UNIVERSITY OF KWAZULU-NATAL

A COST BENEFIT ANALYSIS OF FORESTRY SEED ORCHARD ESTABLISHMENT IN SAPPI FORESTS, SOUTH AFRICA

By

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A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Business Administration

Graduate School of Business & Leadership

College of Law and Management Studies

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2018

UNIVERSITY OF KWAZULU-NATAL
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ACKNOWLEDGEMENTS

I gratefully acknowledge the contributions made by the following people and organisations for their valuable assistance towards the completion of this project:

- To Sappi Forests Southern Africa, for giving me access to the data necessary for completing this project, as well as for providing me with a corporate home for the past ten years, and for supporting me financially and with time off to pursue my business studies, starting with the Management Development Programme in 2011 and now the Master of Business Administration.
- To my boss and friend of the last ten years, Wayne Jones – thank you for all of your support and encouragement, and for assisting me with your encyclopaedic knowledge of seed orchards at Sappi.
- To my colleagues and friends at Sappi, especially Damien Naidu for all the car chats about this thesis, for assistance with NPV and for your encouragement, and to Jacob Crous and Wynand de Swardt for assistance with various Sappi facts and figures.
- To the MBA Vikings – Riaz, Denver, Chris and Thami, thanks for all of the fun that we had together, the late nights working on group assignments, the jokes shared in class, and for keeping me sane for the past two years. Thami, you will be missed.
- Most of all, to my wonderful wife Leigh for taking on the role of ‘MBA widow’ for the past two and a half years, for all of the things that you had to do without me, and for all of the support and encouragement you offered. I owe you more than I can say, and I couldn’t have done it without you!

ABSTRACT

Forest tree seed produced in specialised seed orchards is the primary source of reproductive material for plantation forest regeneration in South Africa. Forestry seed orchards consist of stands of genetically superior trees planted together under management that encourages flowering and cross pollination. Their primary objective is to produce abundant genetically improved seed for sowing. Sappi has produced seed from its own seed orchards since 1995. In this study the costs and benefits of new and existing seed production orchards for Sappi Forests was examined from an economic perspective in the South African plantation forestry context. The impact of nursery seed use efficiency on seed orchard economic feasibility was also examined. Data regarding seedling production, seed orchards and plantations across Sappi's land holdings in KwaZulu-Natal and Mpumalanga were collected from multiple Sappi Forests databases including their Forest Management System, Timber Management System and Sappi Nursery databases. Analysis was undertaken to evaluate the net present values (NPV) of benefits, costs and benefit cost ratios (BCRs) associated with the seed orchard programme versus the use of unimproved planting material. Projected revenue increases from increased timber production were assessed. A number of discount rates typically used in South African forestry economic analyses were evaluated. Findings indicated that BCRs were >1 for both current and future proposed seed orchards, with the seed programme overall having a NPV of over half a billion rand, a BCR of 20 and an IRR of 62.5% at a 6% interest rate. A proposed new orchard had a NPV of R 175 million. It was found that increases in seed use efficiency could lead to increased timber production worth R 2 – 8 million per year under various scenarios. This research concurs with similar studies on the subject that establishment of seed orchards is an excellent investment for forestry managers. Based on this research, it is recommended that new seed orchards be pursued where selections of higher genetic gain than those in current seed orchards are available, and demand for the species is over a large land area. Further, nursery improvements that lead to increased seed use efficiency can be motivated based on increased timber production when there are limited quantities of the highest value seed.

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1. Chapter One: Introduction

1.1. Introduction

Large expanses of the South African landscape are defined by commercial forest plantations, with more than 1.2 million hectares blanketed under countless pine, eucalypt and wattle trees (Forestry South Africa, 2017). The forestry industry is a major driver of the South African economy, contributing over 1% of total GDP, employing 66 000 people directly and another 100 000 indirectly and making up 2% of all exports (DAFF, 2015).

Sappi is a diversified global woodfibre company, headquartered in South Africa that provides dissolving wood pulp, paper pulp and paper to customers in 160 countries. It employs over 12 000 people world-wide and had FY2016 group sales of $5 141 million (Sappi, 2016a). Sappi has three major divisions: in Europe, North America, and South Africa. The South African division is known as Sappi Southern Africa and is an integrated forest products company with three divisions; Specialised Cellulose; Paper and Paper Packaging and Forests. Sappi Forests is responsible for supplying the wood requirements of Sappi Southern Africa - it has 250 000 ha of land under plantations, and fells and replants approximately 16 000 ha a year (Sappi, 2016b). The majority of South African plantations are planted out as seedlings, raised in nurseries from a seed crop collected in hundreds of seed orchards spread across the country. With their relatively low cost and ease of use, seeds remain the most commonly used reproductive material for plantation forest regeneration – in South Africa, and internationally (Lee and Watt, 2012). Sappi Forests currently replants using 60% seedlings and 40% cuttings (personal communication, Wynand de Swardt, June 2018).

Seed production for forest regeneration is done in **seed orchards** – purpose grown stands of genetically superior trees planted together, under a management regime that encourages flowering and cross pollination, whose primary objective is to produce abundant genetically improved seed (Barnes, 1995). Seed orchards are a crucial link between tree breeding and silviculture, taking genetically improved material from breeding population to production populations (Barnes, 1995). Sappi Forests has 124 seed orchards, covering 343.72 hectares, and representing 25 species (personal communication, Wayne Jones, June 2018). Seed orchards are long term investments with substantial biological and economic risks, however, the majority of research on seed orchards focuses on biological and genetic aspects, with less emphasis on economic aspects. This chapter will motivate the purpose of the study, outline a problem statement and focus area, give research questions, aims and objectives.

1.2. Purpose of the study

The purpose of this study is to examine, from an economic perspective in the South African plantation forestry context, the costs and benefits of new and existing seed production orchards for Sappi Forests. Further, to use actual, measured parameters from the past 30 years to develop management tools and resources that enable informed management strategy decisions relating to investments into seed orchards for future seed production based on the net present values of the proposed projects. The impact of nursery seed use efficiency on seed orchard economic feasibility will also be examined.

The outcomes of this study will be of benefit to forestry managers, foresters, seed sellers and seedling nurseries in South Africa and elsewhere. At present there are very few or no published studies describing forestry tree seed orchard costs, seed yields and benefits in South Africa.

1.3. Focus of the study

This study will focus on using secondary data on seed orchards and seedling nurseries from Sappi Southern Africa (costs, production, benefits and seed use efficiency) to enable cost benefit analyses of current seed orchards, proposed future seed orchard development and to determine the impact of nursery seed use efficiency on the economic value of seed orchards.

1.4. Problem statement

The majority of South African plantation forestry is established with seedlings, using seed from purpose grown seed orchards that are a critical link between breeding populations and production populations (plantations). Seed orchards represent a long term investment and are subject to economic and biological risks. The development of new forest seed production orchards is costly in terms of time, space and money. The feasibility of these orchards is influenced by cost factors, management decisions and rates of propagation, as well as level of genetic improvement.

Despite the widespread use of improved seed as a propagation material in South African forestry, little published data exists to describe the costs and benefits of improved seed and seed orchards. At present, funding for seed orchards in South Africa is generally approved on the assumption that they represent good investments. However, while costs are often estimated, return on investment is not - accurate economic analysis being complicated by lack of concrete information on future seed productivity and the long term nature of such projects.

Information is lacking on the parameters that influence the economic justification of new improved seed orchards, such as how much genetic gain is required, what seed yields are necessary, and what level of seed use efficiency must be attained in order for benefits to outweigh costs, taking into account factors including interest rates, fluctuations in wood prices and so on.

1.5. Research aims

- This research project aims to identify and quantify all costs associated with seed production at Sappi, including direct costs of maintenance, harvesting, processing, storing and testing seed, and indirect costs of lost timber generating potential on the land where seed orchards exist.

- The aim of this research is to quantify how much income the sale of seed generated in Sappi's seed orchards to internal and external nurseries has generated.

- This research further aims to quantify the value to Sappi of increased timber production based on the use of genetically improved seed produced in its seed orchards.

- The research aims to determine whether Sappi's seed orchards represent good investment opportunities based on their associated costs and benefits.

- The final aim of this research is to examine the seed use efficiency of Sappi nurseries and determine the difference in net present value between making best use of limited available most improved seed, versus less improved, more plentiful seed, and calculating the increase in present value that could be obtained by increasing seed use efficiency.

1.6. Research objectives

- To identify and quantify all of the costs and benefits associated with seed production in Sappi seed orchards, including direct and indirect costs of establishing and maintaining seed orchards and direct and indirect benefits from the sale and use of genetically improved seed.

- To generate an economic model that can assist with management decision making for seed orchards based on seed production and increased timber production from improved vs. unimproved seed sources.

- To calculate the increase in net present value that is potentially available through improved seed use efficiency at Sappi nurseries.

1.7. Research questions

- How much do Sappi's seed orchards cost, taking into account all costs, including establishment, running costs, harvesting costs and opportunity costs of land use?
- How much income do seed orchards generate directly through sale of seed to Sappi's own and external nurseries?
- What is the value to Sappi of increased timber production through the use of genetically improved seed?
- Can investment in new seed orchards as a management strategy for Sappi Forests be supported on economic grounds, taking into account actual costs, estimated seed production, size of the area to be planted and estimated genetic gains possible?
- What is the increase in present value obtainable by increasing seed use efficiency in Sappi seedling nurseries?

1.8. Methodology

Data will be gathered from various sources within Sappi Forests to first characterise the extent of the seed orchard programme and then identify historical costs of seed orchard establishment and maintenance; the value of seed production and increased timber production, and the impact of nursery seed use efficiency. The present value of the seed orchard programme will be calculated, including the Net Present Value obtained by use of improved planting stock (present value of increased production minus additional costs, multiplied by annual plantation area).

A cost benefit analysis will be undertaken of a proposed new grafted clonal orchard comparing additional costs versus benefits associated with existing, and proposed new orchards. Standard assumptions made regarding costs and benefits will be varied in sensitivity analyses.

1.9. Outline of the dissertation

The aim of this MBA study is to examine seed orchard development at Sappi Forests in South Africa from an economic perspective.

Chapter 1 of this dissertation has introduced the problem statement of the study and explained the benefits that are expected from undertaking this research, as well as defining the focus of the study, the research aims, objectives and proposed methodology.

Chapter 2 of this dissertation is a review of the scientific literature regarding the economics of forestry seed orchards, focusing on forestry in South Africa, the role of seed orchards in the tree breeding process, and various economic approaches to forestry in general and seed orchards in particular. Concepts of seed supply and nursery seed use efficiency, as well as seed pricing are introduced.

Chapter 3 covers the research methodology that was used for this dissertation, including describing the research paradigm and the study setting as well as discussing possible biases and ethical considerations. **Chapter 4** covers results from the study, and includes various illustrative tables and figures. **Chapter 5** of this dissertation is a discussion of the research findings of the study, and explains the results generated in the light of previous research discussed in chapter 2.

Finally, **Chapter 6** gives conclusions and recommendations, including describing the implications of the research and recommendations for further studies.

1.10. Summary

Forestry is an important contributor to the South African economy, employing large numbers of individuals and adding substantially to the country's GDP. Sappi Forests is a large player in South Africa's forestry industry, and like other forestry companies is dependent on seed generated planting material for much of its annual replanting of commercial plantations. Forestry seedlings are generated from seed which is produced in specialised seed orchards. Seed orchards are long term investments that carry substantial risks, however, little research has been conducted on the economic aspects of seed orchard development and use, particularly in the South African context. This study aims to examine seed orchard development from an economic perspective and to provide tools that will aid forestry managers in making informed strategic decisions that will ensure sustainability of future seed supply. The following chapter examines the literature relating to the topics that will be addressed in this study.

2. Chapter Two: The economics of forestry seed orchards

2.1. Introduction

This chapter is a review of scientific literature relating to the economics of forestry seed orchards, focusing on forestry in South Africa in particular. The role of seed orchards in the tree breeding process is discussed, and various economic approaches to forestry in general and seed orchards in particular are introduced. Concepts of seed supply and nursery seed use efficiency, as well as seed pricing are described.

Seed orchards are the source of genetically improved planting material for much of forestry in South Africa and the world, thanks to their relatively low cost and ease of use (compared to vegetative propagation options). It is well recognised that tree improvement is necessary in South Africa in order to increase yield from a static land area, making investments in tree breeding a priority for many South African forestry companies (Boreham and Pallett, 2009).

Like any other investment in forestry, investment in seed orchards must be supported on economic grounds (based on relative costs and benefits over unimproved seed sources) for it to be used as a management strategy. The economic viability of seed orchard development is affected both by biotic factors such as seed yields as well as by management decisions that impact on seed requirements and seed use efficiency in the nursery. To be economically viable, seed produced in improved seed orchards should be sold at a cost that takes into account the costs of producing the seed, as well as the net present value of genetically superior planting stock being available for plantation regeneration.

This chapter will provide a theoretical background describing the subject area that is the topic of this study – looking at seed orchard development within the South African forestry context, briefly explaining typical methods used in forestry economics, and seed orchard economics in particular, before introducing the topics of nursery seed use efficiency and forestry seed pricing.

2.2. Forestry in South Africa

South Africa is a semi-arid country with limited natural forest, consequently it has a long history of plantation forestry – initially to supply wood for local use, and more recently, for export. Forestry in South Africa can be thought of as starting with the planting of the Dutch

East India Company's gardens in 1652 although the concept of commercial forestry really arrived with British rule in 1806. Pine plantations were first established around 1825, and *Eucalyptus* arrived at the Cape in 1828 (Showers, 2010).

South African commercial forestry currently comprises approximately 1.27 million hectares of plantation (compared to 100 000 ha of natural forests), covering around 1% of South Africa's total land area. Roughly half of this area is used for growing pine trees and half for eucalypts, with small quantities of *Acacia* (wattle) and very small areas of other genera. The majority of wood produced is used for pulpwood, with saw logs making up about a quarter of production and small amounts going to mining timber and other uses (DAFF, 2015).

The forestry and forest products industry is an important contributor to the South African economy, with exports of forest products valued at US$1.7bn in 2013 or 2% of the country's total exports (DAFF, 2015). The forestry industry in South Africa employees around 66 000 people directly, and 170 000 taking into account the industry as a whole, including processing (DAFF, 2015).

