

**COMPARATIVE ANALYSIS OF PROFITABILITY OF  
THINNED AND UNTHINNED COMMERCIAL FOREST  
PLANTATIONS WITH AND WITHOUT CARBON REVENUES**

**THE CASE OF PLANTATIONS UNDER GREEN RESOURCES  
LTD AND SAOHIL FOREST PLANTATIONS IN MUFINDI  
DISTRICT**

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**THE CASE OF PLANTATIONS UNDER GREEN RESOURCES  
LTD AND SAOHIL FOREST PLANTATIONS IN MUFINDI  
DISTRICT**

**By  
Hosea Elia**

**A Dissertation Submitted in Partial/Fulfillment of the Requirements for Award  
of the Degree of Master of Business Administration (MBA) of Mzumbe  
University**

**2013**

## CERTIFICATION

We, the undersigned, certify that we have read and hereby recommend for acceptance by the Mzumbe University, a dissertation entitled **Comparative Analysis of Profitability of Thinned and Unthinned Commercial Forest Plantations With and Without Carbon Revenues. The Case of Plantations Under Green Resources Ltd and Saohill Forest Plantations in Mufindi District**, in partial/fulfilment of the requirements for award of the degree of Master of Business Administration of Mzumbe University

*Signature*

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Major Supervisor

*Signature*

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## **DECLARATION**

I, **Hosea Elia**, declare that this thesis is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

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## **DEDICATION**

I dedicate this study to my lovely children **Jackline Hosea and Joseph Hosea**, for whom I pray to Almighty God to be very successful in their life.

## ABBREVIATIONS AND ACRONYMS

AAU	-	Assigned Amount Unit
A/R	-	Afforestation and Reforestation
ANOVA	-	Analysis of Variance
BAU	-	Business-as-usual
CDM	-	Clean development Mechanism
CER	-	Certified Emissions Reductions
CO <sub>2</sub>	-	Carbon Dioxide Gas
CS	-	Carbon Sequestration
CR	-	Carbon Revenue
DOE	-	Designated Operational Entity
e.g.		Latin word "exempli gratia" (means, for example)
ERU	-	Emission Reduction Units
EUA		European Union Allowance
EU ETS	-	European Emissions Trading Scheme
FAO	-	Food and Agricultural Organization
fCER		Forest Certified Emission Reductions
GHG		Green House Gases
GPS	-	Global Positioning System
GRL	-	Green Resources Limited
Gts	-	Giga tons
IETA	-	International Emissions Trading Association
IFP	-	Idete forest Plantation
IPCC	-	Intergovernmental Panel on Climate Change
IRR	-	Internal Rates of Returns
JI	-	Joint Implementation
Ltd		Limited
m.a.s.l	-	Meters above sea level
MAI	-	Mean Annual Increment
MFP	-	Mapanda Forest Plantation
MPM	-	Mufindi Paper Mills
MS-Excel		Microsoft excel
NGO	-	Non-Governmental Organization
PV	-	Present values
Tshs	-	Tanzania shillings
UFP	-	Uchindile Forest Plantation
UK	-	United Kingdom
UNFCCC	-	United Nations Framework Convention on Climate Change
US\$	-	United States of American dollar
USA	-	United States of America

USD	-	United States of America Dollar
UTM		Universal Transverse Mercator
VCM	-	Voluntary Carbon Market
VCS	-	Voluntary Carbon Standards
VCU	-	Voluntary Carbon Units
VGS	-	Voluntary Gold Standards
WGS	-	World Geodetic System
WWF		World Wide Fund
Yr.	-	Year

## ABSTRACT

This dissertation was to provide in depth comparative analysis of profitability of thinned and unthinned commercial forest plantation with and without carbon revenue. The study was conducted for Plantations under Green Resources Ltd and Sao Hill Forest Plantations in Mufindi District. The main objective of this study was to compare the profitability of thinned and unthinned commercial forest plantations with and without carbon sequestration. The study was conducted in two phases; the first phase was a time and work study on thinning operations. The second phase, involved enumeration of thinned and unthinned compartments. Systematic random sampling was used and the plots were distributed systematically throughout the planted area in order to achieve representation of different species, age classes and sites in the forest. The plots were geo referenced using a GPS. Plots were circular with an area of 0.04ha and a radius of 11.28 m. Data were collected by using direct observation, survey, enumeration methods and records of previous years. The study revealed that, there is significant difference on average stem diameter on thinned and unthinned forest plantation both for GRL and Sao hill forests. Furthermore the study revealed that, it is more profitable to invest in thinned forest plantations when combining sawn timber and carbon revenue. Moreover the study revealed that, the trees with ages between 11 to 14 years for Green Resources and Sao hill forest plantations attain high AEV with and without carbon revenue (CR). A plantation with CR has high AEV compared to a plantation without CR. Also between the ages of 11 - 14 years, the forest plantation attain the highest NPV/ha and AEV/ha before and after the last thinning at age 13. Our study tested different thinning methods and the results revealed that, thinning by using a chainsaw significantly reduced cost, time and increased productivity when operating on a large scale and when manpower is inadequate to cover all the operations in managing the forest. It is therefore recommended that, forest plantations owners thin all their forest plantations and forest plantations owners should ensure timely and proper silvicultural treatment in order to ensure high performance of the plantations. Furthermore, it is recommended that, for the sites like Idete that did not show a promising volume, thinning intensity should change and extend the rotation age from 20 to 25 to ensure better gain in

volume and tree diameters. From supply chain matrix, it is recommended that, plantations should be thinned by using chainsaw as it significantly reduces cost, time and increases productivity when operating on a large scale and when manpower is inadequate to cover all the operations in managing the forest. Lastly, I recommend that, forest plantations should also engage in carbon business because it gives high AEV, Net Revenue and NPV compared to the plantations which are not engaged in carbon business.

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## **CHAPETER ONE**

### **1.0.INTRODUCTION**

#### **1.1.Background**

Green Resources<sup>1</sup> is a Norwegian company incorporated in 1995 to become a leading developer of plantations for forestry and a leading producer of greenhouse gas emission credits. The company decided to focus on East Africa because of land availability, good rainfall, highly qualified foresters, low-cost labour, stable governments and a long-standing Nordic development aid presence in the region. Green Resources is a plantation, carbon offset, forest products and renewable energy company. It employed more than 5,300 people at the end 2010 and has invested USD 100million in its African operations since its inception. Green Resources mainly operates in Mozambique, Tanzania and Uganda, with a small operation in Southern Sudan. It is Africa's leading forestation company and has 22,000 ha of forest. It is growing trees to generate carbon credits and bioenergy and to manufacture wood products. Green Resources has probably planted more new trees than any other private company in Africa during the past ten years; a record 6,000 ha of new forest were planted in 2010. In addition, the company holds more than 300,000 ha of land for future planting and conservation. Green Resources Limited (GRL), the Tanzania plantation company, now has three of its forests certified according to the Forest Stewardship Council Standard, the world's leading standard for environmental and sustainable forest management. The certified forests are Idete forest plantation (IFP), Mapanda forest plantation (MFP) and Uchindile forest plantation (UFP). It aims to generate superior return for its shareholders, provide great challenges and an excellent working environment for its employees, protect the environment and help develop local communities where it operates. Green Resources also aims to develop a leading African carbon offset business. The company will absorb and store the maximum amount of CO<sub>2</sub> through forestation projects and by converting plantation forests into renewable energy.

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<sup>1</sup> [www.greenresources.no](http://www.greenresources.no)

## **1.2.Problem setting**

Green Resources is a profit-oriented private company. The company aims to maximize the return to shareholders via share price appreciation and, eventually, through the payment of dividends. It also intends to seek a public listing of its shares.

The company believes that investments in the areas where it operates should yield at least 20-25% return on equity, compared to a return target of 8-12% or lower for traditional forest investment companies and carbon funds in the main global markets.

Green Resources believes the interests of stakeholders, including customers, employees, local communities, the environment, host countries, creditors and the shareholders are best served by creating a financially strong and profitable company. The company believes further that a business based on sustainability and social responsibility, using renewable, green resources, will yield the highest long-term returns. Getting on top of financial measures of business performance is an important part of running a growing business, especially in the current economic climate. Many businesses fail because of poor financial management or planning. Business success can depend on developing and implementing sound financial and management systems. Updating your original business plan is a good place to start.

## **1.3.Statement of the problem**

Afforestation and reforestation have been proposed as a means to help offset carbon losses through the accumulation and long term storage of carbon in plant biomass and soil organic matter (*Brown et al., 1996*). According to *FAO (2004)*, there have been few studies on the potential of carbon sequestration (CS) in developing countries. *Said et al., (2007)* reported that carbon storage in wood products is not always accounted for, since the wood product pools are not considered in the guidelines for the first Commitment Period under the Kyoto Protocol. However, considerable amounts of carbon are stored in long lived wood products and thus, there is need for an improved accounting methodology. Moreover, although afforestation and reforestation have been proposed as major mechanism of carbon sequestration, methods of quantifying carbon stocks in different tropical forest

plantations of various species is little studied. Through afforestation projects, the investors and other local communities have not been paying much attention on the profitability and the impact of thinning operations on the amount of carbon sequestered in both thinned and unthinned plantations. In this study, the researcher conducted a comparative analysis on profitability of thinned and unthinned commercial forest plantation. This study compares the profitability of a commercial forest plantation focusing on the final revenue when combined with carbon revenue on thinned and unthinned stand. This is due to the fact that, so far little is known about the profitability of thinned and unthinned commercial plantations when combined with carbon revenue in Mufindi District. The researcher therefore intended to compare the profitability of thinned and unthinned commercial forest plantations in the district when carbon revenue is also taken in account.

#### **1.4.Objectives**

##### *1.4.1. General objective*

To compare the profitability of thinned and unthinned commercial forest plantations with and without carbon sequestration

##### *1.4.2. Specific objectives*

- i) To compute present values, annual increments and annual expectation values of thinned and unthinned forest plantation in Green resources plantation in Mufindi District.
- ii) To determine the impact of thinning operations and the amount of carbon sequestered in the trees on the final revenue in Mufindi District.
- iii) To assess the impact of thinning operations on carbon revenues gained by the local communities in Mufindi District.
- iv) To estimate the cost of semi-mechanized thinning compared to manual thinning operations in Mufindi District.

- v) To recommend ways of further increasing the profitability of commercial forest plantations in Mufindi District.

### **1.5. Research question**

- What are computed present value (PV), amount of carbon sequestered and the final volumes for thinned and unthinned stand in Mufindi District.?
- What will be the impact of carbon sequestered in the two stands to the final revenue in Mufindi District.?
- What is the value gained by local communities on the carbon revenues from thinned compared to unthinned forest plantation in Mufindi District.?
- What will be the cost of thinning using semi-mechanized method compared manual methods in Mufindi District.?
- What should be done to increase profitability of commercial forest plantations in Mufindi District.?

### **1.6. Scope of the study**

The study covered commercial forest plantations in Mufindi District located in Iringa region. In this area, the researcher focused on Green resources Ltd and Saohill forest plantations.

### **1.7. Significance of the study**

The findings will enable the investors understand how much value is created by undertaking an investment with and without considering the carbon revenues reflected from thinned and unthinned operations. Moreover the findings will help the management decide on whether they should use manual or mechanized methods to improve efficiency and minimize the operational costs. Furthermore, the study will help the surrounding community (villages) to know what they actually deserve in terms of carbon revenues from thinned and unthinned stands.

### **1.8.Rationale or Justification of the study**

The study was selected to be done at Green Resources plantations because there were enough Pinus species for the study. By 2010, 58% of the total planted area was covered with Pinus species; however this dropped to 55% in 2011 due to fire damage.

### **1.9.Limitations of the study**

There were a number of limitations that the researcher faced. One of the limitations of this study was that, time was too short to cover all the silvicultural components in the commercial forest plantation that could contribute to profitability of forests. These components include land preparation, fertilization, weed control (manual and chemical control), pruning, commercial and non-commercial thinning operations. Financial constraint was another limiting factor as the researcher had limited funds for the study.

## CHAPTER TWO

### 2.0.LITERATURE REVIEW

#### Theoretical literature review

#### 2.1.Thinning operations

Thinning is a silvicultural treatment that reallocates stand growth through an evenly spaced population of crop trees. These crop trees can be identified by their dominant or co-dominant position in the stand, superior form and vigor, and lower incidence of disease or injury. If done properly, thinning can increase stand value in two ways: (1) by merchandizing trees that would otherwise die and decay, and (2) by focusing volume production on the trees that are most likely to increase in value (*Timothy B. Harrington, 2001*). Thinning is an artificial reduction of stand density before stand maturity. Thinning operations lead to a temporary reduction of stand productivity due to the removal of stems. However, these reductions are compensated through higher productivity of the remaining stand and through reduced mortality<sup>2</sup>. In case thinning operations are excessive, higher productivity of the remaining stand cannot compensate production loss through the removal of stems. Heavy thinning entries might also compromise timber quality in pines. Therefore periodic, less severe thinning operations are preferred. Thinning removes surplus trees to concentrate timber production on a limited number of the best trees in the plantation resulting in increased diameter growth and producing more valuable larger diameter trees. If forests are left unthinned, there is a high incidence of mortality in the forest i.e. trees will progressively die, leading to a reduction in total timber volume production. If these trees are removed by thinning operations, a proportion of the timber volume can be salvaged resulting in an increase in volume production over similar unthinned stands. Thinning involves changing the stand density of the plantation by a deliberate removal of some trees from it from time to time during its life. As the growth of the plantation continues, the stem wood produced will be distributed amongst the fewer trees which remain after the thinning. As a result, their stem diameter growth rate will accelerate and the trees will produce a larger volume of large diameter logs at

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<sup>2</sup> [www.unuftp.is](http://www.unuftp.is)

earlier ages than would have occurred if the plantations had not been thinned (*Philip W. West, 2006*).

The principal reason for thinning plantations is to speed the production of larger, more valuable logs to be used for sawn wood production. This means, it is usually appropriate to thin only from plantations being grown to produce large logs. Therefore thinning needs to be considered once the trees are utilising all the available growing space. A more detailed assessment of thinning readiness can be done by measuring the diameter of the trees at breast height (1.3 metres above ground) in order to calculate the area taken up by each tree in a plot. These measurements give the basal area per hectare of the stand and are an indication of whether all the available growing space in the stand has been fully utilised.

