactions on Professional Communication* 37 (2): 75-80.
- Shuttleworth, B. 2007. *Harvesting: manual stacking*. Forestry Solutions, White River, South Africa.
- Shuttleworth, B. 2011. *Harvesting: mule extraction*. Forestry Solutions, White River, South Africa.
- Smit, W. 2015. *Small scale plantation in South Africa*. FSA, Pietermaritzburg, South Africa.
- Spalevic, V, Curovic, M, Tanaskovic, V, Djurovic, N, Lenaerts, T and Nyssen, J. 2015. Application of the Interomodel for the assessment of the soil erosion intensity and runoff of the river basin Dragovo Vrelo, Montenegro.
- Spinelli, R, Magagnotti, N and Lombardini, C. 2010. Performance, capability and costs of small-scale cable yarding technology. *Small-scale Forestry* 9 (1): 123-135.
- Upfold, S, Dlamini, N and Ndlela, N. 2015. *Knowledge to support small-scale tree farmers in South Africa*. ICFR, FSA, Pietermaritzburg, South Africa.
- Visser, R and Spinelli, R. 2012. Determining the shape of the productivity function for mechanized felling and felling-processing. *Journal of Forest Research* 17 (5): 397-402.
- WorkSafeBC. 2013. *Cable yarding systems handbook*. Workers' Compensation Board of British Columbia, British Columbia.
- WorkSafeNZ. 2014. *Safe manual tree felling*. 978-0-478-42502-4. Auckland, New Zealand.
- Yovi, EY and Yamada, Y. 2015. Strategy to disseminate occupational safety and health information to forestry workers: the felling safety game. *Journal of Tropical Forest Science* 27 (2): 213-221.