Sappi Forests is a South African timber supply company that grows and sources timber for Sappi's mills in KwaZulu-Natal and Mpumalanga provinces (Morris, 2008). Sappi is one of South Africa's largest private landowners with 500 000 ha of land owned or managed, of which around 250 000 ha are planted to commercial plantations of *Eucalyptus*, pine and wattle. Every year, approximately 16 000 hectares of Sappi forestry plantation (160 km^2) is felled and must be regenerated using seedlings, cuttings or (in limited areas) coppice regrowth.

The success of any tree planting programme depends on, among others, the continuous supply of high quality planting stock from nurseries. At present, Sappi plants approximately 40% of new plantations in the form of cuttings (vegetatively propagated plants) and 60% in the form of seedlings, creating a continuing demand for forest tree seed. Sappi uses almost 50 million seeds per year, generating over 30 million plants in seedling nurseries at Richmond, KwaZulu-Natal and Ngodwana, Mpumalanga.

2.3. Seed orchards

Forest tree seed used to generate seedlings for plantation forestry in South Africa is primarily sourced from specialised *seed orchards*. Forestry seed orchards consist of stands of genetically superior trees planted together under a management regime that encourages flowering and cross pollination. They are the most commonly used sexually reproducing forestry production populations, and their primary objective is to produce abundant genetically improved seed for sowing (Funda and El-Kassaby, 2013).

Seed orchards are used in most countries that have commercial forestry plantations, with, for example, 24 out of 28 countries in the EU having seed orchards, with over 40 species represented over 10 000 ha (Ruotsalainen, 2014). Seed orchards also remain the primary source of genetically improved planting material used for reforestation in the US Northwest (Miller and DeBell, 2013).

2.3.1. Seed orchards in the tree breeding process

Seed orchards represent a critical link between tree breeding / tree improvement efforts and subsequent silvicultural activities, moving genetically improved material from breeding populations into production populations (plantation forests). Breeding efforts lead to improved seed crops that are subsequently deployed operationally in the form of genetically improved planting material. Seed orchards are the primary method used to transfer genetic gains (the positive differences between selected and unselected reproductive material) from tree breeding into forest plantations (Funda and El-Kassaby, 2013).

A typical tree breeding process might start with selection of phenotypically superior trees (plus trees) from either wild stands or progeny trials from which seed or scion are taken to establish seed orchards, where either open pollination or controlled crosses leads to superior seed that can be tested in another round of progeny testing. Testing, crossing and selecting is repeated for generations, with incremental improvement made in each round (Ruotsalainen, 2014).

Production populations (seed orchards) can be formed every generation, or less often. The purpose of the seed orchard is to produce genetically improved offspring (seed or other) for operational deployment. The breeding cycle is concerned with achieving genetic gain, while the production population is intended to deploy maximum genetic gain to operations in a given generation (Figure 2.1). One breeding cycle is completed per generation of improvement in the sequence illustrated. Genetic tests created by planting seedlings from various populations provide breeders with information to make effective decisions (Barnes, 1995).

There are two main kinds of seed orchards, namely Seedling Seed Orchards (SSOs) which are raised from seedlings that have been produced from selected parents through either open or controlled pollination, and Clonal Seed Orchards (CSOs) that are raised from selected clones produced via grafting, cuttings, or tissue culture (FAO, 1993).

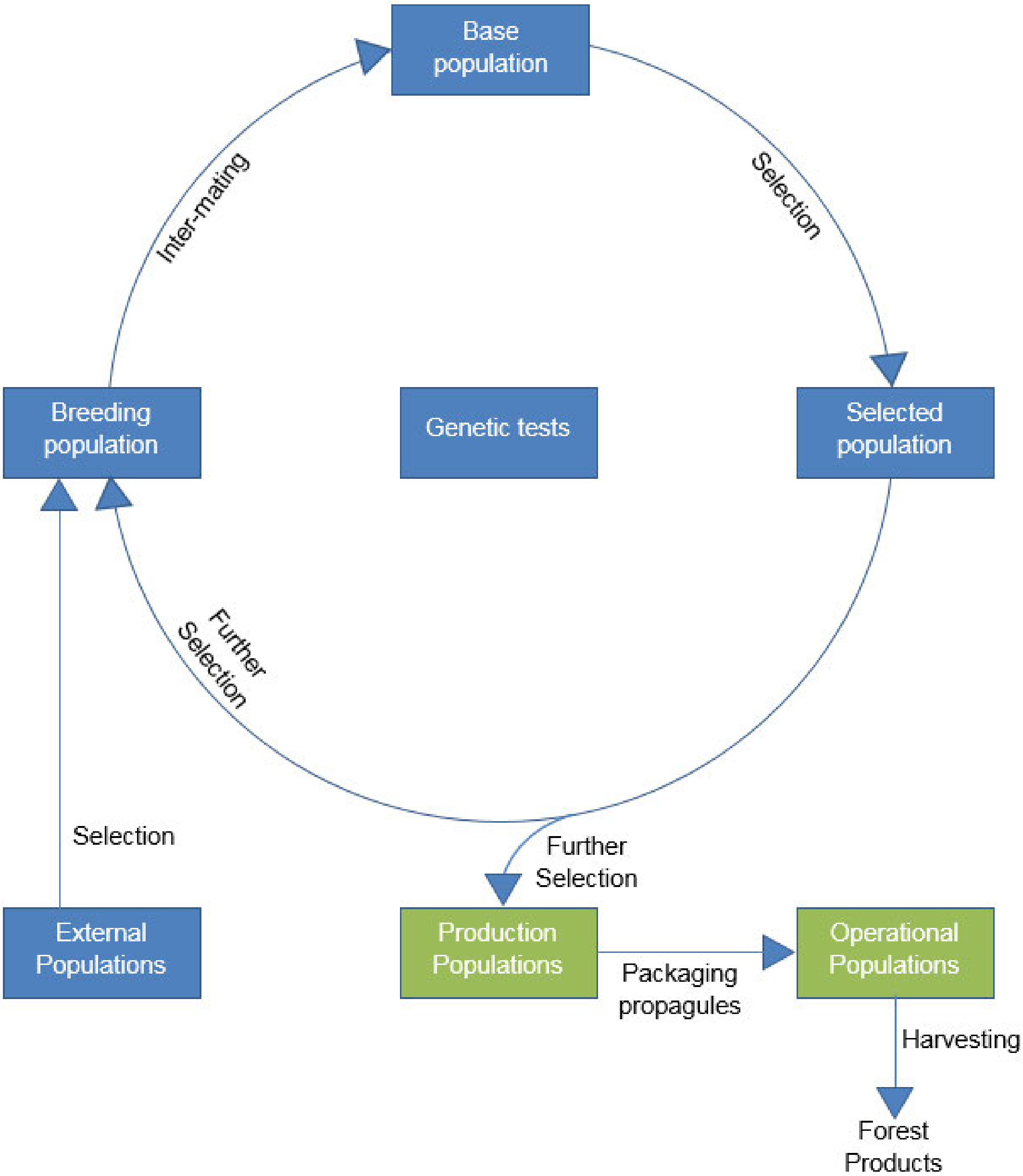

Figure 2.1. The major components of a breeding cycle typical to forest tree improvement programmes. Each breeding generation begins with a selected population. Starting with an external population (such as wild seed collected from superior individuals in natural stands) a breeding population is formed. The selected trees are crossed to allow recombination of genetic material to form a base population. A portion of that base population is selected for the next round of breeding, or placed into a production population – the seed orchard (adapted from White, 1987).

2.3.2. Seed supply from seed orchards

Seed orchards represent a preferable seed source to unimproved seed collected from native stands, plantation trees or opportunistically from individual superior 'plus' trees (Miller and DeBell, 2013). Where seed orchards are not available for seed production, the alternative is often to collect less improved seed from 'land race' material derived from block plantings where selected provenance are thinned by phenotypic selection to the best 100 or so stems per hectare for seed collection purposes (Boreham and Pallett, 2009). As tree improvement programmes require substantial time and investment, these kind of seed production areas can be useful where resources are limited.

In low priority species, or where seed are required in large quantity, seed production areas can meet seed demand by culling inferior trees and allowing the remaining, phenotypically superior trees to continue cross pollinating. Culling inferior trees can also improve seed weight, germination percentage and seedling vigour (Sivakuma et al., 2011).

Until 1995 Sappi obtained all of its seed requirements externally from mostly unimproved sources in Australia and Chile, or from South African landrace material from the Department of Environmental Affairs and Forestry and forestry company Mondi. Landrace material is a variable population which lacks formal crop improvement, but is characterised by being adapted to the environmental conditions of the area of cultivation through repeated grower selection *in situ* (Koskela et al., 2014).

Sappi started planting and developing its own seed orchards from the 1980s, in order to provide for its own needs and gain access to improved material. It is now 90 - 95% self-sufficient in seed supply, relying on external seed providers only for *Acacia mearnsii* seed (sourced from the Institute for Commercial Forestry Research, ICFR) and various industry members for *Pinus taeda*. Sappi has 124 of its own seed orchards, covering 343.72 hectares, and representing 25 species (13 eucalypts, four *Corymbias* (previously categorised as eucalypts) and eight pines). The average age of Sappi's seed orchards is now 23 years (Wayne Jones, personal communication, June 2018).

Sappi is somewhat unusual in world forestry in terms of the wide variety of landscape types that it plants on, influencing the number of species that it works with (currently more than ten pure species and hybrid taxa), this increases the number of seed orchards that are required, while simultaneously decreasing the land area planted to each species, decreasing economic viability of seed orchard production, compared to the dominant paradigm in most forestry areas, where the industry is reliant on a single species or small number of species.

Species use in commercial forestry in South Africa in general and at Sappi in particular have also changed rapidly in recent years due to the introduction of new pests and diseases which is occurring at an ever increasing rate (Wingfield et al., 2013) and which has meant that several species which were once dominant on the landscape are now no longer grown or are grown on greatly reduced areas (e.g. *Pinus patula* hard hit by the *Fusarium circinatum* fungus, *Eucalyptus grandis*, targeted by the gall wasp *Leptocybe invasa, E. nitens* attacked by the cossid moth *Coryphodema tristis* , personal communication, Jolanda Roux, July 2018).

2.4. Economic approaches to forestry

Forest economics has been described as a unique field, although in many ways it can be considered as the application of ordinary economics principles to the field of forestry. Forestry is an extremely capital intensive and long term business. Investors in forests or forest management expect to receive in time, greater reward than their initial investment, with at least as profitable a return as is available for the best alternative investments that carry a similar risk. Some features of forestry economics, while not unique, do add to the challenges of forestry economics. These include the long production periods and uncertainty, nonmonetary outputs from forests, and others (Klemperer, 1996).

The development of economic objectives for forestry and for seed orchard management in particular requires identifying flows of costs and income, the biological traits of interest (level of genetic improvement) and the calculation of economic weights for each trait, taking into account constraining factors such as the availability of flowers and pollen (Berlin et al., 2012). A key question is whether economic incentives exist for commercial forest owners to use more expensive improved material over cheaper unimproved material (Ahtikoski et al., 2013).

Forestry, like any business needs to make continued investments in order to keep growing. Determining which investments are likely to be worthwhile pursuing is one of the key outputs of forestry economics. Return on investment can be calculate in a variety of ways, including payback period, break even, internal rate of return and net present value.

2.4.1. Net present value

The profitability of various management options in forestry as in other fields, is most often assessed using **net present value** (NPV), which calculates the current value of all future cash flows generated by a project by taking the difference between the present value of cash inflows and outflows using the formula:

$$NPV = \sum_{y=0}^{n} [\frac{R_y}{(1+r)^y} - \frac{C_y}{(1+r)^y}]$$

Or in words, net present value is the sum of all revenues from each year (y) discounted back to year 0 at a discount rate 'r', minus the sum of costs treated in a similar fashion. Net present value describes the willingness of an investor to pay for an asset based on the costs, the estimated benefits and taking into account the required or desired rate of return, making NPV a valuable tool for valuing forestry investments.

Only projects with a positive NPV should be pursued, as negative NPVs indicate projects that will return less than they cost. NPV is often the chosen method for determining return on investment when analysing relatively short term forestry investments such as those typical of fast growing species in the southern hemisphere where the time horizon is from five to twenty years (Cubbage et al., 2014).

When making use of NPV in forestry, costs of all treatments must be considered, as must all income streams. Costs could include seedling / cuttings costs, establishment costs, fire protection, weeding, silviculture and so on. Income would be from timber at final felling, and potentially from thinnings. Unit costs / prices are important variable in determining profitability, and are frequently based on best estimates or long term averages. Costs and incomes are discounted to the decision point where the decision between alternative regimes are made. For discounting, the appropriate interest rates should be used. Net present value is used as an investment criterion, to examine threshold values for profitability (Ahtikoski, 2000, Niemistö et al., 2017).

2.4.2. Discount rate

The **discount rate** ‘r’ is the interest rate that is used when discounting future values to present ones. Money that is available now is generally more valuable than the same amount of money later in time (Burgess and Zerbe, 2011). This is due to the ability of the money to be used to make more money, by investing it, buying something to sell later, or earning interest on it in a bank. Furthermore, future money is less valuable than present money because inflation decreases buying power over time. This is known as the ‘time value of money’ and is why a discount rate must be used when comparing the value of money now with the value of money to be received in the future (Gallo, 2014).

The choice of an appropriate discount rate is a key variable in many forestry economic assessments (Griess et al., 2016), and can be difficult to determine (Wu et al., 2015). The rate of discounting chosen must assist in leading to the selection of the best available projects for increasing net present value (Burgess and Zerbe, 2011).

A high discount rate will have the effect of boosting the economic weight of traits that are expressed early, and depreciating those that are expressed late in the rotation (Berlin et al., 2012). Rates of between 6% and 8% are commonly used in South African forestry economic studies (Forestry Economics Services, 2012, Lopez et al., 2010, Griess et al., 2016), but published rates used in studies vary from country to country from 3 – 4% in long term boreal forestry in Latvia, Sweden and Finland based on low risk, long term bond returns (Jansons et al., 2015, Berlin et al., 2012), to 10% in a Chilean case study (Apiolaza and Garrick, 2001) and 8 to 12% in a Colombian study (Lopez et al., 2010).