## **2.2. Management interventions (harvesting)**

Thinning and final felling can be defined for each cohort separately. A thinning is described by the age at which the intervention takes place, intensity of the intervention (fraction of cohort biomass removed), and allocation of the biomass removed from different “raw material” classes as slash, logwood and pulpwood.<sup>3</sup>

## **2.3. Carbon Sequestration concept**

### *2.3.1. Carbon Cycling in Forests*

Carbon sequestration concept can be explained better through photosynthesis process done by the plants. Photosynthesis is the chemical process by which plants use sunlight to convert nutrients into sugars and carbohydrates. Carbon dioxide (CO<sub>2</sub>) is one of the nutrients essential to building the organic chemicals that comprise leaves, roots, and stems. All parts of a plant, the stem, limbs, leaves, and roots contain carbon, but the proportion in each part varies enormously, depending on the plant species and the individual specimen’s age and growth pattern. Nonetheless, as more photosynthesis occurs, more CO<sub>2</sub> is converted into biomass, reducing carbon in the

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<sup>3</sup> [www.scribd.com](http://www.scribd.com)

atmosphere and sequestering (storing) it in plant tissue (vegetation) above and below ground. Plants also respire, using oxygen to maintain life and emitting CO<sub>2</sub> in the process. At times growing forests are net emitters of CO<sub>2</sub>, although they are generally net carbon storage over the life of the forest. When vegetation dies, carbon is released to the atmosphere. This can occur quickly as in a fire, or slowly as fallen trees, leaves, and other detritus decompose. For herbaceous plants, the above-ground biomass dies annually and begins to decompose right away, but for woody plants, some of the above-ground biomass continues to store carbon until the plant dies and decomposes. This is the essence of the carbon cycle in forests net carbon accumulation (sequestration) with vegetative growth, and release of carbon when the vegetation dies. Thus, the amount of carbon sequestered in a forest is constantly changing with growth, death, and decomposition of vegetation. Carbon sequestration is the process of increasing the carbon content of a carbon pool other than the atmosphere (*IPCC, 2000*).

### *2.3.2. Forests to Sequester Carbon: A Global Overview*

An important question is the extent to which forest management can significantly contribute to carbon sequestration and the types of management that are best suited to this task. The Intergovernmental Panel on Climate Change (*IPCC*) estimates that appropriate policy could increase the amount of carbon sequestered as a carbon pool in the terrestrial system by up to 100 Gts over the level of carbon that would be sequestered without that policy (*IPCC 2001*). (Note that this is well below the potential of 600 - 1,200 Gts that is believed to have existed in much earlier times or that is estimated under certain circumstances (*IPCC 2001*)). This amount of carbon is roughly equal to about 30 years of atmospheric carbon build-up at current rates.

### *2.3.3. Plantation Forest Management with Carbon as an Output*

Carbon sequestration has recently come to be recognized as an important output of forests. The carbon sequestration value of a forest, as with many other non-timber outputs, has so far not been captured by forest owners or in markets. This situation appears to be changing. With the advent of the Kyoto Protocol and its

recognition of the use of forestry activities and carbon sinks as acceptable tools for addressing the issue of the build-up of atmospheric carbon, the potential role of planted forests as a vehicle for carbon sequestration has taken on a new significance. Additionally, the emergence of tradable emission permits, and now tradable carbon offsets, provides a vehicle for capturing the benefits of carbon emission reductions and carbon offsetting activities. It should be noted that almost all studies thus far have focused on the cost of carbon sequestration as a single output, rather than as a joint output with timber (*Sedjo R.A, 1995 and Stavin, 1999*)

Forest management traditionally has involved managing the forest for the production of a single output - timber. However, the single output, industrial wood, may come in various forms, like pulpwood and sawn timber, which have different production costs, harvest cycles, and market prices. A prudent forest manager must consider questions of timber volume and timber quality (type) when managing to maximize the profitability of the timber operation (*Timothy B. Harrington, ibid*)

Furthermore, the existence of an opportunity cost of capital (a discount rate) dictates that harvests will usually take place before biological growth is maximized (sometimes referred to as the culmination of mean annual increment). The management must consider, at least, the costs and prices of various outputs obtainable from the forest, the yield function, and the discount rate when determining management regimes and harvesting rotations. The manager then determines the appropriate lengths of the harvesting rotation, thinning, and other silvicultural operations to achieve the output mix and time profile required for maximizing the present value of the timber (*Timothy B. Harrington, ibid*).

Forests have always sequestered carbon, but this ecosystem service went unnoticed and uncompensated. In the past, the forest manager would have been expected to ignore any carbon considerations in his management actions. Suppose now, however, that payments were made for both carbon sequestration and timber. Under this arrangement, timber and carbon sequestration would be viewed as joint products, and the owner would have two market outputs to consider. As the forest matures, its timber stands become more valuable, so does the value of its carbon sequestration services. Suppose an owner receives an annual payment for carbon services on the basis of the volume sequestered but that this payment is forthcoming only as long as

the timber remains “on the- stump.” This approach recognizes the fact that forests need not last forever, and trees do eventually die. Because the amount of carbon sequestered will depend on the forest biomass, the payment for carbon services would be expected to rise as the forest matures. Additionally, suppose payment is received for the timber, but only when it is harvested, then, the manager must make a choice between receiving an annual payment for the carbon sequestration value and receiving a one-time payment for the value for the timber (*Timothy B. Harrington, ibid*)

#### 2.3.4. Carbon transactions

According to *Karan, and Philippe (2007)*, Carbon transactions are defined as purchase contracts whereby one party pays another party in return for GHG emissions reductions or for the right to release a given amount of GHG emissions that the buyer can use to meet his compliance or corporate citizenship objectives against climate change mitigation. Payment is made using one or more of the following forms: cash, equity, debt, convertible debt or warrant, or in-kind contributions such as providing technologies to abate GHG emissions. The carbon transactions can be grouped into two main categories:

***Allowance-based transactions***:- These are the ones in which the buyer purchases emission allowances created and allocated (or auctioned) by regulators under cap-and-trade regimes, such as Assigned Amount Units (AAUs) under the Kyoto Protocol, or EUAs under the EU ETS. Such schemes combine environmental performance (defined by the actual level of caps set) and flexibility, through trading, in order for mandated participants to meet compliance requirements at the lowest possible cost;

***Project-based transactions***: - Here the buyer purchases emission credits from a project that can verifiably demonstrate GHG emission reductions compared with what would have happened otherwise. The most notable examples of such activities are under the CDM and the JI mechanisms of the Kyoto Protocol, generating CERs and ERUs, respectively.

### *2.3.5. Benefits of carbon sequestration through forests*

The benefits of carbon sequestration activities are typically estimates of the amount of carbon sequestered, number of tons of carbon sequestered indefinitely or the number of tons of carbon sequestered for a time period, e.g., for one year. More accurately, the benefits of carbon sequestration are the future damages avoided by reducing the amount of atmospheric carbon. However, the monetary value of the sequestered carbon is difficult to estimate since the potential damages associated with global warming are very uncertain. Some analysts have used the level of proposed carbon taxes as a proxy for the value of the benefits society believes it would receive from sequestration. In addition, it should be noted that the use of forestry does not require the development of any new science or technologies. Societies know how to plant and manage fast-growing forests, and societies know where fast-growing forests will thrive and where they will not. Carbon transfers or trading would have as a by-product the generation of financial transfers, usually from developed to developing countries.

### *2.3.6. The compliance carbon market*

In 1997 the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol which established legally binding targets for greenhouse gas reductions by those countries which ratified the Protocol (predominantly ‘developed’ countries with the notable exceptions of the USA and Australia): these countries are also known as Annex I countries. To enable compliance the Protocol established Flexible Mechanisms to allow these countries to meet their targets by trading carbon credits or emission reduction units. The compliance market is the product of these Flexible Mechanisms established by the Protocol. These mechanisms are: the Clean Development Mechanism (CDM); Joint Implementation (JI); and Emissions Trading. In addition to this, several nations and groups of nations have developed their own trading mechanisms to help them meet their targets; the biggest of these is the European Emissions Trading Scheme (EU ETS).

### *2.3.7. The Clean Development Mechanism (CDM)*

The CDM is a mechanism that allows the Annex I parties to the Kyoto Protocol (such as the UK) to meet their emissions reduction targets by generating credits from emissions reducing or saving projects in developing countries. This allows for the reduction to be made at a lower cost than may otherwise be possible domestically. The projects generate emissions credits called Certified Emissions Reductions (CERs), which can then be bought and traded. One CER is equal to one tonne of carbon dioxide equivalent gases<sup>4</sup>. In order to be recognised in the CDM, projects have to demonstrate that they create savings which are additional to anything that might have happened anyway, a concept known as ‘additionality’.

Additionality is proved by using the CDM toolkit, which provides stringent criteria for a project to meet and provides a methodology for calculating baseline emissions which then give a business-as-usual (BAU) scenario against which the project is compared. The amount of credits that a project is entitled to is the difference between the project emissions and the baseline emissions. The methodology enables project developers to show that the emission reductions would not have happened but for the project. There are currently approximately 60 different methodologies to cover a range of different project types. An authorised third party called the Designated Operational Entity (DOE) is responsible for the verification and certification of a project. Verification involves on-site inspection and review. The certification procedure provides written assurance that the project has achieved the claimed emissions reductions.

### *2.3.8. Joint implementation (JI)*

Joint implementation allows developed countries to meet their emission reduction targets through projects in other developed countries with legally binding targets under the Kyoto Protocol. These projects generate tradable credits which are called Emission Reduction Units (ERUs). As under the CDM, projects must demonstrate additionality and go through a similar verification and certification process.

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<sup>4</sup> <http://en.wikipedia.org>

### *2.3.9. Emissions trading*

The Kyoto emissions trading scheme is a cap-and-trade scheme. In a cap-and-trade system, parties are given an emissions allowance based on an emissions reduction target. In order to create scarcity a limited number of allowances are issued equal to the ‘global’ target below the “business as usual” emissions level for a particular period. In the Kyoto scheme, each allowance is called an Assigned Amount Unit (AAU) which is equivalent to one tonne of carbon dioxide. At the end of a period each party must hold the equivalent number of AAUs equal to the amount of greenhouse gas it emitted. This allows parties to decide whether to reduce their emissions internally, or whether to buy credits from other parties, who may have been able to make an emission reduction more cheaply. Similarly, parties which have reduced their emissions below their target will be able to trade any surplus allowances they make to other parties who cannot, (or who do not want) to meet their targets internally. The rationale behind emissions trading is cost-effectiveness; that in theory, parties will choose the most cost-effective way to either make or buy their emission reductions.

### *2.3.10. The voluntary carbon market*

The voluntary carbon market (VCM) has developed independently of government targets and policies and is a place where anybody, from businesses, to NGOs, to individuals can participate in the business of offsetting. Carbon credits are also created in the voluntary market, but unlike the compliance market where credits are tradable under the Kyoto flexible mechanisms (that is to say, they are ‘fungible’), credits in the voluntary market are generally non-fungible and they are not tradable between schemes.

There is a legally-binding voluntary market where parties can set self-imposed, legally binding greenhouse gas emissions reductions targets: an example of this is the Chicago Climate Exchange. The focus of Chicago Climate Exchange was the non-legally binding voluntary carbon offset market. In this market, people invest in emissions reductions for a variety of reasons, from meeting their own self-imposed emissions reduction targets, to helping to address climate change, or to reduce the

impact of their carbon footprint. Some credits in this market are verified according to certain standards, others do not meet any identifiable verification standards.

#### *2.3.11. The Voluntary Gold Standard (VGS)*

This is one of the emerging voluntary carbon standards which were launched by WWF-UK in May 2006. The Voluntary Gold Standard is a simplified version of the CDM Gold Standard. The methodology is only available for voluntary emissions reductions and creates Voluntary Emissions Reduction Units (VERs). The VGS is only available for projects in developing countries and whilst it uses the basic methodologies of the CDM Gold Standard, its hope is that it will make them easier to apply to the smaller project types more generally found in the voluntary market.

#### *2.3.12. The Voluntary Carbon Standard (VCS)*

The Voluntary Carbon Standard has been developed by The Climate Group and the International Emissions Trading Association (IETA). Version 1 of the VCS was released for consultation on 2<sup>nd</sup> March 2006. The comments from this consultation were incorporated into version 2 of the VCS which was by then still in its consultation stage. The Voluntary Carbon Standard aims to ensure that all voluntary emission reductions projects that want to trade in VCUs are independently verified to meet specific criteria and that these will represent “real, quantifiable, additional and permanent project-based emission reductions”. The VCS will provide protocols and criteria to certification entities and project developers on the specifications for creating, verifying, and registering VCUs. The VCS has created a registry managed by the Bank of New York which is used to register, transfer and retire VCUs from the market.

### **2.4. Profitability analysis**

Profitability is, in general, the efficiency of a company or industry at generating earnings (*Yosbely A. S. 2006*). Profitability analysis is an analysis of costs and revenue to determine whether or not a venture will make a profit, and, if so, how

much. This is important information in deciding on whether to make an investment. The length of time required to repay the initial investment can be a critical factor. The Annual Equivalent Value (AEV) is used as the profitability indicator (Benitez et al., 2001). AEV can be obtained from the Net Present Value (NPV) formula. It was adopted because NPV is not appropriate for comparisons of economic feasibility of projects with different lifetimes<sup>5</sup>

## **2.5. Comparative analysis**

This is an item-by-item comparison of two or more comparable alternatives, processes, products, qualifications, sets of data, systems, or the like. In accounting, for example, changes in a financial statement's items over several accounting periods may be presented together to detect the emerging trends in the company's operations and results<sup>6</sup>.

## **2.6. Time and Work study**

### *2.6.1. Work study*

Work Study is the systematic examination of the methods of carrying out activities such as to improve the effective use of resources and to set up standards of performance for the activities carried out. It is also a term for those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement'. Work study helps in Productivity Improvement, but also in improvement of Quality and Safety.

### *2.6.2. Time study*

Time study is a tried and tested method of work measurement for setting basic times and hence standard times for carrying out specified work. Its roots are back to the period between the two World Wars. The aim of time study is to establish a time for

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<sup>5</sup> Forest Ecology and Management 226 (2006) 341–350

<sup>6</sup> [www.sceaonline.org](http://www.sceaonline.org)

a qualified worker to perform specified work under stated conditions and at a defined rate of working. This is achieved by a qualified practitioner observing the work, recording what is done and then timing (using a time measuring device like a stopwatch). The elements of time to be collected will be working time, necessary delays and unnecessary delays.

- *Working time*

This is the actual time for thinning a tree.

- *Necessary delays*

This involves all work elements that are necessary for the thinning operations to be done like time to move from one tree to another, sharpening the equipment, refilling oil and fuel and moving away lying trees near the area of operation.

- *Unnecessary delay*

This involves all work elements that are not necessary for the work to be accomplished like chatting with friends, phone calls, accidents, eating food, listening to news and the like.