A failure in many studies on forestry economics is the use of a discount rate with no information given as to the choice of that rate (Harrison and Herbohn, 2016). One of the simplest ways to choose a rate is to use the current interest rates on bank loans, although this is seldom appropriate, and does not take into account the inflation rate. The real rate of normal bank loans in South Africa in June 2017 was 10.5% (prime interest rate), minus inflation at 5% (Khumalo, 2017), which would give a discount rate of 5.5%. A preferable method is to use the required rate of return for the specific company being studied based on its weighted average cost of capital, including use of banks and own funds (Harrison and Herbohn, 2016). Another method is to look at the real return on capital for forest investments, which were calculated as 6% for eucalyptus plantations in 2012 (personal communication, Cori Ham, June 2018).

A **sensitivity analysis** is a technique used to determine how various values for independent variables will impact a particular dependent variable – a kind of 'what-if' analysis. For example, what would the impact of varying interest rates have on a bond's price? Sensitivity analysis can be used in forestry to determine the impact on a project's net present value of adjusting various factors including levels of genetic gain, stumpage and saw log prices but most often - the discount rate applied.

In sensitivity analysis of discount rates in forestry projects a range of rates are used, perhaps considering a best case to a worst case scenario, or using the highest and lowest values published in previous studies. For example, a range of discount rates from 3-6% was used in a study of Scots pine orchard development (Ahtikoski et al., 2013) and 6-8% when studying financial performance of pine hybrids in South Africa (Lopez et al., 2018). Sensitivity analysis allows for the possibility of analysing the consequences of various discount rates.

2.4.3. Payback period

The use of the time value of money is what makes NPV superior to the simpler **payback method**, which only answers the question 'how long until we make our money back', or the time that it will take for cash flow from a project to return the initial investment. Shorter payback periods are more desirable, as long payback periods mean greater risk and longer periods in the red.

The payback period in forestry is generally considered to be the number of years from when a plantation was developed, to when it is ready to clear fell – obviously this approach does not translate well to seed orchard development, as seed orchards can produce seed for long periods of time. Short payback periods are normally favoured in forestry projects, as they reduce uncertainty regarding market and prices.

Rather than payback period, some studies in forestry have employed **ROCE** (Return On Capital Employed) to rank various opportunities (Porth et al., 2016). ROCE is calculated as earnings before interest and tax divided by capital employed, which is defined as the sum of shareholders equity and debt. Using ROCE, a hurdle rate can be set to define when a technology or intervention becomes acceptable for investment purposes. ROCE is a useful tool when considering capital intensive sectors as it takes debt and other liabilities into account, providing a better indication of performance for companies with significant debt – often the case in forestry.

2.4.4. Internal rate of return

Related to the NPV is the **internal rate of return (IRR)**, which is simply the discount rate that gives a NPV of zero, where the present value of the revenues is equal to the present value of the costs. Another way of thinking of IRR is that the higher the IRR the more appealing a project is. IRR can therefore be used to rank various investment options. IRR is theoretically inferior in many ways to NPV, but its use continues for practical reasons, given that it is easy to understand and explain, and can be used to compare with other investment metrics, when it is used as a proxy for annual returns (Cubbage et al., 2014). Cubbage et al. showed that returns for exotic forestry plantations were substantial, particularly in South America and China, but also in South Africa, with IRRs ranging from 5% to 14%.

Increases in forest production with low investment can lead to attractive internal rates of return – as in studies where the profitability of various measures to increase forest growth and the effect of land prices, transport costs and site productivity were assessed (Simonsen et al., 2010, Lopez et al., 2010). An internal rate of return of, say, 5% does not indicate that investments will yield 5% per annum, but rather that even if a 5% interest rate is applied for investments, it is more profitable to initiate a project than not (Jansons et al., 2015). The use of Internal Rate of Return over a long period in forestry can be problematic, however, due to the assumptions that all returns can be re-invested at the same rate (Griess et al., 2016). The IRR of an investment is the discount rate at which the net present value equals zero, meaning an investment is acceptable if its IRR is greater than or equal to the investor's minimum acceptable rate of return.

2.4.5. Differential analysis

The **differential approach / differential analysis** involves differential benefits being weighed against the differential costs of various strategies (Jansons et al., 2015). Jansons et al used this technique to perform a differential analysis for the next breeding cycle of Norway spruce. Only the benefits and costs which differ between the various options are then considered (sunk costs are disregarded). This is also known as an **incremental analysis** or a **benefit-cost analysis** where **benefit / cost ratios (BCRs)** are determined (Wu et al., 2015, O'Reilly, 2014). A benefit cost analysis was chosen as the best method to conduct an economic analysis of using seed orchard vs unimproved seed by Wu, while O'Reilly used cost benefit analysis to determine tree improvement investment possibilities.

A BCR of greater than one is required for a project to be economically viable, as present value benefits are greater than present value costs. The basis of a benefit cost analysis is a series of discounted cash flows, similar to NPV.

Related to a benefit cost analysis is a **cost effectiveness analysis** that compares relative costs and effects of various different courses of action, for example the analysis of costs incurred to achieve a 1% gain in forestry (Porth et al., 2016). As such it is different to cost benefit analysis, which is more focused on assigning a monetary value to the measure of effect, and is more similar to cost-utility analysis, helping to identify how resources can be redirected to achieve more.

Many economic analyses of tree improvement programmes were reported in the 1970s and 1980s when many such programmes were being initiated (Wu et al., 2015). When benefits were not yet known, many studies used **break even** analyses to determine whether programmes were justified, without giving precise profitability. Break even occurs where total revenues spent on a project equal total costs, at which point profit is zero.

Necessarily, many of the figures used in these older studies were hypothetical, and assumptions were made. Break even analyses are also used in more recent studies, such as one to determine the economic feasibility of short rotation loblolly biomass plantations and another to determine at what carbon credit price conservation of forests become financially attractive to farmers (Kantavichai et al., 2014, Yamamoto and Takeuchi, 2012).

2.4.6. Land Expected Value

A comprehensive analysis of forest investments requires reliable estimates of yield, **land expected value** (LEV, also referred to as bare land value or soil expectation value) and a calculation of risk (Restrepo and Orrego, 2015). The land expected value is the extension of the net present value concept into perpetuity for infinite forestry rotations with assumed deterministic prices and yields, and as such represents the maximum sum of money that an investor can pay for a unit of land and earn an acceptable rate of return (Kantavichai et al., 2014).

Simply put, it is the value of bare land if put into forest production in perpetuity – effectively a perpetual periodic cash flow, where the rotation age gives the interval between payments (Ahtikoski et al., 2012). LEVs are directly related to unit costs and stumpage prices (stumpage prices are the price paid for the right to harvest timber, that is, the price paid to the grower by the harvester – the harvester will then be paid a price by the sawmill or pulp mill that includes the cost of transport). LEV is often used for long term forestry investments that can be of unequal time lengths (Cubbage et al., 2014).

LEV is often assessed when comparing various forestry management options (Niemistö et al., 2017). LEV can vary greatly depending on the climatic conditions and site quality that is prevalent (Ahtikoski et al., 2013). At the turning point of positive to negative LEV, small increments in, for example, discount rate can make additional expenditure (such as on improved seed) unprofitable, making ventures prone to market related risks. LEV can be used to calculate the effect of genetic gain but converting them into monetary terms (Ahtikoski et al., 2012). Selecting projects that have the highest total LEV for a given land area means that the most net returns will be generated for a fixed sum of capital.

The formula used to calculate LEV is known as the Faustmann formula after the German forester Martin Faustmann, who developed it (Faustmann, 1849). It is a form of net present value calculation that involves compounding each cost and revenue at a given interest rate to determine a future value for net income after a timber rotation (Straka, 2010).

LEV is given by:

$$\mathrm{LEV} = \frac{\mathrm{NFV}}{(1+i)^r - 1}$$

Where LEV is the land expectation value in South African Rands, NFV is the net future value, or the compounded value of net income at the rotation age in Rands, *r* is the rotation length, given in years, and *i* is the interest rate (Straka, 2010).

There are two ways to interpret LEV – firstly, it is the value of bare land to an investor, given a particular management regime, and is therefore the maximum amount that should be paid for land to earn the discount rate. Secondly, it can be used to determine optimal management regimes, or rotation ages by attempting to maximise LEV. One of the limitations of LEV is that it assumes a perpetual series, which is unlikely to be the case given the constant change in markets and entry of new pests and diseases.

When costs and durations of alternative strategies are not the same **equivalent annual annuity** (EAA) can be used to compare options (Jansons et al., 2015). Equivalent annual annuity is an annual real income with the same present value over a project's life as its NPV, and is used as a ranking criterion for projects with different lifespans (projects with shorter life spans must be repeatable with the same IRRs). EAAs are useful for comparing tree planting to land uses for which revenue is received annually.

2.4.7. Risk evaluation

A key aspect of forestry economic analysis is risk evaluation – risk being particularly important in forestry, where returns on investment are often reaped only many years after establishment (Restrepo and Orrego, 2015). Further, uncertainty related to the financial variables such as future interest rates and commodity prices make economic analysis difficult. **Monte Carlo** simulations are thus often used in risk evaluations. Political and legal uncertainty as well as economic and financial risk can be critical for forestry investments, particularly in South Africa.

As well as determining whether a project has a positive NPV and suitable IRR, the risks should be assessed to determine whether they are acceptable given the expected net present value. Forestry investments can be used to lower portfolio risk. The **portfolio method** has been used in the South African context to describe how investment risk can be lowered by producing a mix of timber products – in this case *Pinus patula* for saw timber production and *Eucalyptus grandis* for pulpwood (Griess et al., 2016). Maintaining seed orchards for multiple species forms part of this risk lowering technique based on Markowitz (1952) proof that mixing assets can reduce or exclude certain risk, provided there is less than perfect correlation among, for example, market prices.

2.5. Economic approaches to seed orchards

In order to remain competitive globally, the South African forestry industry (and Sappi) depends on a fast growing, low cost wood supply (Boreham and Pallett, 2009). South Africa is a dry country and land dedicated to forestry is stable or declining. Given these limiting factors, meeting future wood requirements and remaining competitive means generating more timber from the same area. Increasing the wood supply per unit area holds the greatest potential to improving forest productivity and decreasing unit costs of wood production. Updated breeding objectives must also take into account climate change in order to sustain the potential of future forests to adapt to changing environments.

The use of improved material from seed orchards usually results in better returns from forestry plantation due to either higher growth rates, better timber quality, better tree survival or a combination of these (O'Reilly, 2014). As well as offering greater volume growth, improved seed can also add value in terms of reduced unit costs of wood production, higher pest resistance and better survival rates (Ahtikoski et al., 2012).

There are several elements of improving wood supply, which together are known as operational gain – these include the impacts of tree improvement through breeding, propagation, plant use efficiency, correctly matching sites to species, finding the correct stand density and enhancing early growth through silvicultural practices (Boreham and Pallett, 2009). A key question to ask is whether investment into seed orchards as a management strategy for plantation forestry can be supported on economic grounds.

The majority of research work on seed orchards to date has focused on their biological and genetic aspects (Barnes, 1995, Wheeler and Jech, 1992, Funda and El-Kassaby, 2013), with less work done on economic assessment (Ahtikoski, 2000). Several studies have shown that there are considerable economic benefits to be gained from the use of improved tree seed (Ahtikoski et al., 2012, Wu et al., 2015, Jansons et al., 2015), with benefits exceeding the additional costs incurred.

Typically, a generation of tree breeding can increase volume by 10% to 25%, however wood quality traits and growth traits can be negatively correlated, meaning an economic weighting of traits is important (Jansson et al., 2017). Genetically improved seedlings can lead to reduced production costs for wood products, and decreased rotation age, both leading to improved net present value (Jansson et al., 2017).

A recent review noted that most improved materials are currently deployed as seed crops which originate from first generation phenotypic or tested seed orchards, that offer 10 to 25% improvement over unselected material (Ruotsalainen, 2014). Vegetative propagation can offer greater uniformity and gain, but due to the higher production costs associated with clonal (cuttings) approaches to tree improvement many of these have been found to be less cost effective than seedling based approaches despite the higher gain possible with cuttings (Lee and Watt, 2012).

Given the benefits, the demand for improved, seed orchard derived seed is often in excess of the supply, particularly in less developed economies, including those in Southern Africa (Lillesø et al., 2017). Where access to improved seed is limited, or no appreciation for the long term benefits of more expensive improved planting material exists, there is a tendency to use the cheapest material available, which is often of a lower genetic quality (O'Reilly, 2014).

In recent decades tree planting has greatly increased across Africa, and in South Africa. This has taken place at the same time that there is increasing pressure on natural forest resources. The establishment and management of nationally run programmes for tree seed supply, gene resource conservation and integrated tree improvement – that is, national tree seed programmes have become more important (Graudal and Kjær, 2000). Unfortunately many national tree seed centres, despite having received external support, typically for more than ten years, have not become self-sustaining, and in many cases are considered economic burdens, rather than financial assets (Graudal and Kjær, 2000).

The forest industry is also confronted with many risks, both biotic (pests and diseases), abiotic (drought, fire) and market (changing product strategies and fluctuating timber prices). These risks create economic uncertainty and volatility regarding future profits (Griess et al., 2016). Long rotations exacerbate these risks. The establishment of seed orchards is a very long term investment and therefore holds substantial biological and economic risk (Ruotsalainen, 2014). Variation in demand for a seed orchards products can also have a marked effect on their economic viability (Jansons et al., 2015).

For these reasons, seed orchards are owned by or subsidised by the state in many countries, as well as by private forestry companies or even specialist seed producers. Tree improvement programmes, of which seed orchards form part are forest investments like any other (site preparation, thinning, fertilisation) and so their economic desirability must be assessed based on their costs and gains and their contribution to the present net worth of forest ownership.

This emphasises the need for individual companies to run their own seed production facilities in a way that income from seed sales balances, or preferably exceeds expenditure. This is further based on the ability and willingness of users to pay for seed – generally not an issue when the seed provider is vertically integrated with the nursery.

2.6. Seed orchard costs

Funding for seed orchards is often granted based on the assumption that they represent a good investment, however, good financial management demands that not only costs, but return on investment must be known. This is difficult to assess for seed orchards, based on the long term nature of seed orchards and a lack of prior knowledge on their long term productivity. Improved seed from seed orchards necessarily costs more than opportunistically collected wild or unimproved seed, due to the costs of labour, material and overheads for seed orchard establishment, as well as maintenance and harvesting, where safety concerns add additional costs (Miller and DeBell, 2013).

2.6.1. Seed orchard establishment

Seed orchard establishment, together with planting, maintaining and measuring genetic trials represent some of the primary costs associated with tree improvement programmes (Wu et al., 2015). Once the breeding population of plus trees has been selected, the next step in a commercial forestry production programme is to establish seed orchards that are often made up of grafted copies of the empirically determined top plus trees, which are allowed to interbreed freely by open pollination to yield improved seed.

Clonal seed orchards require grafting for vegetative propagation in order to make multiple copies of selections for inclusion in orchards. Graft incompatibility where the rootstock and scion do not grow together can lead to grafted trees dying over years, and is a major limitation in some species where compatibility is an issue (Miller and DeBell, 2013). Seedling seed orchard which are raised from the seed of selected parents cost less to establish than grafted clonal seed orchards, although annual operation costs are the same post establishment.

In some instances, where the establishment of new breeding programmes is not justifiable for minor species, the best approach is to rather use available funds to establish seed orchards (O'Reilly, 2014). The strategy here is to select phenotypically superior trees and use them to establish seed orchards, without going on to the next step which would be to progeny test these trees to determine their genetic worth. Untested seed orchards can deliver additional gains for species where breeding programmes are not justifiable.

2.6.2. Seed orchard maintenance

For a seed orchard to be successful it must be managed intensively, with weed control, crown and graft maintenance, identity control, labelling, crop stimulation and so on adding to costs (Miller and DeBell, 2013). Other seed orchard costs include graft production, preparing the site, planting grafts, blanking operations and annual maintenance including, fire prevention and felling of dead trees.

Treatments to increase flowering such as the application of the Gibberellin synthesis inhibitor Paclobutrazol in eucalypts or use of Gibberellin A4/7 in pines also add to costs (Williams et al., 2003, Rosenberg et al., 2012). Flower enhancement is often necessary to efficiently produce seed from an early age, reliably and heavily – in contrast to the natural state of many forestry species which is to flower sparsely and erratically (Gardner et al., 2016). Techniques to induce flowering range from application of hormones either as drenches or injected into trunks to fertilisation and mechanical methods such as partial girdling (Miller and DeBell, 2013).

2.6.3. Impact of seed yields

The costs of tree improvement and seed orchard establishment tend to be heavily influenced by rotation length, and seed yield (South, 1990). The shorter the rotation length of the species produced, the smaller the genetic improvement required to justify the program economically (Barnes, 1995). This makes eucalyptus seed orchards (10 – 15 year rotation) an easier sell than pine orchards (18 – 25 years).

Seed yields from commercial seed orchards are the output of a complex production process where seed yield in any given year depends on the management activities that occurred in preceding years (e.g. application of flower enhancing chemicals), and the yields of previous years (e.g. a heavy harvest in one year, involving the removal of branches will result in poor harvests the following year as the trees recover). Cone / capsule harvesting, seed extraction, testing and packaging will cost the same for improved and unimproved material.

The area of seed orchard required for a plantation forestry strategy must take into account predicted seed requirements, seed crop per canopy and nursery seed use efficiency. Accurate estimates of seed orchard productivity are important when calculating number of years it will take to cover research and development costs of establishment. There is little publicly available data to assist with this evaluation. Sappi has many years of data from which to draw on and create estimates of productivity for various species.

The seed yields from a new orchard follow a predictable yield curve. First there are several years required for establishment and sexual maturation during which time no seed is produced. Next, a rapid increase in seed yield occurs as the orchard matures, followed by a long commercial production period, where production may vary from year to year, but an average yield is maintained, followed by an eventual decline as the trees grow old, die due wind-fell, lightning and disease, and stop producing seed (Figure 2.2).

In a typical orchard, the duration to first commercial seed harvest is 5 – 8 years (eucalypts) and 6 – 10 years (pines), with significant crops available from 10 and 15 respectively. Commercial production could last 30 to 50 years, although orchards typically become redundant before this time, at which point orchards can be felled or kept as genetic backups (personal communication, Wayne Jones, May 2018).

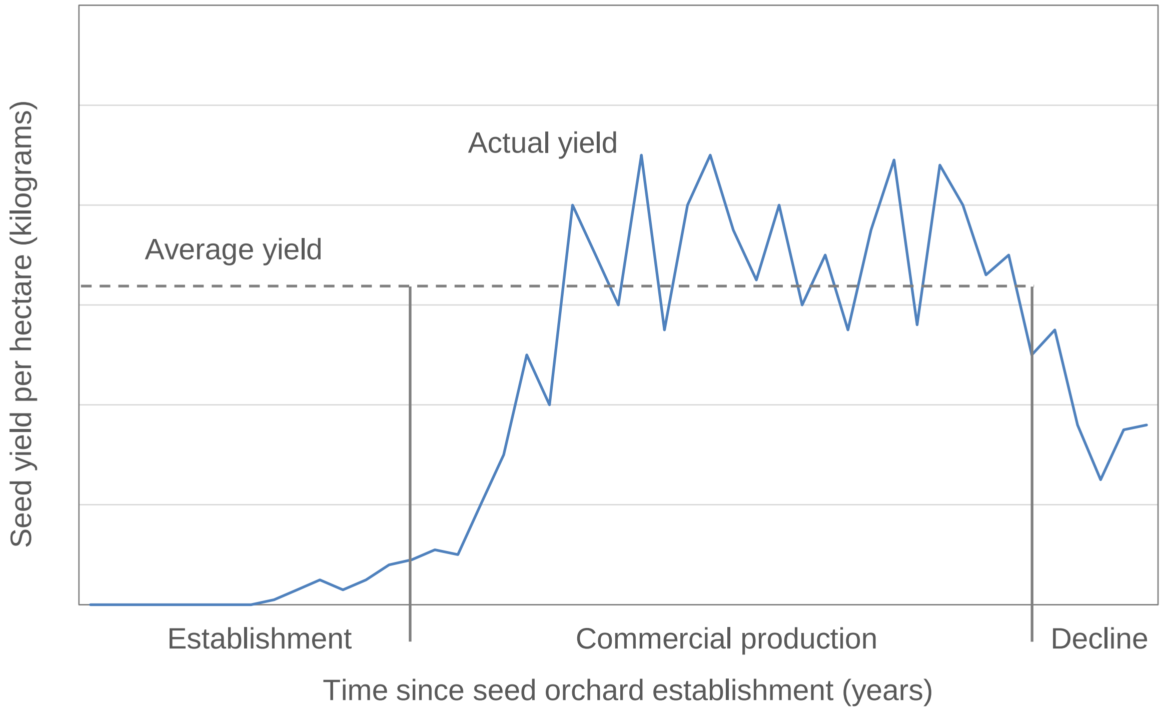

Figure 2.2. Theoretical yield curve for a seed orchard (adapted from Davis, 1967)

To be financially viable, high input seed orchards should be developed only for major species with a large planting area, as the larger the planting area, the more the benefit from the improved material (Jansons et al., 2015). Given a privately owned commercial seed orchard looking to make a normal profit, the expected market price for improved seed would need to cover all production costs, which could include operation and management costs per hectare during establishment years, during harvest years, outlay for capital items such as tractors or buildings. The efficiency of seed orchards have been improved over years, with the development of better management practices that increase reliability and size of crops and reduce damage that occurs due to insects and other pests (Miller and DeBell, 2013).

2.6.4. Capital costs

Costs and stumpage prices related to forestry investments have been considered in previous studies based on time series data, where the extent of the time examined is sufficient to capture both peaks and troughs of economic cycles. Nominal prices can then be deflated to give real prices and averages calculated per time series (Ahtikoski et al., 2013). All of these influence the financial viability of using improved seed material (Ahtikoski et al., 2012).

Depreciating the capital costs of a seed orchard over a fixed planning period is appropriate for seed orchards, as even though the orchard may continue to produce seed for years beyond this period, new generation breeding material will doubtless render the current orchard inefficient after a certain period (Davis, 1967). Key factors in calculating the costs of a seed orchard include the interest rate (as costs of establishment must be paid up to ten years before the first seed is produced by the orchard), the seed production expected per year, the depreciation period and the lag period before the commencement of commercial seed production (Wu et al., 2015).

Larger seed orchards may be more economically efficient than many small orchards as they allow the diffusion of overhead and fixed costs across a larger hectareage resulting in lower total costs per hectare and therefore per kilogram of seed (O'Reilly, 2014). Large orchards are however a greater fire risk. Establishing the largest orchard compatible with risk tolerance and seed requirements can therefore generally be recommended.

Seed orchards do not only generate costs, but also income, either directly in the form of sales of improved seed, or indirectly in the benefits of improved genetic material. The benefits of a seed orchard can be calculated based on its level of seed production, the utilisation of that seed, the genetic gain that is realised, and the gain in stumpage value (Wu et al., 2015).

The present value of a kilogram of genetically improved seeds is based on the value of the extra timber that can be expected at the end of rotation, discounted to present value. Several factors influence the present value of improved seed, including the efficiency of seed use in the nursery, the average rotation age, gain from genetic improvement, stumpage value, tree survival and site productivity (South, 1987).

2.7. Seed supply

There is a need for financial analysis in decision making relating to the choice of regeneration material – from the foresters point of view, the decision on whether to use improved seed should be based on the discounted net gain that can be ascribed to its use (Ahtikoski et al., 2012). While vegetative cuttings are often viewed as being superior to improved seed sources, given the higher costs for these (more than R 2 000 per 1000 vs less than R 1 000 per 1000), the improved yields from cuttings cannot always justify the increased costs, and in many cases seed orchard stock is more appropriate (Lee and Watt, 2012).

Improved seed is often available in limited quantities, and cannot always be utilised despite clear benefits in realisable genetic gain. Increasing the supply of genetically improved seeds is often the most important constraint to change (Simonsen et al., 2010). There is a possibility that seed from superior individuals could result in decreased nursery production costs due to more even seedling growth and heavier seeds. This should be taken into account as an additional benefit of creating new, improved seed orchards (Jansons et al., 2015).

For some forestry species, almost all of the planted seedlings come from genetically improved seedlings. In other instances, the share of improved seedlings varies greatly, influenced by the previous year's orchard seed crop, e.g. Norway Spruce in Scandinavia which varies from 20% to 70% year to year (Jansson et al., 2017), white spruce orchard had a good seed crop every two to three years (Wu et al., 2015). Limited improved seed availability has been listed as an impediment to improvement in Colombia (Lopez et al., 2010), leading foresters to make use of seed from natural forests, thereby losing out on 10% to 20% gains available from a first cycle of improvement. Limited improved seed has historically been available for Sitka Spruce in Scotland (Lee and Watt, 2012).

Where sufficient seed inventory can be built up, this can buffer the variation in seed production, but will lead to additional seed storage costs. Nursery efficiency was noted as 0.47 seedlings produced per seed developed in the case of white spruce in Canada (Wu et al., 2015). One plantable seedling per two seeds has also long been a rule of thumb in the pine growing areas of the Southern United States (Davis, 1967), while South mentions efficiencies of between 40 and 90% (South, 1987) and criticises the fact that many are satisfied with a seed efficiency of 66% for their best improved seed (South, 1990).

2.8. Nursery seed use efficiency

Many forestry organisations, Sappi included, invest millions of Rands annually into tree improvement activities. Investments in nurseries in efforts to conserve the seed produced from this effort, often lag behind however, in many cases nurseries are using the same equipment and techniques that were more appropriate for cheaper unimproved seed.

Given the additional costs and limited quantities of seed orchard seed, it is critical that nurseries use them as economically as possible (Stoehr and El-Kassaby, 2011). Where there is insufficient information available on a seedlot, regarding the germination, purity and seeds per unit mass, the inclination is to purchase and sow more than is needed, to err on the side of caution. This leads to seed wastage with excess seed being either stored for too long, and deteriorating (Rajjou et al., 2012), or sown, leading to excess plants being produced and later destroyed. In both cases, improved seed is wasted, and denied to other producers who could have used it. Wasteful nursery practices can also exacerbate seed shortages.

When forestry nurseries are operated somewhat independently of the forestry enterprise, they often operate with the short term goal of reducing seedling costs, whereas a more integrated approach will see future profit maximisation as a priority (O'Reilly, 2014). In both cases, increased nursery seed efficiency will benefit the organisation. Nurseries that follow short term goals of keeping budget low will not upgrade equipment, and may lose experienced managers by failing to counter offers with higher salaries (South, 1990).

Administrators that appreciate the difference between cost of seedling production and present net value of improved seed will place a high importance on seed efficiency as they know that efficiency in the nursery can improve the economics of an entire tree improvement programme, the efficiency of which can be highly influenced not only by the amount of seed production in seed orchards, but also by the degree of seed use efficiency in the nursery (South, 1990). The increase in present value obtained via improved seed efficiency can be calculated using the following formula created by South (1987):

$$PV = \left(\frac{PSN}{PSO}\right) * \left(\left(\frac{NSE}{OSE}\right) - 1\right) * PV1T * RA * BGR * (VGHS - VGLS)$$

PV = present value of additional wood obtained by increasing the seed efficiency on one hectare of improved seedlings in the nursery

PSN = number of plantable seedling produced per nursery hectare

PSO = number of plantable seedling planted out per hectare

OSE = old seed efficiency (expressed as a decimal value)

NSE = new seed efficiency (expressed as a decimal value)

PV1T = present value of 1 ton of wood harvested at the rotation age

RA = rotation age

BGR = base growth rate in tons/hectare/year for unimproved seedlings

VGHS = average volume gain of higher performing seedlings (at rotation age)

VGLS = average volume gain of lower performing seedlings

2.8.1. Kilogram effective factor

For nurseries, a key figure is the number of saleable seedlings that will be obtained from a given mass of seed (Horsley and Jones, 2011). To calculate this number, Sappi Forests Nurseries use the 'Kilogram Effective Factor' as described by Carter (1979), which was developed by the Rhodesia Forestry Commission who modified the British Forestry Commission method (Aldhous, 1972). This concept has also been described as nursery seed efficiency, which is the number of plantable seedlings produced, divided by the number of pure live seeds sown (a live seed is one with the ability to germinate) (South, 1987).