### 2.6.3. *Description of Cost Models and Modelling Assumptions*

The cost model for thinning is built using MS-Excel and contains establishment and management costs. These costs include activities such as site preparation, herbicide application, seedlings, fertilization, annual management costs, and price or cost/hectare. The financial assumptions used to calculate the optimal rotation age are devised using micro forest tool.

## **2.7. Operational definitions of key variables for the study**

### *2.7.1. Annual Equivalent Value (AEV)*

Annual Equivalent Value (AEV)<sup>7</sup> is simply the Net Present Value (NPV) converted to an annual value paid at the end of each year or period for the life of the investment. The Annual Equivalent Value (AEV) is used as a profitability indicator (*Benitez et al., 2001*). AEV can be obtained from the Net Present Value (NPV) formula. This is one of the profitability indicators for comparing the annual values paid on thinned and unthinned forests with or without carbon revenue consideration

### *2.7.2. Carbon Revenue*

Selling carbon credits allows innovative projects and businesses to earn rewards for generating low-cost emission reductions. Buying carbon credits allows large companies to manage the timing and cost of reducing their own GHG emissions. Large companies can buy credits to complement their own efforts to lower emissions, while investing in worthwhile projects. Over time, this flexibility mechanism channels more financing to clean, innovative businesses and technologies. Therefore, through carbon credits, Green resources will be benefiting from carbon revenues generated from her afforestation projects in Mapanda and Idete.

### *2.7.3. Mean Annual Increment (MAI)*

The mean annual increment (MAI) or mean annual growth refers to the average growth per year a tree or stand of trees has exhibited/experienced to a specified age. Because the typical growth patterns of most trees is sigmoidal, the MAI starts out small, increases to a maximum value as the tree matures, then declines slowly over the remainder of the tree's life. Throughout this period, the MAI always remains positive. The MAI is the average net annual increase in the yield (expressed in terms of volume per unit area) of living trees to a given age, and is calculated by dividing the yield of a stand of trees by its mean age. Mean Annual Increment is an indication of the productivity of forest area and is influential in management decisions,

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<sup>7</sup> [www.sfrc.ufl.edu](http://www.sfrc.ufl.edu)

especially those decisions dealing with timber production.<sup>8</sup> This indicator provides a direct measure of the rate of merchantable timber production across the defined forest area, and an indirect measure of the biological site productivity for other values.

#### 2.7.4. *Net Present Value (NPV)*

Net Present Value (NPV) recognizes money's time value by using the minimum acceptable rate of return to discount all costs and returns back to the time of project initiation (period 0 or period 1, depending on the timing of cash flow). The discounted costs are then subtracted from the discounted revenues. Net present value is used to show the difference between the present value of future revenues and the present value of future costs when calculated using a chosen discount rate. If the result of the NPV calculation is zero or negative, then the costs are either equal to, or greater than, the income; hence the project is not profitable at the chosen discount rate. If the result of the NPV calculation is greater than zero, then the project is expected to be viable and profitable, provided that the discount rate chosen is appropriate. Therefore, for thinned and unthinned forests, the one which will have higher NPV than the other one is more profitable than the other.

#### 2.7.5. *Labour rate*

This is the cost of wages paid to workers during an accounting period on daily, weekly, monthly, or job basis, plus payroll and related taxes and benefits per unit work output. This may be the number of trees per hectare, man-days per hectare, or trees per hour. This is used during time and work study analysis to determine the costs of thinning using manual methods or semi-mechanized methods and the unit task that can be assigned per person in order to maximize profit without affecting manpower.

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<sup>8</sup> *Centre for International Forestry Research (1999)*

### 2.7.6. Volume

Volume is one of the measures of profitability of a forest. When the standing forest is valued by using standing volume or stumpage price, the higher the volume of the forest the higher the profitability and the lower the volume in cubic meters (m<sup>3</sup>) the lower the profitability. This can be the volume of the compartment, block, division or the whole forest under consideration.

## 2.8. Empirical literature review

*David E et al., (2007)* studied on the *Economics of Growing Slash and Loblolly Pine to a 24-year Rotation With and Without Thinning – Impact of Thinning at Various Stumpage Prices in South Carolina and Mississippi*. The study revealed that, the profitability of thinning depends on a combination of yield class, price and site stability. Thinning is more profitable than not thinning for yield class 14 or greater by early thinning. Many private growers have decided to leave their plantations un-thinned or have postponed thinning because, up until recently, the returns from thinning did not cover the costs. The study revealed that it is possible to undertake a first thinning with a loss between €3/m<sup>3</sup> and €6/m<sup>3</sup> and still achieve significantly better returns over the rotation rather than leaving the crop un-thinned. Additionally, there is increased saleability of the thinned plantation should the owner wish to sell the plantation<sup>9</sup>. The study further revealed that, thinning increases overall timber revenue by increasing the volume of saw log produced. This is because larger trees attract significantly higher prices and are less expensive to harvest on a €/m<sup>3</sup> basis and yield more valuable end products. *David E, (2005)* studied on *Economics of Growing Slash and Loblolly Pine to a 24-year Rotation With and Without Thinning, Fertilization, and Pine Straw - Net Revenue and Internal Rate of Return in South Carolina and Mississippi*. The study revealed that, Thinning increases the total harvest revenue and net revenue by \$350 (slash) to \$409/acre (loblolly) compared to the unthinned counterpart. Thinning slash and loblolly pine stands increase IRR by 1.19 to 1.59 per cent.

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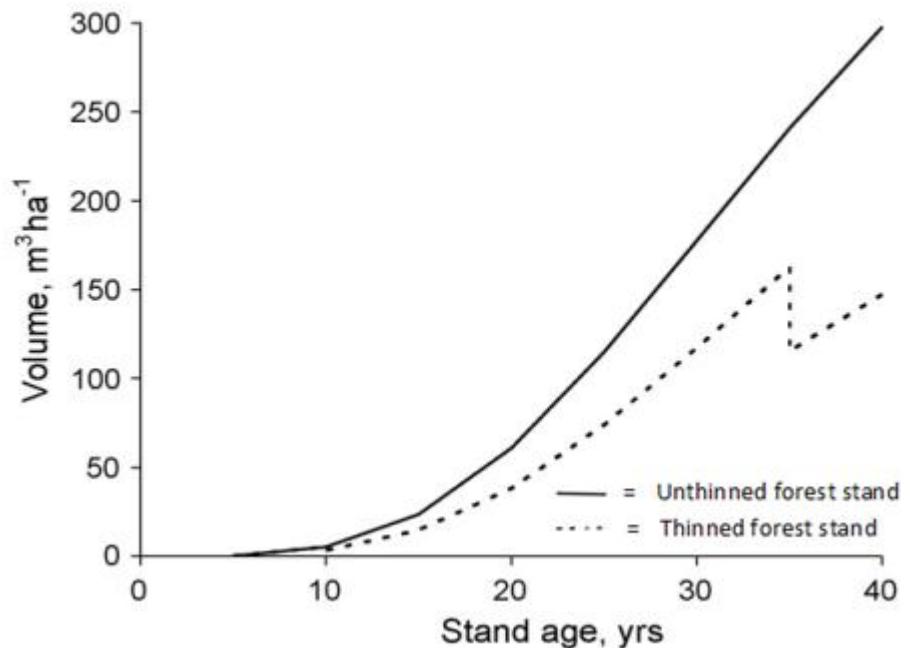
<sup>9</sup> <http://www.ireland-forestry.com>

A study conducted by Robert K and Donald L. (2009) *On Financial Feasibility of Sequestering Carbon for Loblolly Pine Stands in Interior Flatwoods Region in Mississippi for the period of 2008 – 2009*, revealed that the amount of carbon sequestered in a loblolly pine stand, and the amount of carbon released back to the atmosphere increased with final rotation harvest age for both thinned and unthinned management regimes. The largest amount of carbon was accumulated at age 50 years when an unthinned loblolly pine stand accumulated 269 tons of CO<sub>2</sub> per ac (1 ton of carbon = 3.33 tons of CO<sub>2</sub>). At the same age, a loblolly pine stand thinned from below accumulated 141 tons per ac. An unthinned stand achieved maximum mean annual increment (MAI) of CO<sub>2</sub> at year 30 of 7.85 of CO<sub>2</sub> ton/ac/yr whereas a thinned stand achieved maximum MAI of CO<sub>2</sub> at 15 years of 6.20 of CO<sub>2</sub> ton/ac/yr.

Jari Hynynen et al., (2005), studied on *Applying the MOTTI Simulator to Analyse the Effects of Alternative Management Schedules on Timber and Non-timber Production in Finland*. The study revealed that, there were notable differences in the development of the growing stock between the “no management” scenario and the management scenario. At the end of the simulation period the volume of the growing stock was 563 m<sup>3</sup>/ha in the unmanaged stand, of which the proportion of deciduous tree species (aspen and alder) was 4%. In the mixed stand, the stand volume was 393 m<sup>3</sup>/ha, of which 11% were deciduous tree species. In the pure spruce stand the volume of the growing stock was 410 m<sup>3</sup>/ha. Therefore, in terms of volumes from different scenarios, the study shows that, the unmanaged stand is more profitable than mixed and pure stands which will finally account for the carbon revenue in the final harvest. The study also, revealed that, the pure stand management scenario outperformed the other two alternatives when future costs and revenues were discounted with a 2–4% discount rate. With high discount rates (5–6%), however, the mixed stand management scenario became financially the most attractive alternative with high profitability in the final revenues. This is because, in the pure stand management, the cutting removal of the first thinning consists mainly of deciduous tree species, which have lower unit stumpage prices than Norway spruce. These result in a loss of cutting income compared to mixed stand management. With low discount rates, this loss can be outweighed by the sum of the present value of cutting incomes from the second thinning and final cut. Consequently, with high discount

rates, the initial loss cannot be covered, and mixed stand management becomes financially the most feasible.

*Saija Huuskonen and Jari Miina, (2006) Studied on the Stand-level Growth Models for Young Scots Pine Stands in Finland.* In the simulation, the initial stand density was set to 5000 trees per ha, pre-commercial thinning was carried out to a density of 2000 trees per ha at age ten and the first commercial thinning to a density of 1000 trees per ha (Dominant height = 14.5 meter). The study revealed that, dominant height was not affected, but the dominant diameter was increased by thinnings. The thinning method affects the diameter distribution of a stand, and therefore it also affects the relationship between the number of stems and the stand basal area. For example, in order to achieve the same remaining stand basal area, more trees are removed in thinning from below than in thinning from above. Thinning also increases the diameter growth of the remaining trees as shown in the figure below.



**Figure 1: Effect of thinning on volume and diameter development**

The economics of thinning depends on a combination of yield class, price and site stability. Thinning increases revenue but incurs a risk in terms of wind throw on unstable sites. The critical issue in terms of revenue from first thinning for the private owner is to maximise the volume of the higher value stake wood and pallet wood

assortments (Hanrahan, 2001). However, this should not occur at the expense of delaying first thinning and/or missing the optimum time for pruning.

Plakash N, et al., (2008) Studied on *the Financial Feasibility of Sequestering Carbon for Loblolly Pine Stands in Interior Flatwoods Region in Mississippi*. The study revealed that, on the profitability of both thinned and unthinned forest plantation, in the “no thinning” scenario, the “carbon sequestration only” regime generated higher revenue at 10% and 15% MARR<sup>10</sup> relative to the “timber production only” regime. The “no thinning” scenario reduced diameter growth in the stand causing the “timber production only” regime to be less profitable than the “carbon sequestration only” regime. However, in the thinning scenario, the study revealed that the “carbon sequestration only” regime generated less revenue than the “timber production only” regime for a 5% MARR<sup>11</sup> and carbon credit prices of \$4.50 and \$10/ton of CO<sub>2</sub> (except 20-year rotation). This suggests that, the financial incentives for carbon sequestration in this scenario were too small to induce forest owners to manage their stands for carbon sequestration only. The “carbon sequestration only” regime tended to generate more revenue than the “timber production only” regime for higher MARRs (10% and 15%). The study moreover, revealed that, there is more carbon stored in “unthinned” stands than in “thinned” stands. Also it was determined that the optimal harvest age was longer if the stand was to be managed only for carbon sequestration. Managing the same stand jointly for timber and carbon or for timber only resulted in a shorter rotation. Profitability of “joint production of timber and carbon” regimes at optimal rotation age was always greater than the profitability from the “timber production only” and “carbon sequestration only” regimes.

Miguel Espinosa et al., (2005) studied on *Carbon Sink Potential of Radiata Pine Plantations in Chile*. The study revealed that, the potential for net C sequestration adds significantly to these benefits, and places Chile in a position to offer C credits to industrialized countries that must reduce CO<sub>2</sub> emissions according to the Kyoto Protocol.

Victor H.G et al., (2006), studied on *Maximizing the Profitability of Forestry Projects under the Clean Development Mechanism Using a Forest Management*

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<sup>10</sup>MARR= Mean Average Rate of Return

<sup>11</sup> <http://www.ireland-forestry.com>

*Optimization Model.* The study revealed that, profitability of forestry projects under the CDM is influenced by timber and fCER prices. If a project developer thins his forest, the fraction of biomass removed will be counted as instant emissions and will not generate payments from CERs. On the other hand, if forests are left unthinned, revenues from timber will not be received until the end of the rotation period, but the quantity of fCERs generated will be high.

## **CHAPTER THREE**

### **3.0. RESEARCH METHODOLOGY**

#### **3.1. Study Area**

This research was conducted at Green Resources Ltd (GRL), a subsidiary company of Green Resources AS, located in Mufindi District, Iringa region. The study was conducted for three forest plantations, namely Idete and Mapanda forest plantations owned by GRL and Saohill forest plantation which is a government owned forest, located in Mufindi District of Iringa Region.

#### **3.2. Geographical Location, Size, and Altitude**

Idete Forest Plantation (IFP), with a total area of 14,163 ha of land is owned by Green Resources Limited (GRL). It is located 110km South East from the tarmac road at Mafinga, which is the main road running south-west from Dar es Salaam. The Plantation co-ordinates are  $8^{\circ} 52' 36.5''$  S and  $35^{\circ} 16' 36.47''$  E, bordering Mufindi Paper Mill to the west and Idete village to the south. The altitude of the area is between 1,100m and 1,550m above sea level, with an average annual rainfall of 1,050mm. The mean annual temperature of the area is  $16^{\circ}\text{C}$  and rainy Season is from November to May.

Mapanda Forest Plantation (MFP) is also located in Mufindi district, Iringa region. It is 130km South East from the main tarmac road at Mafinga. Mapanda Forest spans a total of 6,258 ha, of which 3,536 ha are plantable, 774 ha are for conservation and 1,948 ha are set aside for research and other uses. The Plantation co-ordinates are  $8^{\circ} 57' 36.52''$  S and  $35^{\circ} 4' 31.97''$  E, bordering Sao Hill Forest Project to the west and Highland Forest Project to the south. The altitude ranges from 1400m to 1760m above sea level, with an average annual rainfall of 1,050mm. The mean annual temperature is  $14^{\circ}\text{C}$ , and the rainy season is from December to April.

Figure 2: Satellite images showing the location of the study areas of Idete, Mapanda and Sao hill Forest Plantations in Mufindi District



### 3.3. Research design

The study is a comparative analysis of profitability of thinned and unthinned commercial forest plantation with and without carbon revenue. The study was conducted in two phases; the first phase was a time and work study on thinning operations. The second phase, involved enumeration of thinned and unthinned compartments. According to the *CDM methodology*, “the size of plots is (usually) between 100 m<sup>2</sup> for dense stands and 1000 m<sup>2</sup> for open stands. The plots were distributed systematically throughout the planted area in order to achieve representation of different species, age classes and sites in the forest<sup>12</sup>. The plots were geo referenced using a GPS. Plots were circular with an area of 0.04ha and a radius of 11.28 m. Tree numbering progressed clockwise and tree number one were the tree in the northern direction but nearest to the plot centre.

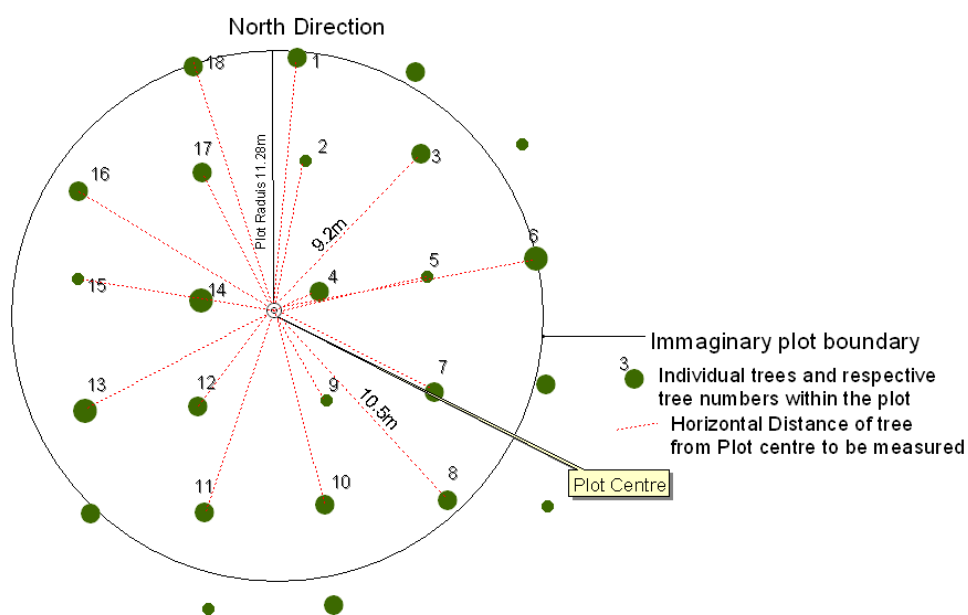


Figure 3: Design of sample plot and tree numbering during data collection

<sup>12</sup> <http://cdm.unfccc.int>

### **3.4. Population**

The study population included Green Resources Ltd (GRL) forest plantations, Saohill forest plantation (which is government owned), Mufindi Paper Mills (MPM); Fox forest plantation, and community woodlots in Mufindi district.

### **3.5. Sample and Sampling method**

In this study, Mapanda forest plantation and Idete forest plantation from Green Resources Ltd and Saohill forest plantation, (a government owned plantation), were purposively picked as a sample of commercial forest plantations in Mufindi district. In each forest of the sample, both systematic and stratified random sampling was used to determine the representative sample plots from each plantation according to *UNFCCC/ version 2 A/R Methodological Tool, "Calculation of the number of sample plots for measurements within A/R CDM project activities*. This method was used to determine the number of plots studied per hectare.

### **3.6. Types and Sources of Data**

Both Primary and secondary data were used during the study. Primary data were obtained directly from the forest through direct observation and enumeration; these included tree diameters, tree heights, number of stems per hectare, silvicultural score, time, and areas in hectares. Secondary data included the previous enumeration data before thinning was done, historical and current prices of logs, timber and carbon marketing prices. The heights and diameters helped to calculate the volumes of thinned and unthinned forest plantations, also to estimate the amount of carbon that has been sequestered in each stand of thinned and unthinned forest. "Time" helped to develop a cost matrix needed to determine the optimal work or task that can be assigned to a worker in a given time. The "prices" helped to estimate the profitability of thinned and unthinned forest when the volumes were converted into sales in Tshs.

### **3.7. Methods of data collection**

Data were collected by using direct observation, survey, enumeration methods and records of previous years. Direct observation were used for time and work study while survey and enumeration were used to collect data for both thinned and

unthinned stands. Hence, all primary data were collected by direct observation and enumeration method while secondary data were obtained from the records of previous years. During enumeration, the diameter of the tree in centimeters and height in meters were recorded in the data collection sheet shown in appendices 2 and 3 on pages 54 and 55. Other secondary data like historical prices and previous volumes for thinned and unthinned forest were obtained from Government forest database and micro-forest database. The data which were collected during the study, were captured in an excel sheet using *MS-Excel 2013*. The data included time (hours) and their work elements, diameter of each tree in the plot, heights for four dominant trees and the silvicultural score for quality of the trees measured. The expected output includes the standing volumes, mean annual increment and basal area in m<sup>2</sup>. These helped to calculate the present values, rates of return and the amount of carbon sequestered in thinned and unthinned forests. The results were presented using graphs, tables and statistical means<sup>13</sup> for comparison purposes

### 3.8.Data analysis

Data were analysed by using an advanced excel analysis tool pack. A two way ANOVA will be used to determine if there is significant difference on the profitability of thinned and unthinned plantation. The t-test in the regression analysis was used to determine the statistical significance of coefficients for thinned and unthinned forest plantations. The regression, mean annual increment (MAI), present values (PVs) were calculated by using the following formulae.

- *Regression analysis*

$$y = \beta x + c \text{ (linear regression model for time and work elements)}$$

Where;  $y$  = work output,

$x$  = working time,

$\beta$  = coefficient of  $x$  and

$c$  =  $y$  intercept

- *Mean Annual Increment (MAI)*

$$\text{MAI} = \frac{V}{\text{age}}$$

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<sup>13</sup> Mean = Average

Where  $V =$  volume of a tree  $m^3$

- Annual Expectation Value (AEV)

$$AEV = \sum \frac{NPV \times i}{1 - (1+i)^{-t}}$$

Where;  $n$  is the lifetime of the project and  $i$  is the discount rate

- Net present value (NPV)

$$NPV = \sum_{t=1}^n \frac{NCF}{(1+r)^t}$$

Whereby:  $t =$  Time of the cash flow;  $n =$  Total time of the project;  $r =$  discount rate,  
 $C_t =$  Net cash flow (the amount of cash) at time  $t$ ;  $NPV =$  Net Present Value,  $NCF =$   
Net Cash Flow

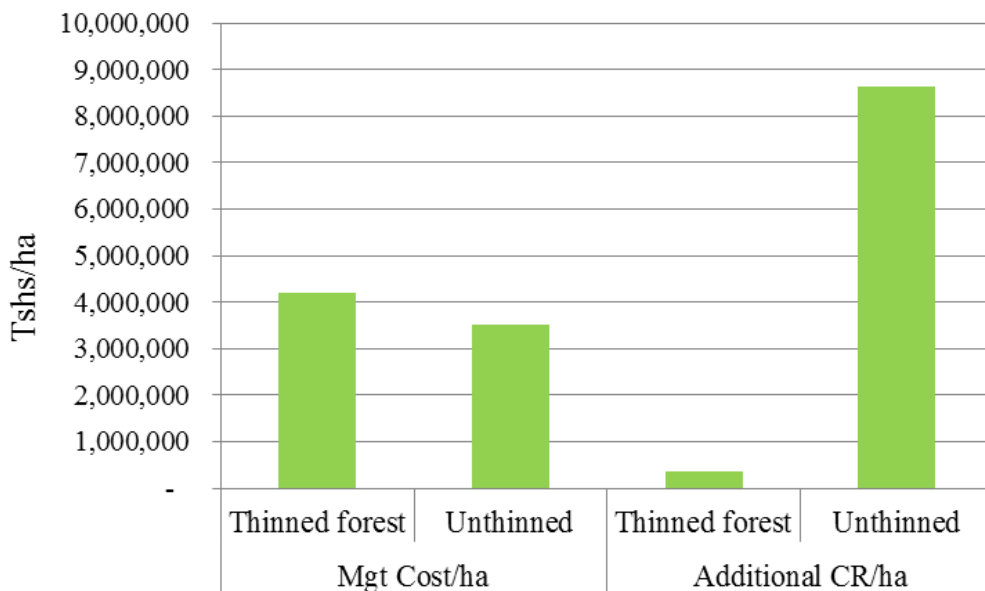
## CHAPTER FOUR

### 4.0. RESEARCH FINDINGS

#### 4.1. Forest Management costs in thinned and unthinned forests vs. Additional CR in Mufindi District.

Management of forestry plantations is concerned with the overall administrative, economic, legal and social aspects. It also includes the essentially scientific and technical aspects. This is especially silviculture, forest protection, and forest regulation which include management for biodiversity, water bodies, wilderness, wildlife, wood products, forest genetic resources and other forest resource values. The management costs that can be involved can be incurred either on thinned or unthinned plantation forest excluding administrative and establishment costs. In Mufindi District, the management costs shows on unthinned pines are 14% less than the costs of managing a thinned forest. The cost difference is due to the thinning which is done twice over the rotation period; this is shown in figure 4 below.

**Figure 4: Management costs for thinned and unthinned forest in Mufindi District**



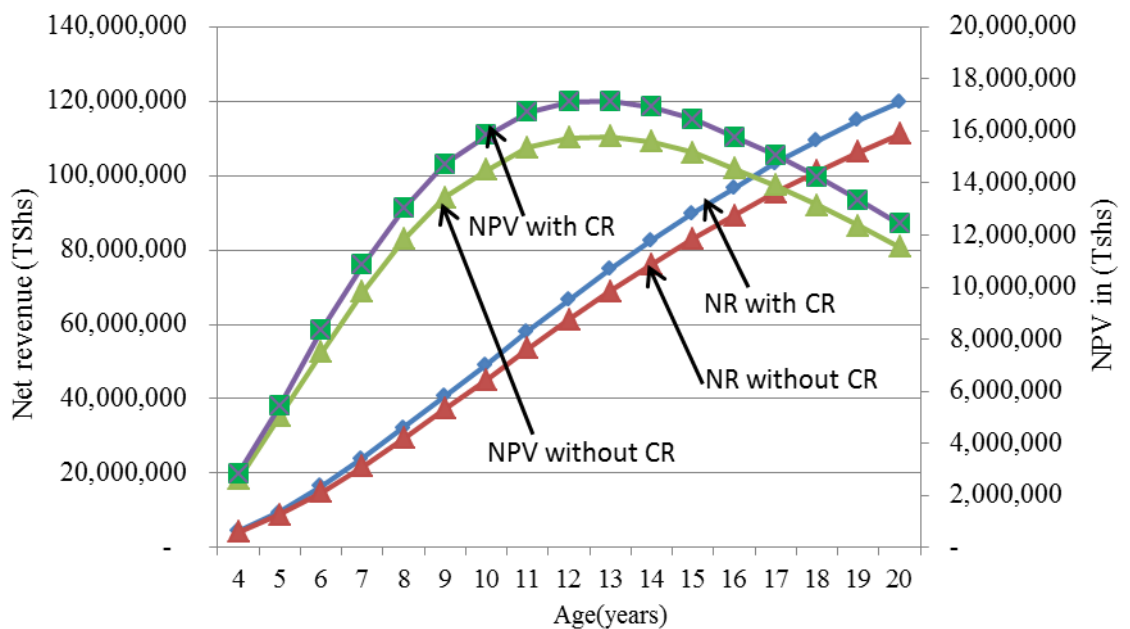
Management costs of thinned plantation in Mufindi District was revealed that, at the rotation age of 20 years is 3,503,000 Tshs/ha for an unthinned forests while in a thinned forest is 4,198,400 Tshs/ha. If these plantations will be involved in Carbon

business, the addition revenue from carbon other than sawn timber will be 8,636,475 Tshs/ha for an unthinned forest plantation while in a thinned forest will be 352,948 Tshs/ha.

#### 4.2. Comparative analysis of profitability on the final revenue in Mufindi district

In Mufindi District, the trees with ages between 11 to 14 years for Green Resources and Sao hill forest plantations attain high AEV with and without carbon revenue (CR). A plantation with CR has high AEV compared to a plantation without CR. The AEV in the plantation managed without CR is 1,895,804 Tshs/ha with a net revenue of 68,936,075 Tshs/ha, while in a plantation with CR, the AEV is 2,058,559 Tshs/ha with a net revenue of 74,854,243 Tshs/ha. At the final harvest a plantation is expected to have net revenue of 111,245,770 Tshs/ha without CR and 119,882,245 Tshs/ha with CR at age 20 since this is when, revenue is generated from sawn timber at the final rotational age as shown on figure 5 below.