At Sappi, seed use efficiency can vary substantially both within and between species depending on time of year, seedlot, seed size grade and other factors, but is typically on the order of 1.5 viable seeds used per seedling sold (Wynand de Swardt, personal communication, June 2018). A substantial reduction in seed consumption through improved nursery technique is therefore possible. Improved nursery technique will decrease the number of seeds that are needed to produce a given number of plants, the impact of this is clearly understandable in that if the number of hectares of seed orchard required for a planting programme can be halved if number of seedlings produced per kilogram of seed sown is doubled.

Several key inputs are needed to allow precise estimation of KEF, namely: accurate estimates of the number of seeds per kilogram; absolute germination potentials of seedlots (as measured under optimum conditions in a laboratory) and estimates of the influence of the nursery environment on germination (nursery factor) (Solomon, 2017).

2.8.2. Seed counts per kilogram

The objective of seed counting is to accurately determine the number of seeds present per kilogram for each species and seed size grade. Due to the large number of seeds per kilogram, particularly in eucalypts, this value is by necessity an estimate, inferred from a given starting point.

Variation in seed size within a species can occur due to genetic effects or environmental factors during seed development. Accurate estimates of the number of seed for a given species and size grade are important, as they determine the recommended weight of seed to be sold to give a required seedling number. If the estimate of seeds per kilogram is too high, insufficient seed will be sown, and apparent germination will be low. If the estimate is too low, excess seed will be sown, giving unrealistically high germination results (Horsley and Jones, 2011).

2.8.3. Nursery factor

While absolute germination potential of a given seedlot is measured in the laboratory under ideal climatic conditions, real-world germination takes place in commercial nurseries, where the environment is not as closely controlled and where germinating seeds may be exposed to sub-optimal temperatures, humidity or presence of various pests and diseases. The nursery factor is a value used to adjust achieved laboratory seed germination to a more realistically achievable expected nursery germination (Solomon, 2013).

The theory behind the nursery factor is that it should give a nursery germination target that while possible, is a stretch target, requiring constant improvement in seed handling and management in the nursery to achieve. Sappi nursery standard is to take the third quartile value of viable germination results achieved in the nursery. Viable seed germination percentage is calculated as actual nursery germination / predicted nursery germination. For example, if lab germination were 100% and the given nursery factor was 0.1, then an actual nursery germination score of 90% would be considered 100% of viable germination.

For many nurseries, seed costs are the most expensive input for producing improved seedlings (one third of input costs at Sappi Nurseries: Wynand de Swardt, personal communication, February 2018). Improvements in seed use efficiency can therefore be justified economically purely on the cost of seed. The greater impact, however, comes later as profitability of tree improvement programmes correspond directly to seedling yields from the nursery, as the value of genetic improvements is not realised until planting stock is produced. Any hectare that is re-established with seedlings of low genetic potential represents a lost opportunity cost.

Volume gains cannot be achieved simply by increasing genetic potential of seeds, but are also dependent on optimizing the process of converting seeds into seedlings. By improving seed use efficiency, seed costs can be decreased, and future volume gains improved by conserving a valuable and limited resource. Improved nursery technique will lower the costs for establishing seed orchards and the costs of commercial plantations by reducing the number of seeds that are used per seedling (Wu et al., 2015).

2.9. Seed pricing

It has been noted that while sale of tree seed constitutes the most immediate income to seed centres, other activities can generate income in the longer term (such as seed source management), and other activities generate income to other stakeholders (for example establishment of best practices) and some activities generate benefits that are difficult to quantify monetarily (such as protection of genetic resources – a societal benefit) (Graudal and Kjær, 2000).

In principle, the sale of tree seed should cover production costs, and provide revenue that recognises the value of the seed sold. Many forest seed producers, however, in South Africa and elsewhere, do not charge for improved seed in a way that includes the costs of selection, orchard management, progeny testing, geneticist salaries and overheads, with the market price for seed sold externally often lower than the true cost of production. If seed is provided internally to nurseries at only the costs of harvesting and extraction, this creates little or no economic incentive for nursery managers to be more efficient with improved seed (South, 1990).

Seed and seedlings are often sold simply at cost price, or sometimes even below cost price or free of charge, in the case of some national tree seed centres that support local development (Graudal and Kjær, 2000). Giving seed away free of charge to aid development tends to be self-defeating, as it does not emphasise the value of using the best available seed. Pricing seed can be difficult, as the long term nature of tree production means that the genetic quality of the tree seed can only be revealed after many years. This leads to the market price being unduly influenced by the cheapest seed that is available (Nyoka et al., 2015).

In the simplest calculation of seed costs, the number of hectares of seed orchard required for every hectare of annual planting is first calculated. Initial orchard establishment costs and annual maintenance costs are calculated. The interest rate is of crucial importance, as the costs of establishment have to be paid ten years or more before seed will be produced in the seed orchard. The yearly production of the seed orchard (kilograms of seed per hectare, viable seed per kilogram) must be estimated. The lifespan of the orchard can be set at 20 years, or an appropriate value, and the costs of establishment depreciated over this period. These costs can then be divided among the seedlings that are expected to be produced. This cost is the additional cost of producing one seedling due to the costs of establishing and maintaining a seed orchard (Kjær and Foster, 1996).

2.10. Summary

South Africa has a long history of plantation forestry, starting in the 1800s. Much of plantation forestry in South Africa is propagated via seedlings, grown from seed produced in seed orchards, stands of genetically superior trees planted together and managed for flowering and seed production. Seed orchards represent a large investment with uncertain outcomes and high levels of risk. A large portion of the literature on seed orchards is focussed on their genetic and biological aspects, with less research focused on economic aspects.

Funding for seed orchards is often granted on the assumption that they represent a good investment, but full cost benefit analysis is not often performed, taking into account the many costs associated with a seed orchard programme, and the implications of orchard productivity. Economic analyses of seed orchards often involve cost benefit analyses, using net present values and sensitivity analysis. Choosing an appropriate discount rate can have a large impact on assessments of economic viability. Analysis must take into account the opportunity cost of not producing timber on a piece of land set aside for seed production – the land expected value.

Improved seed is often available in limited quantities, and the economic viability of an orchard can be affected by the efficiency with which the seed produced is used in the nursery. Nurseries that appreciate the present net value of improved seed will place a high importance on seed use efficiency as they understand that the economics of an entire tree improvement programme are affected by the degree of seed use efficiency in the nursery, as the value of genetic improvement is only realised once planting stock is produced.
Seed producers do not always take into account the true costs of seed production and the true value of improved seed when setting their prices for seed sale.

In the following chapter, the research methodology for the study is discussed, including the methods used to obtain data, the study setting and research paradigm, data analysis, the reliability and validity of the study and potential biases.

3. Chapter Three: Research methodology

3.1. Introduction

This chapter describes the research design that was followed for the study, including the aim of the study, the design and methods employed and the study setting. The data collection techniques used and confidence in the reliability of the data are discussed, as are potential sources of bias.

3.2. Research design and methods

This study is in effect a case study, as it takes an in depth look at the issue of forestry seed orchard development in its real life setting (Yin, 2017) within one company, Sappi Forests. Case study research focuses intensively on a single case and is concerned with understanding a topic within its context (Elman et al., 2016). As such it is not an experimental strategy where variables are controlled, or a survey strategy (Saunders, 2011). Case studies can generate insight and aid in the development of theory by studying an issue within its natural setting. The in-depth nature of case studies makes them widely used for business management research as they are focused on what is happening and why it is happening (Leppäaho et al., 2016).

Case studies are frequently used in qualitative research (Hyett et al., 2014), and a review of articles from international business research found case studies to be the most popular qualitative research strategy, where it is used primarily for inductive theory building (Welch et al., 2011). Case studies can, however, draw on both quantitative (numerically based) and qualitative (non-numerically based) research, or make use of a mixed methods approach, using aspects of each of these techniques (Birkinshaw et al., 2011).

This case study makes use of quantitative mixed methods, as more than one type of data collection technique is used, and data collected is analysed using various quantitative procedures. While case studies have been criticised by some for their small sample sizes and not contributing generalizable theoretical knowledge, this criticism has been countered as the use of quantitative and mixed method approaches gains more widespread acceptance in case studies (Saunders, 2011, Elman et al., 2016). This case study is a descriptive and exploratory case study, providing an example that can be compared against other cases in future research.

This study is a holistic case study of a single organisation (not a multiple-case study). Single case studies are often selected where the organisation examined is an extreme or unique case, or where the organisation can be considered typical of a kind (Saunders, 2011). This case selected of Sappi Forests may be considered to be typical of the experience of forestry companies working in South Africa. Case study strategies that consider multiple cases are interested in investigating whether the findings in the various cases can be replicated (Saunders, 2011), here the findings from Sappi Forests are compared in the discussion to other single case studies of organisations in other parts of the world.

One of the objectives of this research is to identify costs and benefits associated with seed production in Sappi seed orchards. In order to do this for the seed orchard programme as a whole, it is necessary to view Sappi's seed orchard programme as a single project with multiple cash flows, both positive and negative, spread over the course of the last several decades. For the sake of this study, the seed orchard 'project' will be considered as beginning in 1986, the first year that significant areas of seed orchards were established. Data will be collected on the extent of the seed orchard programme (hectares, site quality) from Sappi's Forest Management System and its Forestrax database of ongoing research projects and trials.

The project runs from 1986 to the present, and continues into the future. In order to mark an end of the project, an assumption is made that no orchard currently established will still be used for seed collection in 20 years, making 2037 the end of the project. While this is necessarily a somewhat arbitrary endpoint, changing species requirements and the movement to new and more advanced breeding stock over time as it becomes available makes this a reasonable seed orchard duration for the purposes of this study. This assumption errs on the side of caution, as while orchards may produce seed for longer than 20 years, this endpoint requires management decisions to assume a limited useful lifespan.

As we are examining Sappi's entire seed orchard programme rather than a single orchard, it is necessary to make various assumptions to avoid the project becoming excessively complex. The impact of varying these assumptions can be tested in future research. Each orchard is assigned direct establishment costs on a per hectare basis in the year they were established, and annual maintenance costs (fire protection, weeding) for the life of the orchard. Establishment and maintenance costs are based on current costs, depreciated by CPI to the years in which the orchards were established.

As orchards age they become less productive, and more prone to tree death. Furthermore, the breeding material used to establish them is more likely to have been replaced with more recent selections. For this reason, orchards will be assumed to be present on the land for 40 years only (no orchards have yet reached 40 years of age).

Indirect costs of seed orchard establishment are the loss of timber production that is deferred while a seed orchard is present on land that would otherwise have been used for plantations. Given that seed orchards are planted on a variety of site qualities where various species would have been planted for timber rotations, an average value per ton of timber will be used, with an assumed four commercial plantation rotations of ten years each deferred after the year of orchard establishment.

Information on the direct benefit of seed orchards in the form of actual income from seed sales is available for more recent years, earlier years and future years of seed income are calculated based on educated assumptions.

The indirect benefit of the seed orchard programme will be calculated as the increase in timber production from the use of improved planting stock. Estimates will be made of the Rand value of increased timber supply delivered through the use of improved seed, using historical data on seed production, estimates of genetic gain from Sappi's Tree Breeding programme and timber supply data from Sappi's Timber Management System.

This indirect benefit will be based on the number of hectares sown using improved seed from the year that Sappi generated seed first replaced bought in seed (1995) up to the project end in 2037. Increased timber supply will be based on an assumption of average genetic gain from improved seed sources of 10% and on an average timber rotation of 10 years. All costs and benefits will be discounted to the start of the project.

The value of a proposed new seed orchard will be calculated based on Sappi Seed Technology programme on graft survival, flowering percentages, number of grams of seed produced per tree, number of viable seeds per gram, and nursery seed use efficiency.

The impact of seed use efficiency on value addition through the use of improved seed will be determined using data from Sappi Nurseries on average seed use efficiencies that are achieved and Seed Technology data on improvement levels of harvested seed.

3.3. Research paradigm

The study examines the case of the seed orchard programme at Sappi Forests and is objectivist in its approach and positivist-functionalist in its paradigm (Saunders, 2011), using structured methodology, quantifiable observations and statistical analysis.

3.4. Study setting

The study is set within Sappi Forests Southern Africa, which is spread geographically across the provinces of KwaZulu-Natal and Mpumalanga, South Africa. Two Sappi seedling nurseries at Richmond, KwaZulu-Natal and Ngodwana, Mpumalanga form part of the study. Sappi is the employer of the researcher and offers access to data on the economic aspects of seed orchards that are not available to the general public, but which are representative of other, similar seed orchard programmes in Southern Africa and around the world.

3.5. Population and sample of the study

The case study will consider all currently extant seed orchards of Sappi Forests, regardless of whether they have been used to produce seed or not. As such, sampling methods are not applicable to this study.

3.6. Data collection

The study is based primarily on quantitative secondary data compiled from multiple Sappi Forests resources, including databases such as Forestrax, Forest Management System, and Timber Management System. Other sources of data are Sappi Nursery databases on seed use efficiency (previously collected for Kilogram Effective Factor or KEF analysis).

3.7. Data analysis

The value of land devoted to production of seed rather than timber was calculated using the Faustmann formula or Land Expectation Value (LEV), a standard discounted cash flow technique applied to many forestry scenarios (Straka, 2010, Niemistö et al., 2017, Ahtikoski et al., 2012). LEV is a special case of discounted cash flow with a perpetual stream of costs and revenues considered. LEV is based on the standard discounting formula for the present value of a perpetual periodic annuity where

$$LEV = \frac{NFV}{(1+i)^r - 1}$$

The standard LEV calculation uses a real interest rate (nominal interest rate minus the inflation rate) and constant Rands. Although the assumption of constant values is unrealistic, assumptions made about rotations far into the future will have limited impact on the LEV due to the discounting of their value.