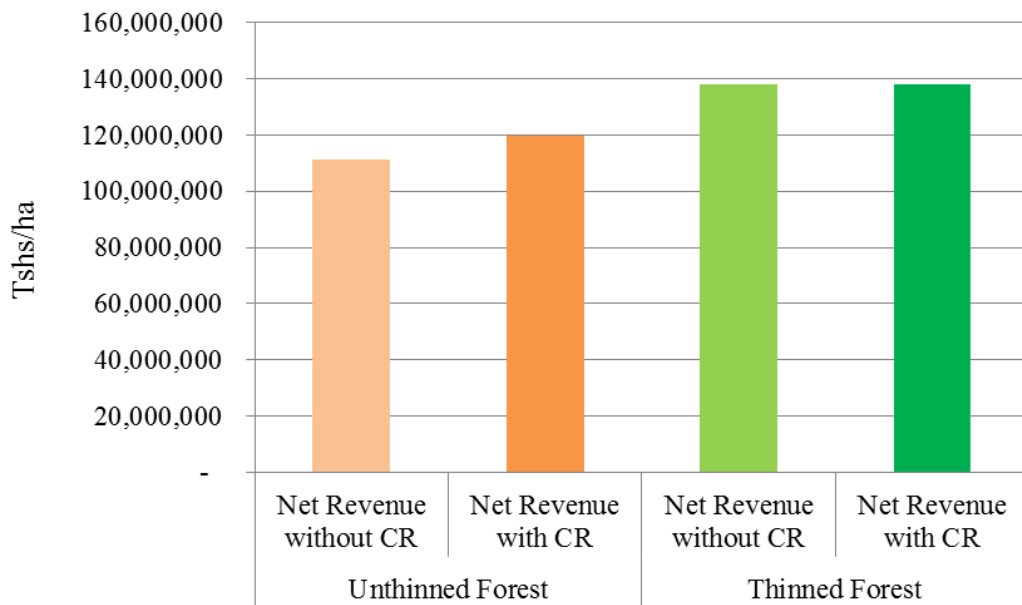
Figure 5: Comparison of Net revenue Vs. NPV in Mufindi District



The study has also revealed that, in Mufindi District investing in carbon sequestration business give high returns compared to the forest plantations that are not involving in the carbon sequestration business. Both in an unthinned forest and

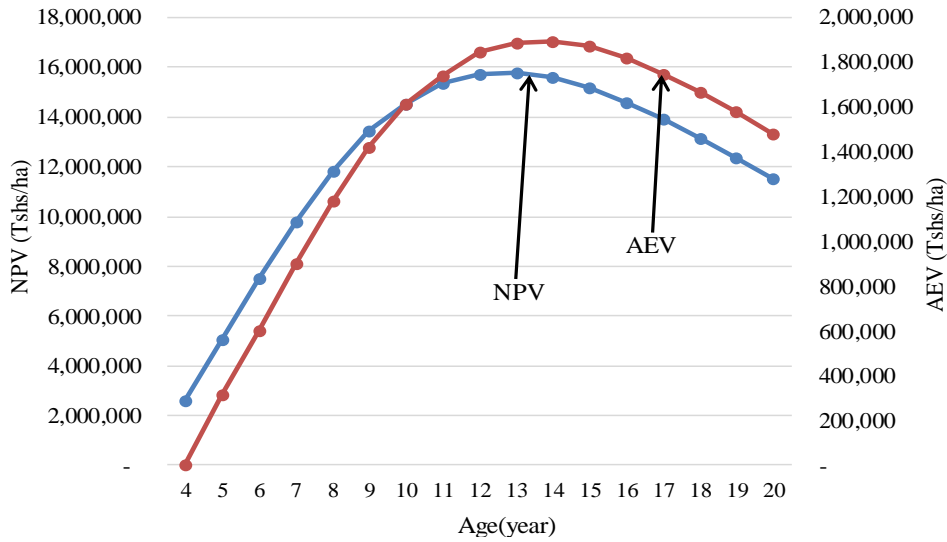
thinned forest plantations showed higher revenues when combined with CR compared to when the forest plantation is without CR as shown in figure 6 below.

**Figure 6: Forest Productivity with and without CR in Mufindi District**



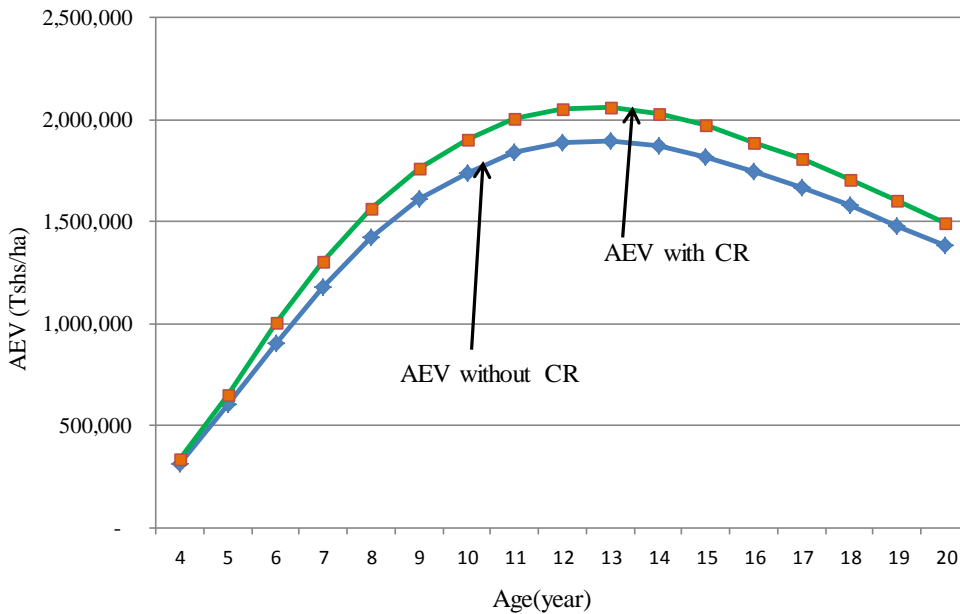
The study in Mufindi District, reveals that, between the ages of 11 - 14 years, the forest plantation attain the highest NPV/ha and AEV/ha before and after the last thinning at age 13, as shown in figure 7.

**Figure 7: Comparison of NPV/ha Vs. AEV/ha in Mufindi District**



The study reveals that, investing in carbon business in Mufindi District enables the plantations to have high AEV of at ages 11 to 14 while the final revenue with CR leads to AEV which is higher than the revenue without CR at the final harvest, as shown in figure 8 below.

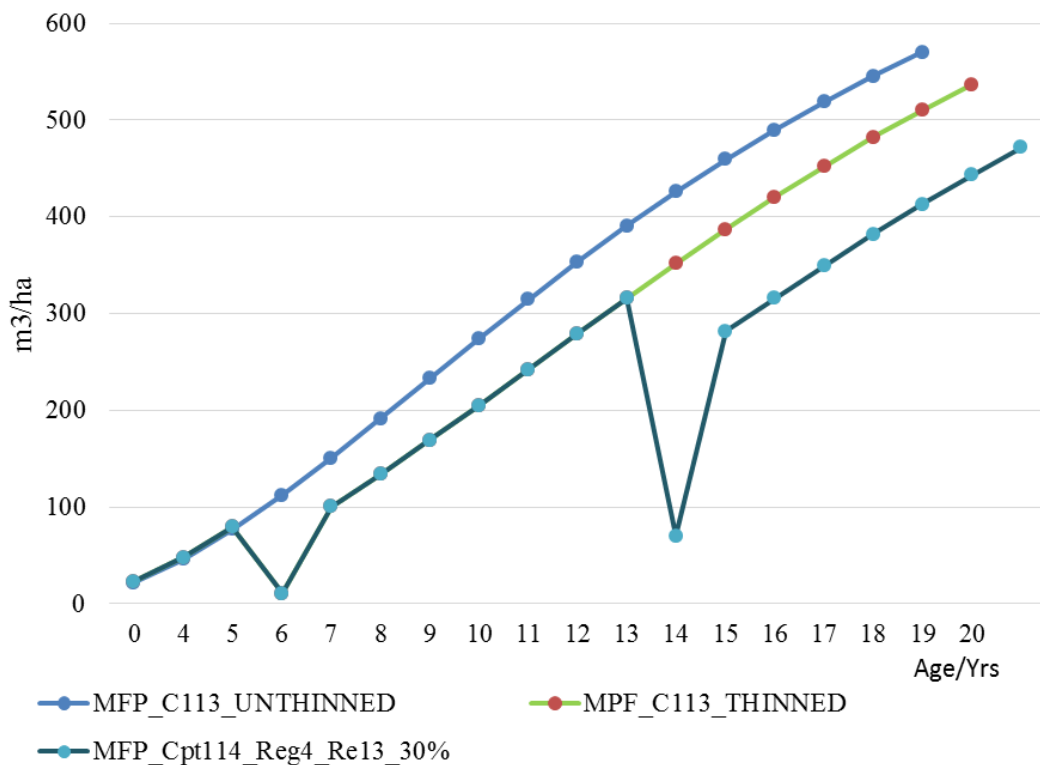
**Figure 8: AEV with and without carbon revenue in Mufindi District**



### 4.3. The impact of thinning operations and the amount of carbon sequestered in Mufindi District.

In Mapanda Forest Plantation (MFP), the regime that was studied for thinning was 6 and 6:13<sup>14</sup> by removing 30% of the standing trees. There was delayed thinning in most of the compartments that were supposed to follow a regime of 4:8:13. The volume projection at final harvest in unthinned forest after simulation will be 570.14m<sup>3</sup>/ha while in a thinned forest will be 531m<sup>3</sup>/ha for a thinning regime of 6 and 470m<sup>3</sup>/ha for a thinning regime of 6:13 as shown in figure 9.

**Figure 9: Volume projection on thinned forest at age 6 in Mapanda**

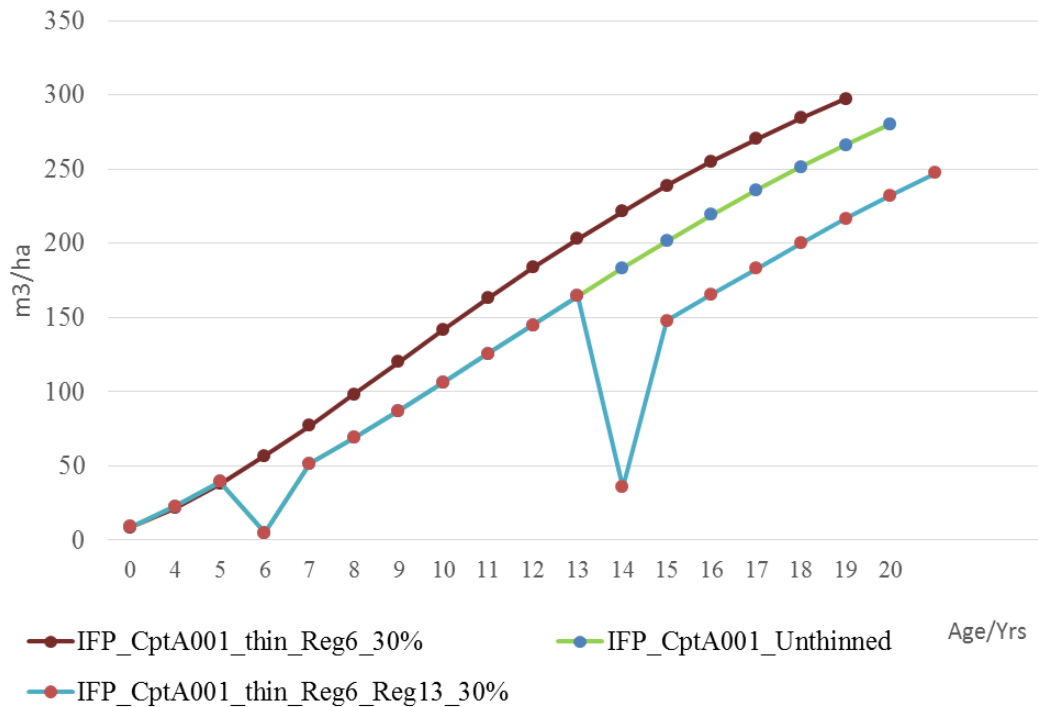


In Idete Forest Plantation (IFP), the same regime as in MFP was tested for thinning which was 6 and 6:13 by removing 30% of the standing trees. There was also delayed thinning in most of the compartments that were supposed to follow a regime

<sup>14</sup> 6:13; Means, The first thinning was done at the age of 6years and the second thinning at 13 years

of 4:8:13<sup>15</sup>. The volume projection at final harvest in unthinned forest was 297.5m<sup>3</sup>/ha while in a thinned forest it was 280m<sup>3</sup>/ha for a thinning regime of 6 and 247.2m<sup>3</sup>/ha for a thinning regime of 6:13 as shown in figure 10 below.

**Figure 10: Volume projection on thinned forest at age 6 in Idete Forest Plantation**

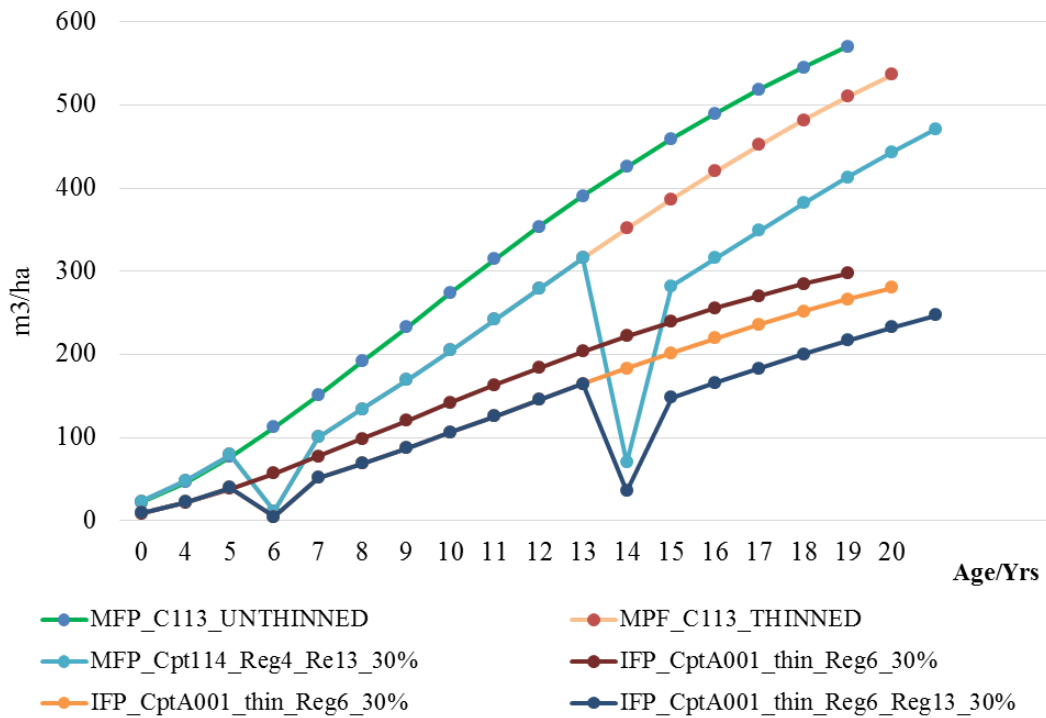


A comparative analysis on volume projection between MFP and IFP shows a significant difference between volumes at the final harvest. If the two forest plantations are not thinned, MFP has 273m<sup>3</sup>/ha more than IFP, and if it adopts a thinning regime of 6yrs only it will have 251m<sup>3</sup>/ha more than IFP and for a regime of 6:13<sup>16</sup> it will have 223m<sup>3</sup>/ha more than IFP. Generally the volume projection between two plantations shows a difference of 47% of volume (m<sup>3</sup>/ha) in the final harvest if they are all harvested at 20 years as shown in figure 11.

<sup>15</sup> 4:8:13; Means, The first thinning was done at the age of 4years and the second thinning at 8 years and the third thinning at 13 years old stand

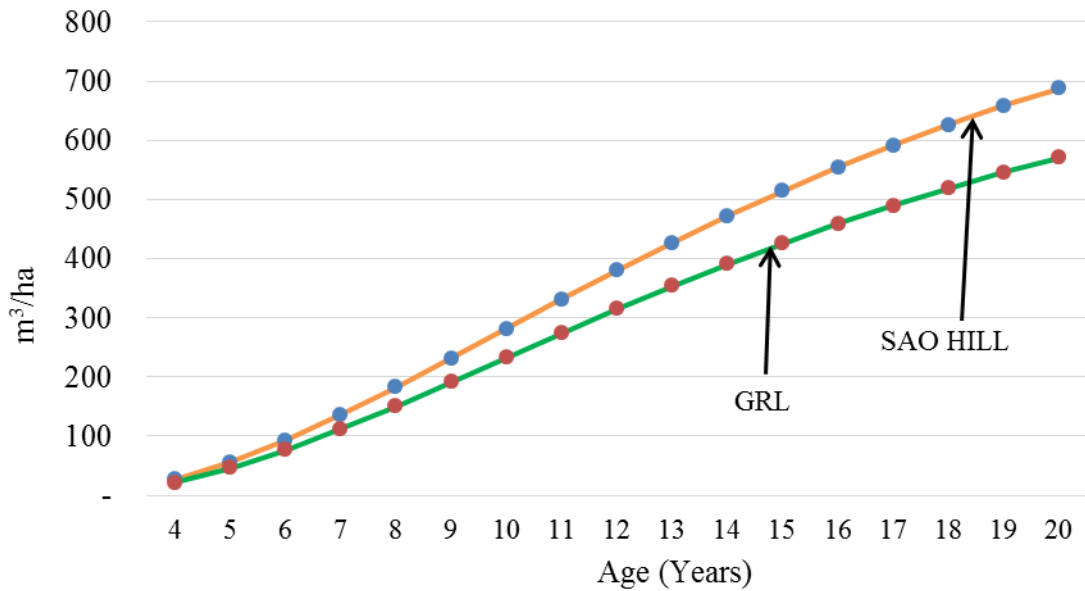
<sup>16</sup> 6:13; Means, The first thinning was done at the age of 6years and the second thinning at 13 years

**Figure 11: A comparative volume projection between MFP and IFP**



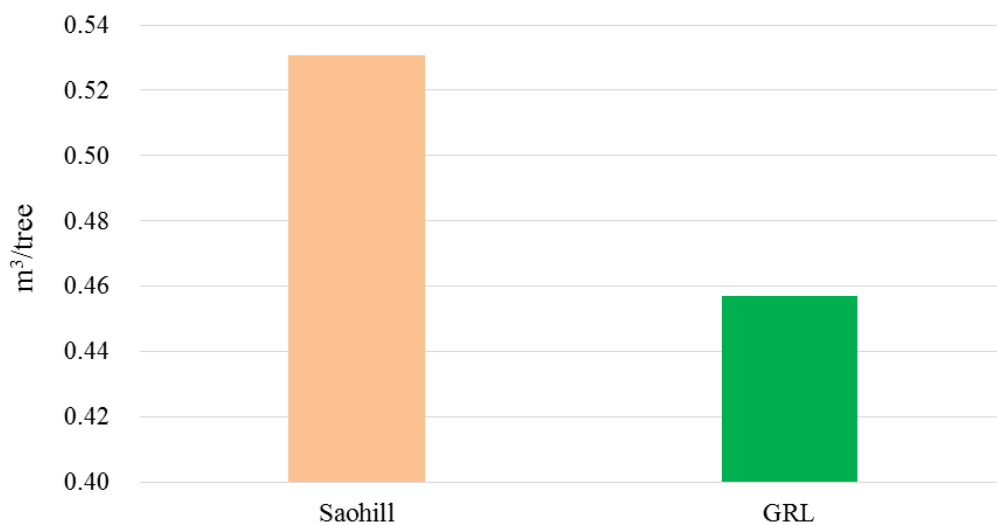
Also a comparative analysis of volume development was made between forests located in Kilosa-Mufindi which is Government Forest Plantation under Sao hill Forest plantation near Mapanda Forest Plantation under Green resources ltd (GRL). If the plantations are not thinned until the final harvest, Sao hill is expected to have an average standing volume of 687m<sup>3</sup>/ha with an average diameter of 25cm while in GRL (Mapanda) is expected to have 570m<sup>3</sup>/ha with an average diameter 24.7cm which means Sao hill yields 117 m<sup>3</sup>/ha more than in GRL, which is about 20.5% higher at age 20 as shown in figure 12.

**Figure 12: Comparison of Volume development for unthinned Forests in Mufindi District per ha**



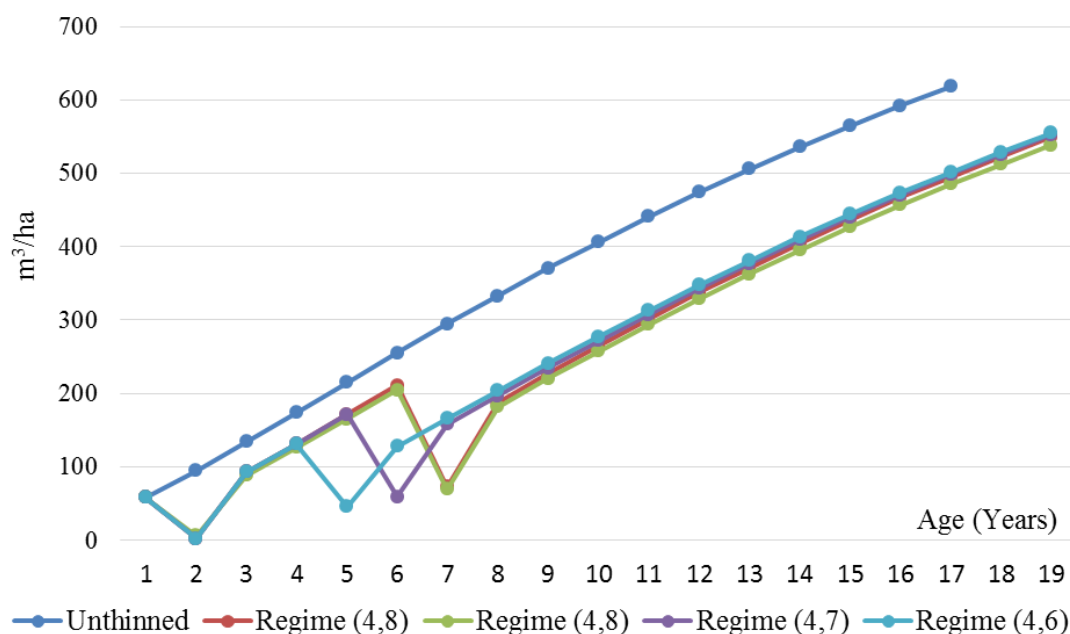
The volume comparison between the two forests shows that, an average tree volume at the final harvest in GRL will be  $0.46\text{m}^3/\text{tree}$  while at Sao hill this will be  $0.53\text{m}^3/\text{tree}$ , expecting a final stocking to be 1250 stems per hectare (sph). If the management of the two plantations is assumed to be the same, Sao hill shows high productivity in volume production compared to GRL (Mapanda) forests, as shown in figure 13 below.

**Figure 13: Comparison of Volume development for unthinned Forests in Mufindi District per tree**



The study was also conducted to test the effect of different thinning regimes on the Eucalyptus species to determine the optimal thinning regime if thinning is to be done to maximize the standing volume per tree. The findings revealed that, there were no significant differences in volumes at the final harvest. The regimes that were studied were 4:8 by 900:500<sup>17</sup> sph, 4:8 by 800:450<sup>18</sup>sph, 4:7 by 900:500<sup>19</sup>sph, 4:6 by 900:500<sup>20</sup>sph<sup>21</sup> as shown on figure 14 below

**Figure 14: The effect of different thinning regimes on the Eucalyptus species**



The study also revealed that, if the harvesting period is extended from 20years to an optimal rotation of 25year but not more than 28 years, all thinned forests will have gained near the same volume per hectare as that of unthinned forest although the two have different number of stems per hectare (sph) and different diameter classes as shown in figure 15 below from Sao hill forest plantation.

<sup>17</sup> 4:8 by 900:500; Means, the first thinning was done at the age of 4 years leaving 900 sph and the second thinning was done at year 8 leaving 500 sph.

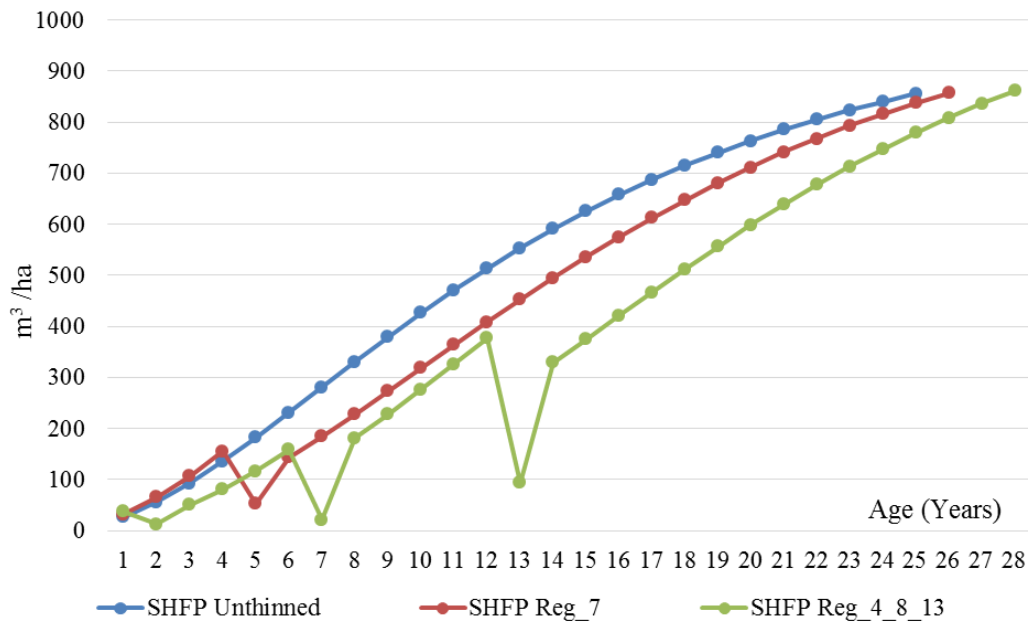
<sup>18</sup> 4:8 by 800:450; Means, the first thinning was done at the age of 4 years leaving 800 sph and the second thinning was done at year 8 leaving 450 sph.

<sup>19</sup> 4:7 by 900:500; Means, the first thinning was done at the age of 4 years leaving 900 sph and the second thinning was done at year leaving 500 sph.

<sup>20</sup> 4:6 by 900:500; Means, the first thinning was done at the age of 4 years leaving 900 sph and the second thinning was done at year 6 leaving 500 sph.

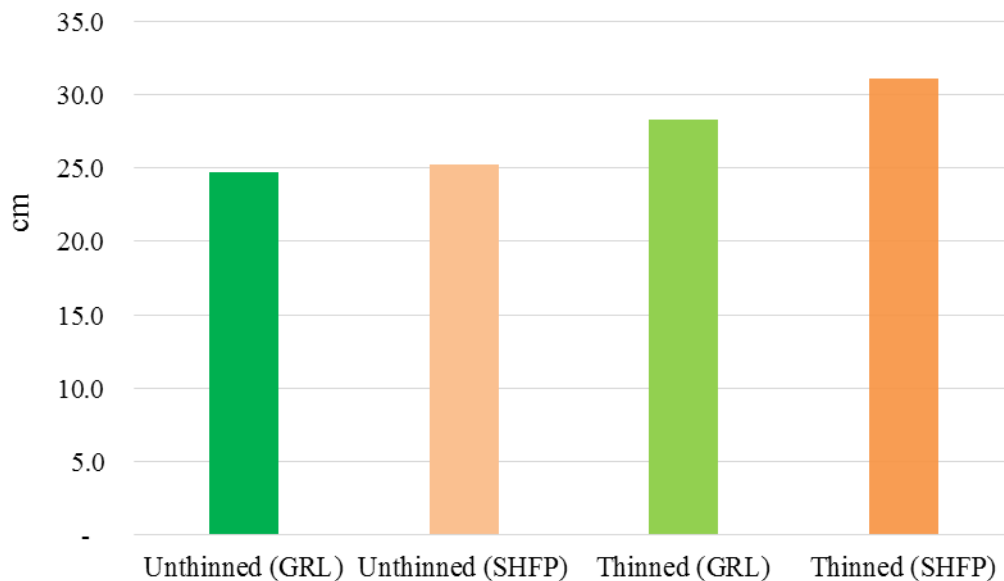
<sup>21</sup> Sph = (Stems per hectare)

**Figure 15: effect of different thinning intensities on the final Volumes**



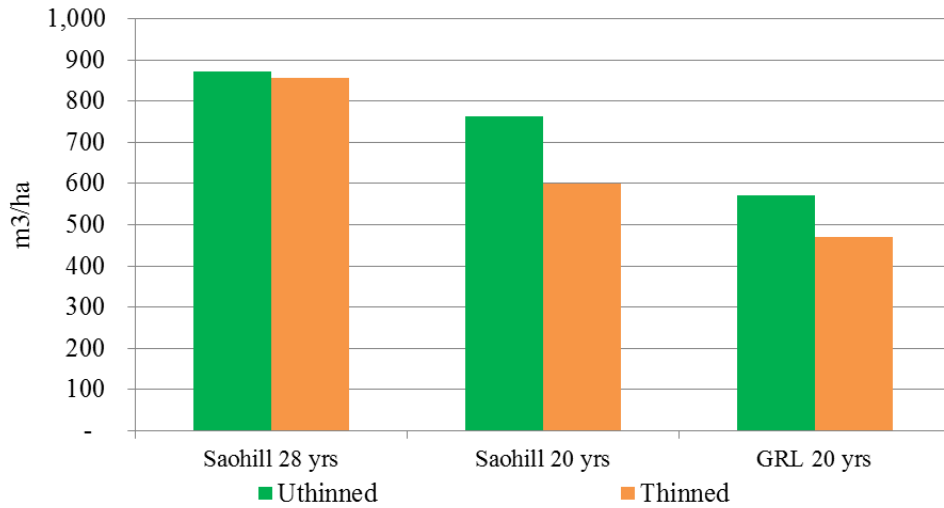
The study also revealed further that, there is significant difference on average stem diameter on thinned and unthinned forest plantation both for GRL and Sao hill forests. In GRL, an unthinned forest has an average diameter of 25cm with a MAI of 24.2m<sup>3</sup>/ha/year while a thinned forest of GRL has an average diameter of 28.3cm with a MAI of 23.3m<sup>3</sup>/ha/year at the final harvest. At Sao hill forest, unthinned forest has an average diameter of 25cm with a MAI of 29.74m<sup>3</sup>/ha/year while a thinned forest has an average diameter of 31cm with a MAI of 30.28m<sup>3</sup>/ha/year, as shown on figure 16 below.