The value of increased timber production resulting from the use of improved seed sources was calculated using the present value of a ton of wood at rotation age as a starting point, and considering the increased production thanks to improved seedling genetics, across the hectares planted to improved seedlings over time, using the same discount rate as used in calculating Net Present Value (choice of an appropriate rate is discussed in Chapter 2.4.2). The present value formula is:

$$PV = \frac{1}{(1+r)^t}$$

Benefit cost analysis is based on discounted cash flows based on costs that are incurred in the orchard programme and benefits accrued from seed sales and increased timber production. Due to the long periods over which this project is being assessed, costs and benefits have been converted to the start year of the project either by discounting, or by compounding, using the present value formula as above. Net Present Value is then the present value of both the positive and negative cash flows as given by the standard NPV formula below. Internal Rate of Return (IRR) is the discount rate which gives an NPV of zero, and is also calculated for this project.

$$NPV = \sum_{y=0}^{n}[\frac{R_y}{(1+r)^y} - \frac{C_y}{(1+r)^y}]$$

Projected future cash flows for NPV calculations were calculated based on current cash flows multiplied by an assumed CPI of 5% per annum, the current value in 2018.

Benefit Cost Ratios are simply calculated by dividing the present value of the benefits by the costs, where the ratio of 1 or more denotes a return that is greater than the real discount rate used in the analysis.

3.8. Reliability and validity of study

Quantitative data on seed orchard size, seed production, planted areas and seed use efficiency used in the study were all collected from internal company databases that are checked and tested regularly and can be considered to be reliable. The findings of the study have validity as they are applicable to other companies similar to Sappi Forests. As the research was performed by an internal / practitioner researcher, research access was not a hurdle.

3.9. Bias

There are various sources of bias with a case study approach that should be acknowledged and compensated for where possible. Familiarity with the case study company is a potential source of bias. As an internal researcher, various assumptions and preconceptions formed over many years of working in the company could prevent certain research aspects from being fully explored. Observer bias (Saunders, 2011) is possible as there is a desire to present the company in a good light, and to emphasise the importance of seed orchards, as the researcher's job revolves around maintaining and developing seed orchards. It is often argued with case studies that they are too subjective, giving excessive scope for the interpretations of the researcher (Flyvbjerg, 2006).

As most of the work done is quantitative in nature, the potential for bias that would be present with qualitative opinions is largely removed, however, and replaced with factual data. Assumptions made when analysing the data, however, may represent management opinions – to avoid this, ranges of potential values have been used rather than single values (as in sensitivity analysis), to avoid the impact of, for example, assuming a single discount rate when calculating net present value, as seen in research by Lopez et al (Lopez et al., 2010, Lopez et al., 2018).

3.10. Ethical considerations

This research is quantitative in nature and relies on secondary data that does not involve any personal data or human participants. While people are not the subject of the work, the research could be perceived as leading to changes that would affect, for example, nurserymen who are largely responsible for managing seed use efficiency. Any findings from the research, however, would not be used to harm any participant, but could provide insight into their work that would enable better allocation of resources and efforts which would provide the most value. An ethical clearance for the research was obtained from the University of KwaZulu-Natal’s research ethics committee (Appendix B).

3.11. Summary

This study aims to examine the economic implications of a seed orchard programme that is tasked with producing genetically improved seed. Using a multi-method quantitative research design, data was collected on the extent of Sappi Forests seed orchard programme, the Rand value of increased timber supply delivered through the use of improved seed, and the impact of seed use efficiency on that value addition. Data reliability and validity have been considered and efforts made to decrease any sources of researcher bias.

In the following chapter, data from the study are presented, together with various figures and tables.

4. Chapter Four: Presentation of results

4.1. Introduction

In this chapter, results and data resulting from the study are presented, primarily in the form of descriptive statistics on the extent of Sappi's seed orchards, estimates of the direct and indirect costs of establishing and running them, and income generated by them, both directly and indirectly. Benefit cost ratios are calculated for both the seed orchard programme as a whole as well as a proposed single new orchard, followed by an assessment of the increases in net present value that are possible through increased seed use efficiency in Sappi nurseries.

4.2. Results

4.2.1. Extent of Sappi seed orchards

The extent of Sappi's seed orchard land holdings was calculated by tabulating all areas set aside for seed production, whether or not seed has been collected from them. Sappi has seed orchard resources for a total of 25 species, including thirteen eucalypts, eight pines and four *Corymbias* (Table 4.1).

Table 4.1. Sappi seed orchards by species, count and area (Source: Sappi FMS database)

Species	Orchards	Area (ha)
P. patula	23	86.1
E. smithii	16	55.7
E. grandis	12	45.9
E. dunnii	21	42.22
E. nitens	14	41.9
E. macarthurii	8	16.8
P. caribaea	3	10.7
P. taeda	2	6.2
P. tecunumanii	2	6.2
P. elliottii	2	5
E. benthamii	2	4.3
C. henryi	2	3.6
P. greggii	2	3.1
E. viminalis	2	3
E. urophylla	1	2.2
E. saligna	1	1.9

Species	Orchards	Area (ha)
E. fraxinoides	2	1.6
P. kesiya	1	1.3
E. badjensis	1	1.1
C. citriodora	1	0.9
C. maculata	1	0.9
E. pellita	1	0.9
P. maximinoi	2	0.8
C. torelliana	1	0.7
E. dorrigoensis	1	0.7
Grand Total	**124**	**343.72**

A total area of 343.72 ha is set aside for seed production, out of a total planted area of around 250 000 ha or only 0.14% of the total planted area. Approximately one third of the orchard area is made up of clonal seed orchards (99.8 ha), with the remainder made up of seedling seed orchards (243.92 ha).

The majority of Sappi's seed orchards were established in the late 1980s and early 1990s, reaching a peak of new orchard establishment in 1993 (Figure 4.1). Few orchards have been established in the past 20 years, meaning the majority of Sappi's existing orchards are at least half way through their expected useful lifespan.

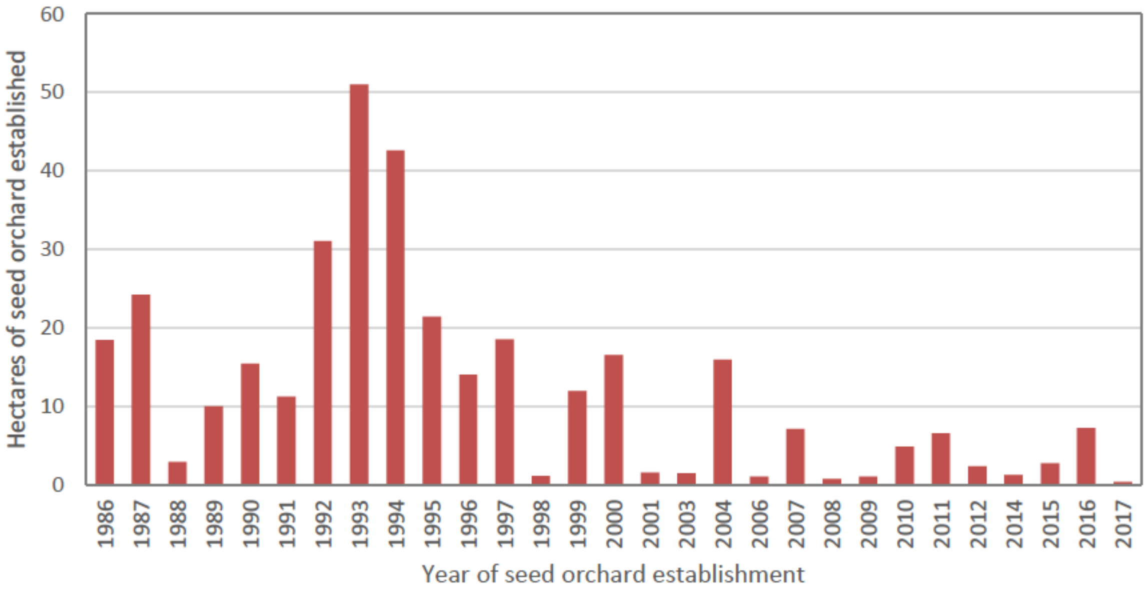

Figure 4.1. Seed orchard establishment at Sappi Forests (Source: Sappi FMS database)

4.2.2. Orchard costs

To determine the extent to which investment in seed orchard development can be supported on economic grounds, it is important to have an accurate representation of the present values of the relative costs and benefits associated with their use versus the use of unimproved wild seed. Costs associated with seed orchard use can be divided into the **direct** costs of establishing and managing them and the **indirect** opportunity costs of forgoing timber production on the areas set aside for seed production.

4.2.2.1. Direct costs

The direct costs of establishing a new seed orchard vary depending on whether a seedling seed orchard or a clonal seed orchard approach (which includes the expenses of collecting scion and producing grafts) is pursued. Typical costs for establishing and maintaining orchards based on figures available from the Forests and Seed Technology departments of Sappi Forests are presented below in Table 4.2 and 4.3.

Table 4.2. Typical costs for a seedling seed orchard on a per hectare basis (2017)

Seedling seed orchard		
Source	Year	Cost / ha / year (Rands)
Initial costs		
Site preparation	0	2 960
Establishment (mark, plant)	0	3 083
Establishment (water, fertilise)	0	1 760
Total		**7 803**
Annual maintenance		
Fire breaks preparation	every year	625
Road maintenance	every year	147
Weeding	every year	250
Total		**1 022**

Table 4.3. Typical costs for a clonal seed orchard on a per hectare basis (2017)

Clonal grafted seed orchard		
Source	Year	Cost / ha / year (Rands)
Initial costs		
Scion collection	0	9 250
Grafting	0	2 890
Establishment (mark, plant)	1	3 083
Establishment (water, fertilise)	1	1 760
Total		**16 983**
Annual maintenance		
Fire breaks preparation	every year	625
Road maintenance	every year	147
Weeding	every year	250
Total		**1 022**

Given the split of seedling to grafted seed orchards, the weighted average cost of establishing a seed orchard can be set at R10 468.44, with annual maintenance of approximately R1 022. As these prices have changed greatly over the years, and will also depend on the region in which the orchard is planted, there is a fair degree of error around the average, and so for further analysis R10 000 / ha for establishment and R 1 000 / ha for maintenance will be used for simplicity sake. When calculating future costs, inflation is accounted for by escalating costs at an estimated CPI of 5% per annum. Past costs are deflated according to historical CPI values.

Apart from the cost of establishing and maintaining orchards, other direct costs of the seed orchard programme to consider are the costs of harvesting, processing, testing, storing and selling seed, including facilities such as the Sappi seed centre, with its fridges, laboratories and seed extraction equipment. In addition to these costs are parts of the salaries of a Programme Leader, Research Officer, Research Forester, Team Leaders and multiple Team Members and contract staff used to keep the programme running. An estimate has been made of 60% of the overhead costs of the Seed Technology Programme or approximately R 3m in 2017. Note that the full budget of the department is not used, as some of the expenses are already accounted for in the establishment and maintenance of orchards, and because the Seed Technology Programme does a portion of its work which is unrelated to commercial open pollinated seed production.

4.2.2.2. Indirect costs

The indirect costs of a seed orchard programme include the opportunity cost of forgoing timber production on the land set aside for seed production. In the most extreme case, this forgoing of timber production could be viewed as permanent. In this case the indirect cost of taking land out of timber production is equivalent to the LEV or Land Expectation Value. The LEV is used to indicate the value of the bare land under a typical forestry regime by using the Faustmann formula to compound costs and revenues at an appropriate interest rate to determine what the future value would be of net income at the end of a timber rotation. This rotation is assumed to continue in perpetuity, creating a perpetual periodic cash flow. The LEV represents the value that the land can generate when permanently dedicated to timber production.

The LEV is a form of net present value calculation, with the amounts calculated for LEV representing the residual value after the real interest rate (here 6% is used, the real return on capital for South African eucalyptus plantations, see literature review 2.4.2). Therefore the land earns the rate of return, plus the LEV. As LEV is dependent on the net future value of a timber rotation, it will vary depending on the number of tons that can be grown on a site and the length of the rotation. Sappi Forests uses a Site Quality index to represent an area's production potential, where Site Quality 1 has the highest production potential, and Site Quality 5 the lowest potential. To determine the LEV for all Sappi land currently under seed orchards, a first step is to allocate each orchard to a particular site quality (Table 4.4). Most of Sappi's seed orchards are on lower site quality sites.

Table 4.4. Hectares of Sappi seed orchard per site quality (Source: Sappi FMS database)

Site Quality	Ha
1	23.3
2	78.12
3	182.1
4	56.4
5	3.8
Grand Total	**343.72**

For this calculation, mean annual increments (average growth of a stand of trees per year) ranging from 26.9 wet white tons / hectare / year on Site Quality 1 to 8.3 wwt/ha/yr on Site Quality 5 were used based on internal Sappi research. Rotation lengths of 8 years for SQ1-3 and 10 years for SQ4 and 5 were used. A mill delivered price of R700 / ton was used.

Harvest value was calculated as MAI (wwt/ha/year) * rotation length (years) * mill delivered price (R/wwt). Establishment costs per hectare of plantation timber were calculated as R10 000 (equal to average seed orchard establishment costs, but seed orchard spacing has 185 trees per hectare, vs 1666 in plantation), with annual costs (fire protection, noxious weeding, road maintenance) of R1 000 per hectare. Hectares of orchard area per site quality taken from Table 4.4 above. The weighted average MAI of the area under seed orchards was 16 wwt/ha/yr.

Based on an analysis of LEV for the land used for seed production, the indirect costs for the seed orchard project are calculated at just over R40 million (Table 4.5). Note that this calculation uses a real discount rate (net of inflation) and so costs and revenues are also not inflated (constant Rands) (Straka, 2010).

Table 4.5. Calculation of LEV for land used by Sappi seed orchards (6% real discount rate)

Receipt / expenditure	Value / ha	Multiplier	Future value at rotation age (NFV)
Site Quality 1			
Harvest at year 8	150 640	NA	150 640
Site prep at year 0	-10 000	(1+r)^8	-15 938
Annual cost	-1 000	((1+r)^8 – 1) / r	-9 897
Net future value at rotation age			124 804
Land expectation value = NFV/((1+r)^{rotation} - 1)			210 162
Hectares		23.3	4 896 765
Site Quality 2			
Harvest at year 8	117 600	NA	117 600
Site prep at year 0	-10 000	(1+r)^8	-15 938
Annual cost	-1 000	((1+r)^8 – 1) / r	-9 897
Net future value at rotation age			91 764
Land expectation value = NFV/((1+r)^{rotation} - 1)			154 524
Hectares		78.12	12 071 451
Site Quality 3			
Harvest at year 8	89 600	NA	89 600
Site prep at year 0	-10 000	(1+r)^8	-15 938
Annual cost	-1 000	((1+r)^8 – 1) / r	-9 897
Net future value at rotation age			63 764
Land expectation value = NFV/((1+r)^{rotation} - 1)			107 374
Hectares		182.1	19 552 869
Site Quality 4			
Harvest at year 10	83 300	NA	83 300

Site prep at year 0	-10 000	(1+r)^10	-17 908
Annual cost	-1 000	((1+r)^8 – 1) / r	-13 181
Net future value at rotation age			52 211
Land expectation value = NFV/((1+r)^{rotation} - 1)			66 019
Hectares		56.4	3 723 454
Site Quality 5			
Harvest at year 10	58 100	NA	58 100
Site prep at year 0	-10 000	(1+r)^10	-17 908
Annual cost	-1 000	((1+r)^8 – 1) / r	-13 181
Net future value at rotation age			27 011
Land expectation value = NFV/((1+r)^{rotation} - 1)			34 154
Hectares		3.8	129 786
Total			**40 374 325**

As land set aside for seed production purposes is in practice not permanently removed from commercial use and would typically return to timber production at the end of the seed orchard's life (estimated at 40 years for most orchards), a more accurate calculation of indirect costs of the orchard programme would be to assume that on average, seed orchards are present on the land for forty years, or approximately four rotations of timber production are lost (at ten years per rotation) with four deferred income amounts at ten year intervals.

Appendix A (NPV Seed Orchard Programme) shows the costs of establishment and maintenance versus the value of deferred timber production from the start of the project in 1986 to the end in 2037 (Cash Flow 1). In this model, costs have been taken from 2017 and either deescalated by CPI per annum, or increased at an assumed constant future CPI of 5%. Using this approach, the value of the land (measured as deferred timber production less establishment and maintenance costs) is calculated at an NPV of R18.8 million.

4.2.3. Orchard Income

4.2.3.1. Rand value of seed production

Seed orchards generate income directly through the sale of harvested seed. Seed sales are determined by seed availability and market opportunity (availability of customers). Figure 4.2 below shows seed production by Sappi seed orchards (millions of viable seed harvested) per annum for the past 19 years, the period for which data are available. On average 70 million viable seeds were harvested per year. Due to the size difference between pine and eucalypt seeds, viable seeds is a more meaningful measure of seed harvest than weight, however the trend in kilograms of seeds harvested tracks the viable seeds fairly closely (data not shown). The average number of kilograms of cleaned seed harvested per year for the time period shown is 366 kg.

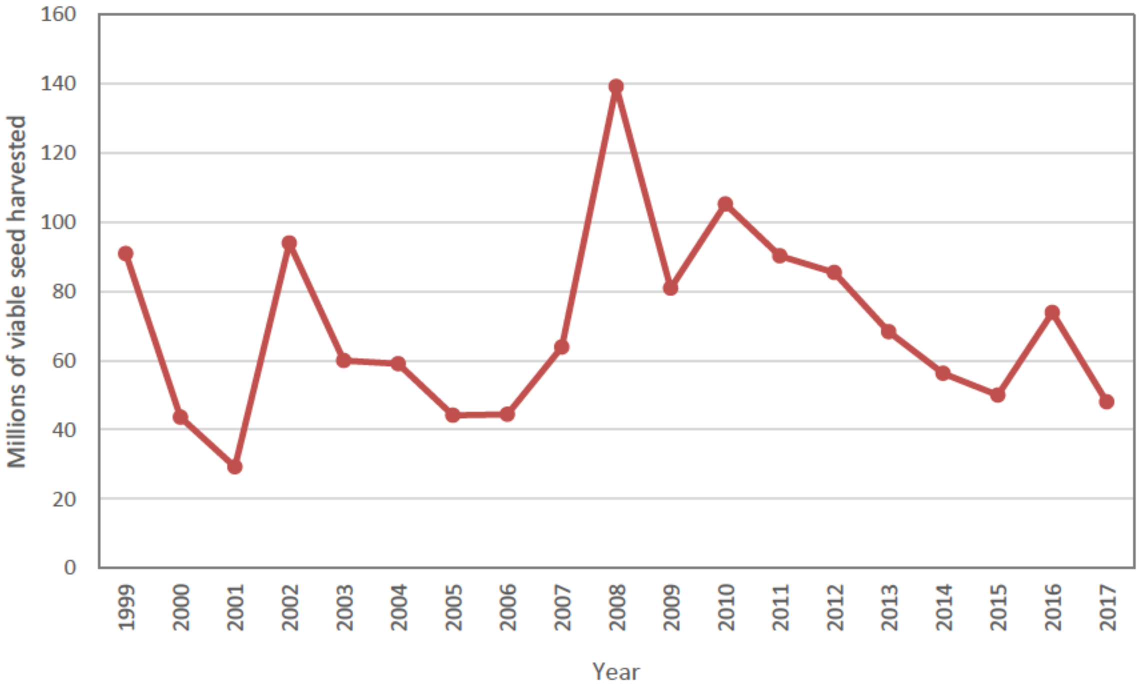

Figure 4.2. Millions of viable seeds harvested per year from Sappi seed orchards 1999 to 2017.

Sappi charges for seed based on the level of genetic improvement, with three categories, namely: Select, Superior and Elite. The seed prices per viable seed (FY2017) are ZAR 0.10 for Select, ZAR 0.13 for Superior and ZAR 0.17 for Elite seed (Figure 4.3). The majority of seed harvested falls into the Superior category, with smaller quantities of Select and Elite seed. In years such as 2008 when seed demand was high due to extensive fires the previous year, more Select seed was harvested to meet demand (data not shown).

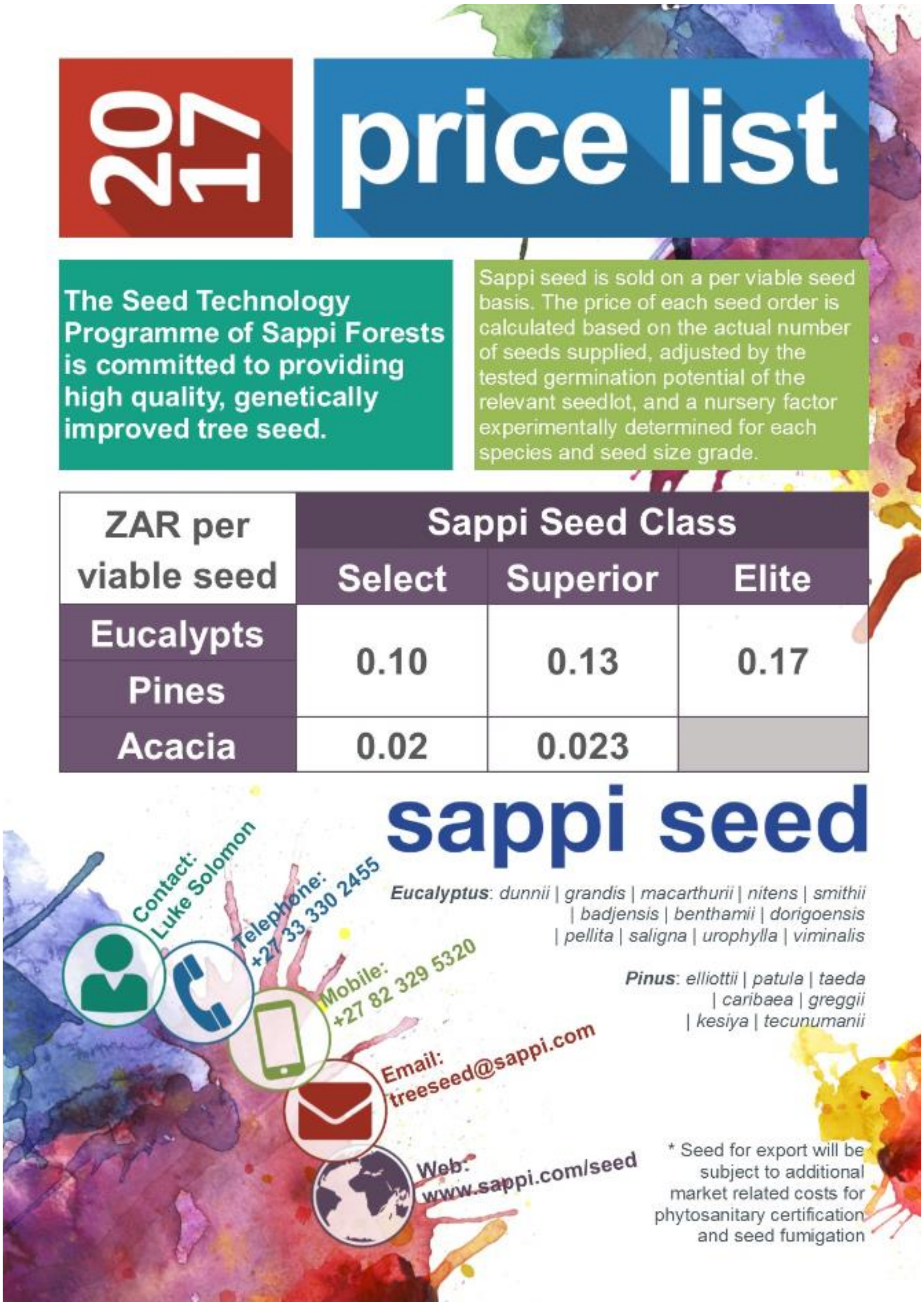

Figure 4.3. Sappi seed pricelist 2017 (Source: www.sappi.com)

Not all of the seed harvested in a given year is sold in that year, Figure 4.4 below shows the income from seed sales for each year from 1999 to 2017, and the income trends are clearly different from the seed collection trends above. Two lines are shown, one in red indicating the estimated value of the seed sold each year based on the number of viables per class sold in each year, multiplied by the 2017 seed prices and the other in green showing the actual income for that year (adjusted for inflation and shown in 2017 Rands).

There is a clear divergence of the two lines prior to 2010. In early years of the seed programme seed was sold on a per kilogram basis, resulting in lower sales values. Seed sales were converted from a per kilogram to a per viable seed basis in 2011. Actual income data are only available from 2001 onward. Income from seed sales increased in real terms from 2000 to around 2011 and then began to gradually decline with an increase in the proportion of Sappi land planted to vegetatively produced cuttings.

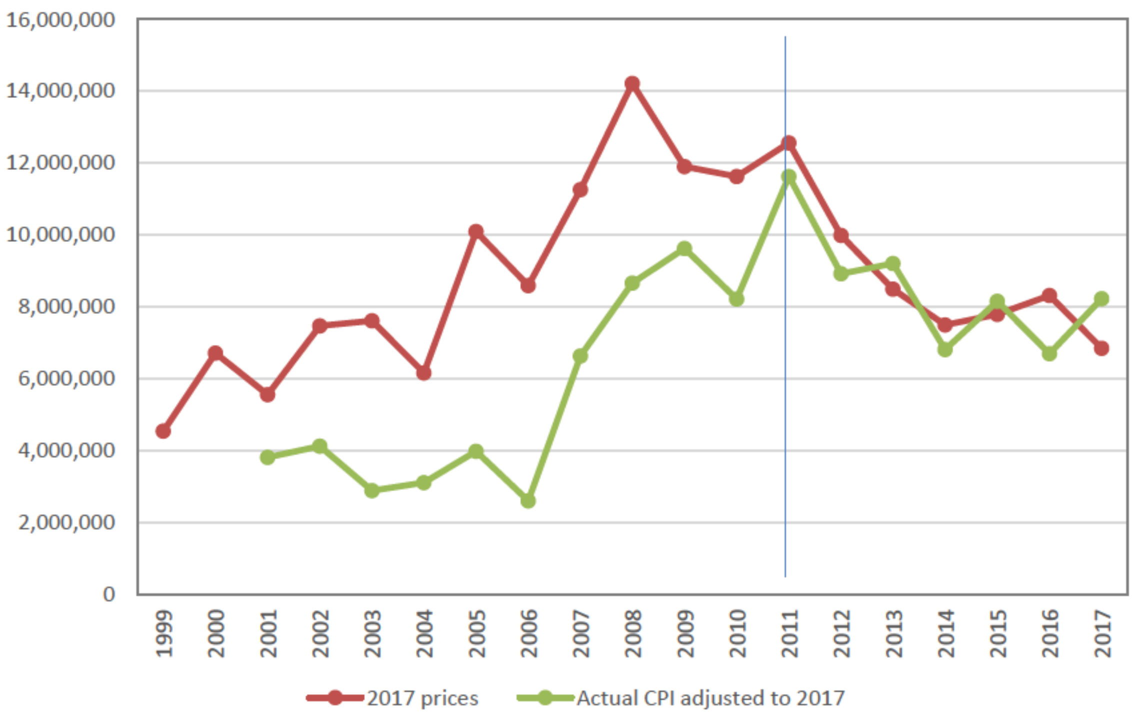

Figure 4.4. Seed income 1999 to 2017.

The total actual income for the period 2001 to 2017 is a not insignificant R 80m, averaging R 4.7m a year. Adjusting previous income to 2017 values using CPI adjustments, the total for the period is R 113m, averaging R 6.6m a year.

4.2.3.2. Rand value of increased timber supply thanks to improved seed

The benefit of a seed orchard programme is realised primarily through its realised genetic gain and subsequent gain in stumpage value as more timber can be produced from the same land base in a given rotation. To calculate this value, it is assumed that Sappi's seed orchards produced sufficient seed for all of Sappi's reforestation needs. This is a reasonable assumption, given that the annual plant requirement in BP2016 was 43 million plants, of which 28 million were seedlings and 15 million cuttings. Average potential seedling production can be calculated as 70 million viable seeds (average number produced by the programme per year) multiplied by the nursery efficiency (seedlings produced per viable seed used) which has averaged 0.63 at Sappi over the past seven years (period for which data is available), giving 44 million potential seedlings (70 * 0.63), well in excess of Sappi requirements.