**Figure 16: Projected diameters at the final harvest in Pines**



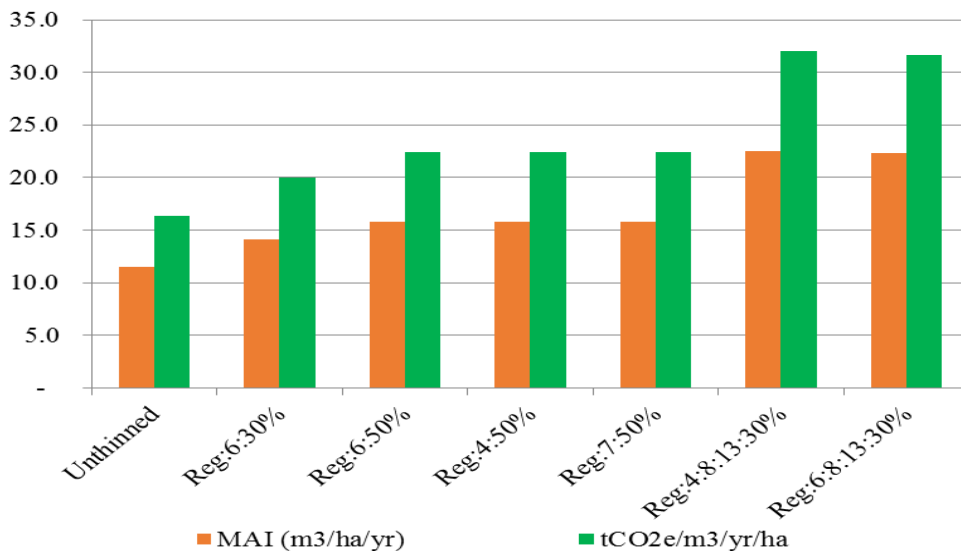
A comparative analysis on the final volumes at different rotation ages at Sao hill and GRL revealed that, if the rotation age for both plantations is assumed to be 20 years, GRL is expected to have 570m<sup>3</sup>/ha on an unthinned forest plantation and 471m<sup>3</sup>/ha in a thinned forest plantation. At Sao hill forest plantation stand projections for 20 years rotation will have 764m<sup>3</sup>/ha on unthinned forest plantation while in a thinned forest plantation there will be 599m<sup>3</sup>/ha. If the rotation is prolonged to 25 years (but not more than 28 years) on unthinned forest plantation will have 873m<sup>3</sup>/ha while a thinned forest will have 858m<sup>3</sup>/ha. This makes a significant volume increase in both thinned and unthinned forest plantations. In GRL forest plantation, if the forest is not thinned with an extended rotation age, only 109m<sup>3</sup>/ha will be added with MAI of 37.86m<sup>3</sup>/ha/year, while on thinned plantation 259m<sup>3</sup>/ha will be added with a MAI of 48.29m<sup>3</sup>/ha/year. Sao hill forest plantation will have 303m<sup>3</sup>/ha added with a MAI of 13.68m<sup>3</sup>/ha/year on unthinned forest while on thinned forest it will have 386m<sup>3</sup>/ha with a MAI of 32.36m<sup>3</sup>/ha/year as shown in figure 17 below.

**Figure 17: Comparison of final volumes at the rotation age in Mufindi District**



The study furthermore revealed a significant difference in productivity for different thinning regimes. For example a regime of 4:8:13 will have a volume increase (after thinning) of 180m<sup>3</sup>/ha with a MAI of 22.5m<sup>3</sup>/ha/yr and an additional carbon sequestered of 32 tCO<sub>2</sub>e/m<sup>3</sup>/ha/yr. For the regime of 6:8:13, the volume increase will be 178.6m<sup>3</sup>/ha with a MAI of 22.3m<sup>3</sup>/ha/yr and an additional carbon sequestered of 31.2 tCO<sub>2</sub>e/m<sup>3</sup>/ha/yr as shown in figure 18 below.

**Figure 18: Forest Productivity on different thinning regimes in Mufindi District**



#### 4.4. Modelling thinning costs using “INPUT - OUTPUT MODEL”

The study on thinning operation was conducted using three methods or tools; these were an axe, bush knife and a chainsaw. The study revealed that, if thinning will be done using an axe it will take 1.7minutes/tree, while with a bush knife it will take 1.4minutes/tree and 0.18minutes/tree for a chainsaw. The study also revealed that, an axe can cut 35trees/hour, a bush knife 41trees/hour and 333tree/hour for a chainsaw. In terms of man-days, thinning by using an axe takes 10man-days/ha, for bush knife it takes 8man-days/ha and 1man-day/ha with a chainsaw. The cost model for manual and semi-mechanized thinning was developed using supply chain matrix technique called “INPUT-OUTPUT MODEL” to determine the cost of thinning using different methods. The cost model revealed that, there is a significant difference on the output in terms of efficiency, cost, volume of work to be done and per unit time spent per hectare (ha). By using a chain saw the cost 12,859 Tshs/day compared to 8,450Tshs/day when using manual methods (Bush knife or an Axe) as shown on the technology matrices in figures 19, 20 and 21 below

**Figure 19: Cost Model for Chainsaw with Fuel Cost**

		Chainsaw				
		INPUT				OUT PUT
		Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Time allocation		0.5	1.17	1.17	0	0
Chainsaw operator		0	1	0	-0.003	0
Skidder (Man)		0	0	1	-0.0035	0
System derivery		0	0	0	1	990
		Technology matrix				Y
		2	2.33	2.33	0.02	15
		0	1	0	0.003	3
		0	0	1	0.0035	3
		0	0	0	1	990
Cost Vector		0	2800	1300	0	12,859 Tshs/day

**Figure 20: Cost Model for Chainsaw without Fuel Cost**

<sup>22</sup> Cost vector inputs is wage per hour

Chainsaw					
INPUT					OUT PUT
Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	
Time allocation	0.5	- 1.17	- 1.17	0	0
Chainsaw operator	0	1	0	-0.003	0
Skidder (Man)	0	0	1	-0.0035	0
System derivery	0	0	0	1	990
<b>Technology matrix</b>					<b>Y</b>
	2	2.33	2.33	0.02	15
	0	1	0	0.003	3
	0	0	1	0.0035	3
	0	0	0	1	990
Cost Vector	0	1300	1300	0	8,386 Tshs/day

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**Figure 21: Cost Model for Manual Method**

Manual Method					
INPUT					OUT PUT
Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	
Time allocation	1	- 1.17	- 1.17	0	0
Chainsaw operator	0	1	0	- 0.02	0
Skidder (Man)	0	0	1	- 0.03	0
System derivery	0	0	0	1	135
<b>Technology matrix</b>					<b>Y</b>
	1	1.17	1.17	0.06	8
	0	1	0	0.02	3
	0	0	1	0.03	4
	0	0	0	1	135
Cost Vector	0	1300	1300	0	8,450 Tshs/day

<sup>23</sup> Phase 1= Accessing the forest and preparation, phase 2= cutting down the trees, Phase 3= Lying down cut trees and prepare for the next tree, Phase 4= System delivery through manual skidding and Phase 5 = Final out-put of the system.

The study also revealed that, the productivity of a chainsaw is high compared to manual method. The operational cost per day for a chainsaw is high compared to manual method (Axe and Bush knife) the advantage of the chainsaw is that, it gives high output compared to manual methods. A chainsaw can thin 3 to 4 ha/day while using manual method can thin only 0.4ha/day. The operational cost for a chainsaw is very low about 13Tshs/tree compared to 63Tshs/tree when using manual method, as shown in table 1below.

**Table 1: Productivity of different thinning methods in Mufindi District**

<b>Method used</b>	<b>Trees cut/day</b>	<b>Cost (Tshs)/day</b>	<b>Cost (Tshs)/Tree</b>	<b>Output (ha/day)</b>
Chainsaw	999	12,859	13	3.0
Manual Method	135	8,450	63	0.4

## CHAPTER FIVE

### 5.0.DISCUSSION OF FINDINGS

#### 5.1.Profitability analysis of thinned and unthinned forest plantation

In this study, a discounted cash flow analysis was conducted using 2012 costs and timber prices from Sao hill Industry (SHI) and a real <sup>24</sup>discount rate of 12%. A Net Present Value (NPV) was determined for two stand management goals; unthinned forest plantation and thinned forest plantation with and without carbon revenue. It was assumed that the forest owner (Government forest and Green resources) would first enrol in afforestation carbon offset contract, thereafter continue abiding by the forest carbon offset contract and payments for carbon credits being made on an annual basis. Payments from harvested wood product's carbon were assumed to be available at the year of harvest. The study involved a <sup>25</sup>comparative analysis and it revealed that, managing a forest by combining carbon sequestration potentials, is more profitable compared to a forest which is managed for sawn timber only (without CR). The study also revealed that, the forest plantations will achieve the highest values at ages 11 to 14 years where the AEV in the plantation managed without CR will be 1,895,804 Tshs/ha, with a net revenue of 68,936,075 Tshs/ha, while in a plantation with CR the AEV will be 2,058,559 Tshs/ha with a net revenue of 74,854,243 Tshs/ha. At the final harvest (at age 20) the plantation was expected to have net revenue of 111,245,770 Tshs/ha without CR and 119,882,245 Tshs/ha with CR since revenue is also generated from sawn timber at the final rotational age. In this case, Green Resources is expected to benefit more by involving in carbon business compared to the Government forest which is managed for timber only. Green Resources also benefits more on AEV and NPV by 9% for trees between ages 11 – 14 years and 8% at the final harvest compared to Sao Hill forest plantations. By involving in Carbon business, the additional revenue that Green Resources will benefit from additional revenue on CR that can cover twice as much of the plantation management cost excluding establishment and administrative costs.

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<sup>24</sup> See appendices 1 and 2

<sup>25</sup> See pages 31, 32,33, 39 and 40

## **5.2.The impact of thinning operations on the final volumes and the amount of carbon sequestered in Mufindi District**

The study reveals that, thinning has significant impact especially when carbon revenue is considered. The study aimed at testing different thinning regimes in three different locations of Mufindi District. The locations were Kilosa/Mufindi under Sao hill forest plantation, Mapanda and Idete forest plantations under Green Resources plantations. The study revealed that, the volume projection at final harvest in unthinned forest after simulation in Mapanda forest plantation was 570.14m<sup>3</sup>/ha and in Idete 402 m<sup>3</sup>/ha while in a thinned forest in MFP it was 531m<sup>3</sup>/ha for a thinning regime of 6 years compared to Idete forest plantation with 296 m<sup>3</sup>/ha.

However, if the two forest plantations are not thinned, <sup>26</sup>MFP will have 168m<sup>3</sup>/ha more than IFP, and if MFP adopts a thinning regime of 6years it will have 251m<sup>3</sup>/ha more than IFP and for a regime of 6:13 it will have 231m<sup>3</sup>/ha more than IFP. In general the volume projection between two plantations shows a difference of 44% of volume (m<sup>3</sup>/ha) in the final harvest if they are all harvested at the age of 20 years. Also thinning influences diameter increment which develop after thinning operation. In GRL, the study revealed that, an unthinned forest has an average diameter of 25cm with a MAI of 24.2m<sup>3</sup>/ha/year while a thinned forest of GRL has an average diameter of 28.3cm with a MAI of 23.3m<sup>3</sup>/ha/year at the final harvest. At Sao hill forest, unthinned forest has an average diameter of 25cm with a MAI of 29.74m<sup>3</sup>/ha/year while a thinned forest has an average diameter of 31cm with a MAI of 30.28m<sup>3</sup>/ha/year. Honggang S et al, (2012) pointed out that, large-diameter trees are more likely to develop after thinning with a low initial planting density than with a high initial planting density. Also thinning stands with a high initial planting density can promote tree growth and increase total merchantable volume; the diameter class distribution shifts rapidly from small- to intermediate- to large-sized stems. The productivity in IFP seems to be low compared to MFP although there is a room for improvement on the same land by looking critically on the best species that can perform well based on the site qualities (soil analysis, site and species matching

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<sup>26</sup> See page 35

and proper silvicultural treatment). It is important for investor(s) to put more effort in MFP than in IFP where pines do not promise much in terms of volume. Moreover, the management should determine the causes of poor performance in IFP and if possible make improvement on silvicultural treatment to increase performance of the plantation. Comparing Green Resources with Sao hill forest plantations shows that, if the plantations are not thinned until the final harvest, Sao Hill is expected to have an average standing volume of 687m<sup>3</sup>/ha with an average diameter of 25cm while GRL (Mapanda) will have 570m<sup>3</sup>/ha with an average diameter 24.7cm, which gives a difference of 117 m<sup>3</sup>/ha in favor of MFP which is about 20.5% of volume (m<sup>3</sup>/ha). Also comparison of average tree volumes at the final harvest shows that GRL have 0.46m<sup>3</sup>/tree while Sao Hill have 0.53m<sup>3</sup>/tree expecting a final stocking to be 1250 stems per hectare (sph). Again on this account, Sao hill is considered to be more profitable than GRL if both choose to manage unthinned forest plantations with the same management regimes with and without carbon revenue. Investing in carbon business has shown a significant increase in the final revenues. The plantations that invest in carbon business combined with timber business have high AEV, net revenue and high NPV. <sup>27</sup>For plantations that are managed without CR, the AEV is 1,895,804 Tshs/ha with a net revenue of 68,936,075 Tshs/ha while for a plantation with CR the AEV is 2,058,559 Tshs/ha with a net revenue of 74,854,243 Tshs/ha at ages between 11 to 14 years. At the final harvest the plantation is expected to have net revenue of 111,245,770 Tshs/ha without CR and 119,882,245 Tshs/ha with CR at the age of 20 years, although if management is extended to a rotation of 25 years, the additional revenue on the CR could cover twice as much on the management costs as shown in figure 22. The Management costs (silvicultural management) per year in a pine plantation is 3,503,000 Tshs/ha/yr while the additional CR in the same plantation is 8,636,475 Tshs/ha/yr which is enough to cover all management costs that an investor could incur per year per hectare. In fact, <sup>28</sup>to confirm that NPV of thinned stands is equal to or higher than in unthinned stands, one must look at the estimated NPV for the thinning and final harvest combined. The maximum NPV for

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<sup>27</sup> See pages 31, 32 and 33

<sup>28</sup> [www.for.gov.bc.ca/hfp/pubs.htm](http://www.for.gov.bc.ca/hfp/pubs.htm)

a chosen regime, species, site index and final harvest age should be compared to the NPV for the comparable unthinned stand. In <sup>29</sup>GRL forest plantation, if the forest is not thinned with an extended rotation age of 25 years, only 109m<sup>3</sup>/ha will be added with MAI of 37.86m<sup>3</sup>/ha/year, while a thinned forest one will have 259m<sup>3</sup>/ha with a MAI of 48.29m<sup>3</sup>/ha/year. A Sao hill forest plantation will have 303m<sup>3</sup>/ha with a MAI of 13.68m<sup>3</sup>/ha/year on unthinned forest while a thinned forest will have 386m<sup>3</sup>/ha with a MAI of 32.36m<sup>3</sup>/ha/year. The study has also revealed that, <sup>30</sup>forest productivity on different thinning regimes has significant volume increment after thinning of 180m<sup>3</sup>/ha with a MAI of 22.5m<sup>3</sup>/ha/year and an addition of 32 tCO<sub>2</sub>e/m<sup>3</sup>/ha/year and 178.6m<sup>3</sup>/ha with a MAI of 22.3m<sup>3</sup>/ha/year and 31.7 tCO<sub>2</sub>e/m<sup>3</sup>/ha/year respectively at the rotation age as shown on. The study by Plakash N, (2008) shows that in case of a thinned stand, the rate of carbon sequestration depended on a thinning regime, while Franklin O et al., (2009) points out that, to maximize current net increment in a thinning scenario, carbon should be kept as near the optimum as possible. In theory this could be achieved by frequent thinnings that never allow the stand to deviate from the optimal carbon. In practice, thinnings are associated with costs and a very frequent thinning regime is not realistic. The amount of CO<sub>2</sub> sequestered in harvested wood products varied depending on implemented thinning regimes and harvest ages. In general, CO<sub>2</sub> in harvested wood products tended to increase with harvest age and more frequent light thinning. In general, a light thinning promoted a greater accumulation of carbon both in standing trees and in harvested wood products. <sup>31</sup>The post-thinning growth of a residual tree depends on the amount of new growing space created as well as factors such as site quality, species, age and vigour. For a vigorous tree, growth is generally proportional to growing space, up to the point where a tree is growing at its full potential and is largely unaffected by neighbours. The study has also revealed that, there is no significant difference in volumes at the final harvest in different *Eucalyptus species*

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<sup>29</sup> See page 40

<sup>30</sup> See page 40 - 41

<sup>31</sup> [www.for.gov.bc.ca/hfp/pubs.htm](http://www.for.gov.bc.ca/hfp/pubs.htm)

although thinning can be done depending on purpose of the forest as for timber, poles, pulp or for energy wood.

### **5.3. Modeling thinning costs in Mufindi District**

This study determined the best method that could optimize thinning costs, planning and budgeting in large scale like Green Resources and Sao Hill forest plantations. The study revealed that, <sup>32</sup>thinning using an axe uses 1.7minutes/tree, while with a bush knife it uses 1.4minutes/tree and 0.18minutes/tree for a chainsaw. Moreover an axe can cut 35trees/hour, a bush knife 41trees/hour and 333tree/hour for a chainsaw. For management, using chainsaw as an option for thinning will maximize the productivity of thinning operations. A chainsaw can thin 1ha/hr while a manual method (axe and bush knife) can thin 0.1 ha/hr. Moreover, using a chain saw <sup>33</sup>according to the supply chain matrix, the cost of thinning is 12,859Tshs/day including fuel cost and 8,386 Tshs/day compared to 8,450Tshs/day using manual methods (Bush knife or an Axe). Our study results revealed that, thinning by using a chainsaw significantly reduces cost, time and increases productivity when operating on a large scale and when manpower is inadequate to cover all the operations in managing the forest. Therefore, it is important for the forest owners to critically look into different cost items and budget constraints before they decide on a method for thinning.

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<sup>32</sup> See page 42

<sup>33</sup> See pages 42 and 44

## CHAPTER SIX

### 6.0.SUMMARY AND RECOMMENDATION

#### 6.1. Summary

Carbon forestry activities have received considerable attention due to their potential to mitigate climate change, enhance forest conservation and foster local development. It is timely to provide empirical evidence from on-going carbon forestry activities in order to examine their potential to achieve environmental and developmental goals. In Mufindi District, a thinned forest plantation that has been enrolled in Carbon business give high and more promising profitability compared to thinned without CR and unthinned forests with and without CR. The study has revealed that, it is more profitable to invest in thinned forest plantations when combining sawn timber and carbon revenue. The trees with ages between 11 to 14 years for Green Resources and Sao hill forest plantations attain high AEV with and without carbon revenue (CR). A plantation with CR has high AEV compared to a plantation without CR. Also between the ages of 11 - 14 years, the forest plantation attain the highest NPV/ha and AEV/ha before and after the last thinning at age 13. The study furthermore revealed a <sup>34</sup>significant difference in productivity for different thinning regimes. For example a regime of 4:8:13 will have a volume increase (after thinning) of 180m<sup>3</sup>/ha with a MAI of 22.5m<sup>3</sup>/ha/yr and an additional carbon sequestered of 32 tCo<sub>2</sub>e/m<sup>3</sup>/ha/yr. For the regime of 6:8:13, the volume increase will be 178.6m<sup>3</sup>/ha with a MAI of 22.3m<sup>3</sup>/ha/yr with an additional carbon sequestered 31.2 tCo<sub>2</sub>e/m<sup>3</sup>/ha/yr. The study tested different thinning methods and the results revealed that, a chainsaw can thin 1ha/hr while a manual method (axe and bush knife) can thin 0.1 ha/hr. Moreover, using a chain saw according to the supply chain matrix, the cost of thinning<sup>35</sup> is 12,859Tshs/day compared to 8,450Tshs/day using manual methods (Bush knife or an Axe). However, the <sup>36</sup>cost per tree for chainsaw is 13Tshs/tree compared to 63 Tshs/tree using manual method.

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<sup>34</sup> See page 41

<sup>35</sup> See page 42 and 44

<sup>36</sup> See table 1 in page 44

## 6.2. Recommendation

To ensure high and better return from commercial forest plantation, it is important that the entire plantation be thinned to encourage large diameter trees that can produce different sizes of timber to suit market demand and compete with others in the same industry. Having large diameter logs promises high profitability of the forest and higher recovery compared to small log diameters from unthinned forest plantation. The forest plantations owner can start recovering some of the costs from the second thinning at age 8 and 13 years. It is therefore recommended that, forest plantations owners thin all their forest plantations.

It is also recommended that, forest plantations owners should ensure timely and proper silvicultural treatment in order to ensure high performance of the plantations. Furthermore, it is recommended that, for the sites like Idete that did not show a promising volume, thinning intensity should change and extend the rotation age from 20 to 25 to ensure better gain in volume and tree diameters. For example, if the rotation is prolonged to 25 years (but not more than 28 years), an unthinned forest plantation will have 873m<sup>3</sup>/ha while a thinned forest will have 858m<sup>3</sup>/ha. This makes a significant volume increase in both thinned and unthinned forest plantations. The study revealed that, thinning by using a chainsaw significantly reduces cost, time and increases productivity when operating on a large scale and when manpower is inadequate to cover all the operations in managing the forest. It is recommended that, plantations should be thinned by using chainsaw.

Lastly, I recommend that, forest plantations should also engage in carbon business because it gives high AEV<sup>37</sup>, Net Revenue and NPV compared to the plantations which are not engaged in carbon business.

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<sup>37</sup> See pages 31, 32 and 33

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## APPENDICES

### Appendix 1: Revenue with and without CR in Mufindi District

Age (years)	Net Revenue without CR	Net Revenue with CR	Additional revenues with Carbon (Tshs/ha)	Mgt Cost/Tshs/ha	Discount rate %
4	4,114,900	4,445,126	330,226	147,000	0.12
5	8,873,340	9,573,177	699,837	305,760	0.12
6	14,824,330	16,520,753	1,696,423	476,280	0.12
7	21,711,765	23,994,567	2,282,802	658,560	0.12
8	29,336,450	32,235,321	2,898,871	783,960	0.12
9	37,279,835	40,806,742	3,526,907	916,960	0.12
10	45,069,825	49,222,192	4,152,367	1,365,400	0.12
11	53,442,260	58,206,757	4,764,497	1,513,600	0.12
12	61,334,815	66,688,872	5,354,057	1,669,400	0.12
13	68,936,075	74,854,243	5,918,168	1,832,800	0.12
14	76,208,895	82,658,758	6,449,863	2,003,800	0.12
15	83,063,345	90,015,515	6,952,170	2,182,400	0.12
16	89,224,925	96,643,653	7,418,728	2,682,200	0.12
17	95,552,325	103,409,133	7,856,808	2,876,000	0.12
18	101,198,585	109,458,178	8,259,593	3,077,400	0.12
19	106,389,330	115,025,805	8,636,475	3,286,400	0.12
20	111,245,770	119,882,245	8,636,475	3,503,000	0.12

### Appendix 2: NPV and AEV with and without CR in Mufindi District

Age (years)	NPV without CR	NPV with CR	AEV without CR	AEV with CR	Discount rate %
4	2,615,093	2,824,958	313,811	338,994	0.12
5	5,034,971	5,432,078	604,196	651,849	0.12
6	7,510,467	8,369,928	901,256	1,004,391	0.12
7	9,821,300	10,853,924	1,178,556	1,302,470	0.12
8	11,848,500	13,019,305	1,421,820	1,562,316	0.12
9	13,443,482	14,715,320	1,613,218	1,765,838	0.12
10	14,511,277	15,848,228	1,741,353	1,901,787	0.12
11	15,363,373	16,733,052	1,843,604	2,007,966	0.12
12	15,743,119	17,117,372	1,889,174	2,054,084	0.12
13	15,798,369	17,154,661	1,895,804	2,058,559	0.12
14	15,593,850	16,913,620	1,871,262	2,029,634	0.12
15	15,175,363	16,445,498	1,821,043	1,973,459	0.12
16	14,554,518	15,764,673	1,746,542	1,891,760	0.12
17	13,916,655	15,060,955	1,669,999	1,807,314	0.12
18	13,159,823	14,233,897	1,579,179	1,708,067	0.12
19	12,352,522	13,355,275	1,482,303	1,602,632	0.12
20	11,532,489	12,427,805	1,383,899	1,491,336	0.12

### **Appendix 3: List of tools and equipment used during the Research in Mufindi District**

- Vertex
- Trans-ponder
- Caliper
- Tape measure
- GPS
- 1.3meter stick
- Compass
- Data collection sheets
- A string
- AA-batteries
- Maps
- Bush knife
- Paint
- Stop watch
- Pencil
- Safety gears

**Appendix 4: Data collection form used for thinned and unthinned stand in Mufindi District**



**DATA COLLECTION FORM FOR THINNED AND UNTHINNED STAND**

Project	<input type="text"/>	Cpt No.	<input type="text"/>	Slope (%)	<input type="text"/>
Country	<input type="text"/>	Plot No.	<input type="text"/>	Easting	<input type="text"/>
Forest	<input type="text"/>	Altitude (m)	<input type="text"/>	Northing	<input type="text"/>
Block Name	<input type="text"/>	Plant Date	<input type="text"/>	UTM Zone	<input type="text"/>
Enum No.	<input type="text"/>	Enum Date	<input type="text"/>		<input type="text"/>

Site Codes and Notes

TreeNo.	Old No.	Dist (m)	Spp code	Short Name	Diam (cm)	Hgt (m)	Coded Notes	Silv	Observations
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

**Appendix 5: Data collection form used for time and work study.**



**DATA COLLECTION FORM FOR TIME AND WORK STUDY  
ON THINNING OPERATIONS**

Project	<input type="text"/>	Cpt No.	<input type="text"/>	Easting	<input type="text"/>
Country	<input type="text"/>	Plot No.	<input type="text"/>	Northing	<input type="text"/>
Forest	<input type="text"/>	Altitude (m)	<input type="text"/>	Datum	<input type="text"/>
Block Name	<input type="text"/>	Slope (%)	<input type="text"/>	UTM Zone	<input type="text"/>
		Plot area	<input type="text"/>	Plant Date	<input type="text"/>

TREE NO	WORKING	NECESSARY DELAYS	UNNECESSARY DELAYS	REMARKS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

## Appendix 6: Code notes

Code	Meaning	Description
NT	No tree.	A tree present at an earlier measurement cannot be found at all (no stump, fallen stem or other trace). This code must be recorded for any
DT	Dead tree	Tree clearly dead, but still standing. Standing dead trees must be measured normally for diameter
ST	Suppressed tree	Suppressed tree with no live foliage.
FT	Fallen tree	Tree fallen and on the ground. The tree may still be alive. The root system has not been uplifted (see UT). It is not necessary to measure such trees. A tree is fallen if the angle with the ground is less than 45°
LT	Leaning tree	The tree is leaning, but at an angle of less than 45° from the vertical, has not been fully uprooted, and is still alive. These trees should be measured for diameter
HT	Harvested tree	A cut stump has been found, indicating a harvested tree
UT	Uprooted tree	(Probably wind throw). The tree has fallen with the root system being exposed Assess as for FT - the only difference is that the roots have been uplifted, almost certainly indicating wind damage
FD	Fire damage	Charred bark, burnt pipe or branches, or burnt foliage from fire
RS	Rotten stem	Signs of fungi or rot on the bole, rotten pipe at base of tree
RB	Rotten branch	Dead or rotten branch, decay in the upper stem or crown
EX	Excrescences	Bumps or growths on the stem, sometimes with epicormic growth. Usually a sign of fungal or insect damage
EB	Epicormic branch	Usually a sign of ill-health or past severe fire damage
AD	Ants or termite damage	Evident signs of ant or termite damage (hollowed bole, small trees can be pushed over). Do not use this code if ants/termites are present but there is no direct evidence of tree damage
BT	Broken top	main bole broken. Look for signs of decay and add RS code if found (but not if unsure).
CD	Crown damage	Branches or tip of crown damaged for any reason (wind, tree felling etc). Do not use this code for dieback
DB	Dieback	Leading branches are dead, but main crown still alive. Do not use this for foliage loss due to suppression or fire damage
FS	Forked stem	Make a note of the estimated height of the fork. If the stem forks at or below 1.3 m, the tree should be counted as two trees on the plot, with the MS code
FX	Foxtail	Abnormally long, branchless leader, particularly applicable to <i>P.caribaea</i> and <i>P.oocarpa</i>
NR	Natural regeneration	(Does not apply to coppice). Only include if stem exceeds 20 cm dbh. Make sure species recorded if not the same as the main crop
CP	Coppice	This must always be given at the first measurement for all coppice stems