Realised genetic gain is calculated at Sappi by the Tree Breeding programme by performing genetic gain trials with large plots of improved versus unimproved seedlings. Various trials of this kind have indicated that on average the improved seed produced in Sappi orchards delivers a 10% increase in volume / ha over unimproved seed sources. Gains in stumpage value through the use of improved seed can then be estimated by multiplying the genetic gain by the unit stumpage rate. For this study a conservative assumption is made that stumpage rates will remain constant in the future. Further, no savings generated by larger trees are considered (in reality increased timber piece sizes lead to lower harvesting costs and increased recovery rate).

The present value of timber harvested from a hectare of seedling derived timber varies based on the stumpage value (how much is paid per ton of wood), the mill delivered value (which is dependent on factors such as the distance of a plantation from the mill), the number of years that the trees have been on the land and the real interest rate. Looking at a variety of likely rotation ages, stumpage values and real interest rates, the present value of one ton of wood at rotation age can vary greatly from less than R300 to more than R900 (Table 4.6).

Table 4.6. Present value of one ton of wood at rotation age given various stumpage values, rotation ages and real interest rates.

Stumpage value*	Rotation age	Real interest rate		
		4%	6%	8%
700	8	511.48	439.19	378.19
	10	472.89	390.88	324.24
	12	437.22	347.88	**277.98**
1000	8	730.69	627.41	540.27
	10	675.56	**558.39**	463.19
	12	624.60	496.97	397.11
1300	8	**949.90**	815.64	702.35
	10	878.23	725.91	602.15
	12	811.98	646.06	516.25

* Rands per wwt at time of harvest

The area of Sappi Forests land planted to seedlings is shown in Figure 4.5. On average, Sappi planted 10 870 hectares of improved seedlings per year from 1995 to 2017. The average area forecast for seedling plantation in the next 20 years to 2037 is slightly lower at 8 333 hectares per year, due to the introduction of increasing quantities of vegetatively propagated material.

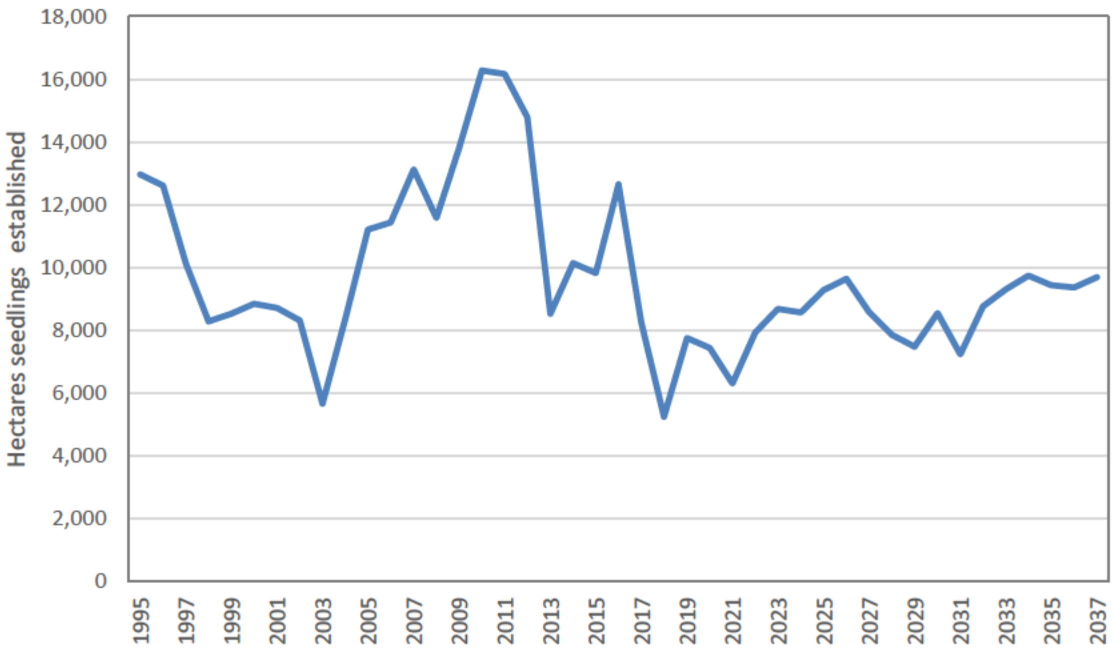

Figure 4.5. Hectares of seedlings established from Sappi's own improved seed sources 1995 to 2017 (forecast values given for 2018 to 2037). Source: Sappi Seed Technology.

Given a weighted average MAI for seedlings sown during the period under investigation of 16 wwt/ha/yr using improved seed, the amount of wood produced from seedlings at rotation age over the period 1995 to 2037 can be calculated as averaging 1.55 million tons per annum (Appendix A, Seedlings Planted).

The present value of this timber at rotation age (2017 Rands) averages R866 million per annum using a stumpage value of R558.39 (Table 4.5, stumpage value = 1000, rotation age = 10 years, real interest rate = 6%). Assuming that the average MAI of 16 was achieved with improved seed that yields 10% additional timber over unimproved seed, the average MAI with unimproved seed would have been 14.5. The average amount of timber that would have been produced with unimproved seedlings yielding an MAI of 14.5 would have been 1.4 million tons per annum, with a value of R784 million, a decrease of R82 million worth of timber a year.

4.2.4. Net present value of the Sappi seed orchard programme and cost - benefit analysis

The basis of net present value and cost – benefit analyses are a series of cash flows, in this case comparing the incurred costs in establishing and maintaining an orchard and deferring timber production versus the benefits of seed sales and gains in stumpage value. To allow comparison of the costs and benefits, all of these must be converted to a specific year by discounting or compounding, in this case to 1986, the start of the seed orchard programme (Appendix A, NPV Seed Orchard Programme).

When considering the costs of establishing and maintaining orchards, harvesting and processing seed and the cost of deferring timber production on land used for seed orchards against the income from seed sales, the net present value of the seed orchard programme is negative (-R 8.4 m, Cash Flow 2). The implication from this result is that while seed orchards generate significant income in the form of seed sales, at the prices which seed are being sold by Sappi, the seed income generated is not sufficient to cover the value of the deferred timber production, along with the expenses of creating and maintaining orchards.

The value addition from increased timber production however is significant (an additional R 31.7 m in the first year that timber derived from improved seedlings is harvested). When the benefit of increased timber is included in the net present value analysis, the project becomes strongly positive, at R 516 m with an interest rate of 6% (Cash Flow 3 – Appendix

A). The project remains NPV positive at interest rates as high as 10% (R 193 m) and 20% (R 33 m) and only reaches zero when the interest rate is 62.5% (IRR = 62.5%). At an interest rate of 6%, the BCR is 20. The payback period for the project is ten years – the first year that additional timber revenues are received.

4.2.5. Proposed new orchard

In the previous section it was shown that given the large areas established each year using improved seed and the impact of a ten percent increase in timber production, the benefit cost ratio for the seed orchard programme as a whole is overwhelmingly positive.

In this section the potential costs and benefits of a single proposed new orchard, designed to provide seed for a prescribed period will be calculated a priori. Sappi's current largest seedling species is *E. dunnii*. The average level of improvement of seed collected from the existing *E. dunnii* orchards is around 10% over unimproved seed sources. A new orchard could be created by grafting top selections offering improvement levels of 20% over unimproved.

The predicted average demand for *E. dunnii* seedlings is for 14 million seedlings every year for the next twenty years, sufficient seedlings to plant 7 000 ha annually. To supply this need, the orchard would need to be established on an area of around 6.5 hectares, at a planting density of 185 trees per hectare, giving 1 200 trees (Appendix A, Proposed new orchard). Seed would be collected after five years from planting, with initially only 10% of final seed production assumed, rising 10% per year up to full production capacity at 14 years after planting. The lifespan of the orchard is assumed to be 20 years, after which a cuttings programme is assumed to give superior yields, leading to orchard redundancy. The value of the proposed orchard is therefore potentially underestimated, as the orchard could conceivably yield seed for an additional 20 years.

Included in the analysis are establishment costs including grafting, annual maintenance costs, indirect costs of deferred timber production, benefits of seed sales, and increased timber production which is based on seed production, area planted, and realized genetic gain over the currently available seed source. Due to the envisioned intensely managed nature of this orchard and its high value, the costs of establishment and maintenance are set higher than the values used in the estimation of the NPV of the seed orchard programme as a whole.

Assuming a rotation of 10 years, and assigning a value of R500/ ton to wwt of timber (in this analysis, R500 / ton is used as this is the approximate difference in price at the mill between timber produced by own operations and timber purchased on the open market). Cash flow for the project is positive from year 8 (payback period is 8 years), and the net present value of the proposed new orchard is R175 m at an interest rate of 6%, decreasing to R 76 m at 10% interest. The benefit cost ratio is very high at 122 (6% interest).

The model shows that given the relatively limited input costs (grafting, planting and maintenance expenses, along with deferred timber production off a fairly small land area), the proposed new orchard returns a positive NPV, even given conservative estimates on seed production, and genetic gain. Based on this analysis, new orchards should be pursued, even if they offer only a limited increase in MAI (NPV remains positive, R 15.6 m, even when increased timber benefits are removed, based solely on seed sales). This is partly due to the fact that the proposed new orchard is assumed not to add to Seed Tech costs.

4.2.6. Net present value of improved nursery seed use efficiency

When seed is abundant and its value is low (as with wild seed), nursery practices that produce as little as five or fewer plantable seedlings for every ten viable seeds sown may be acceptable economically. However, as seed value increases and availability decreases, better (more expensive) nursery practices must be put in place to ensure greater seed use efficiency.

Sappi’s nurseries produce some 25 to 30 million seedlings per year, with an average seed cost of 14 cents, and spend around R 5 million a year on direct seed costs. A 10% increase in seed use efficiency (from the current 0.63 seedlings produced per viable seed used, to 0.69) would lead to a direct saving of R500 000.

Seed purchases represent one of the biggest expenses for Sappi nurseries. In 2017 Rands, seed purchases have averaged just over 5 million rand a year for the past ten years, representing approximately one third of nursery expenses over the period (Figure 4.6).

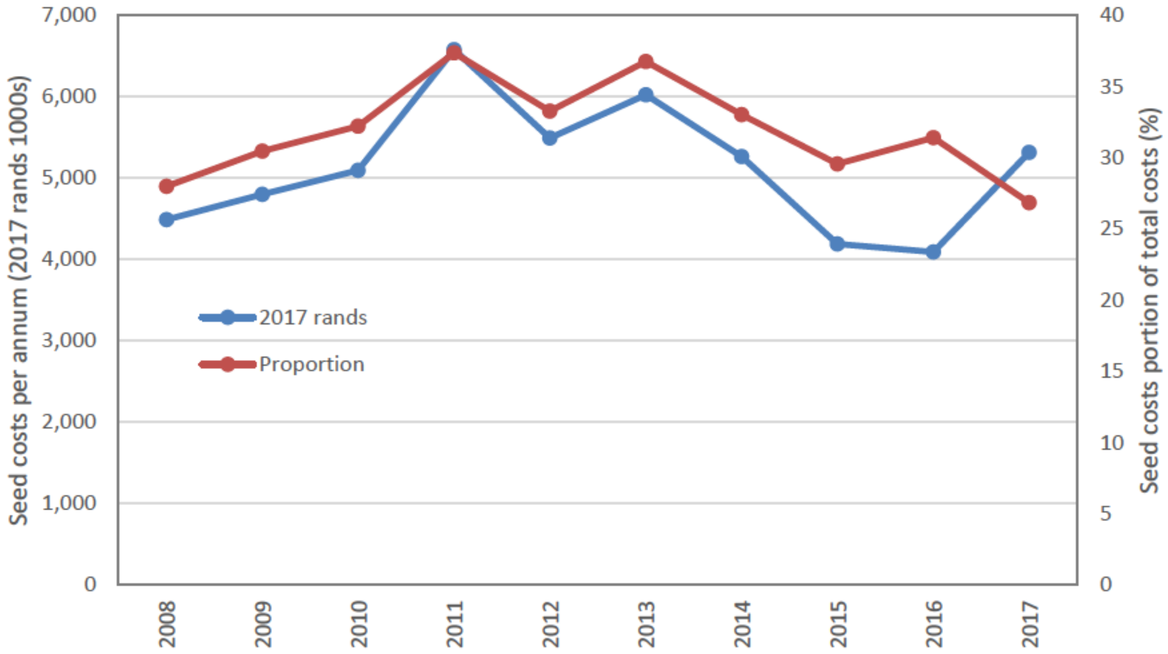

Figure 4.6. Sappi seedling nursery seed costs per annum (adjusted to 2017 Rands) and the proportion of nursery costs made up by seed costs.

However, the long term benefit of improved seed use efficiency comes mainly in the form of increased volume gains in plantations. For Sappi, every hectare of land reforested with seedlings of low genetic potential represents an opportunity cost. If improving seed use efficiency means that an additional number of hectares can be planted with more improved rather than less improved material, the net present value of future gains in volume can be calculated as the present value of timber produced per hectare multiplied by hectares under seedlings and the increase in volume gain (South, 1987).

The majority of seed produced in Sappi orchards has a level of improvement (FG) of around 10. Some seed with an FG below 10 is harvested, and relatively small quantities of seed with FG 15, 20 and 25 is collected. By improving seed use efficiency, the relatively small proportions of higher FG seed will both produce more plants, and will represent a larger proportion of the total plants produced. The higher the seed use efficiency (measured as KEF), the fewer the number of low FG seeds that will be needed (Appendix A, Seed Use NPV). In Figure 4.7 below, the impact of improving KEF on average FG is shown, given an annual requirement for 30 million seedlings from Sappi Nurseries (seedling capacity is close to 30 million). As KEF increases from 1 to 1.5 (seed use efficiency declines from 100% to 67%), Fibre Gain (growth volume improvement) decreases from 14.3 to 12.8. The annual value of increased timber production is R 8.4 million.

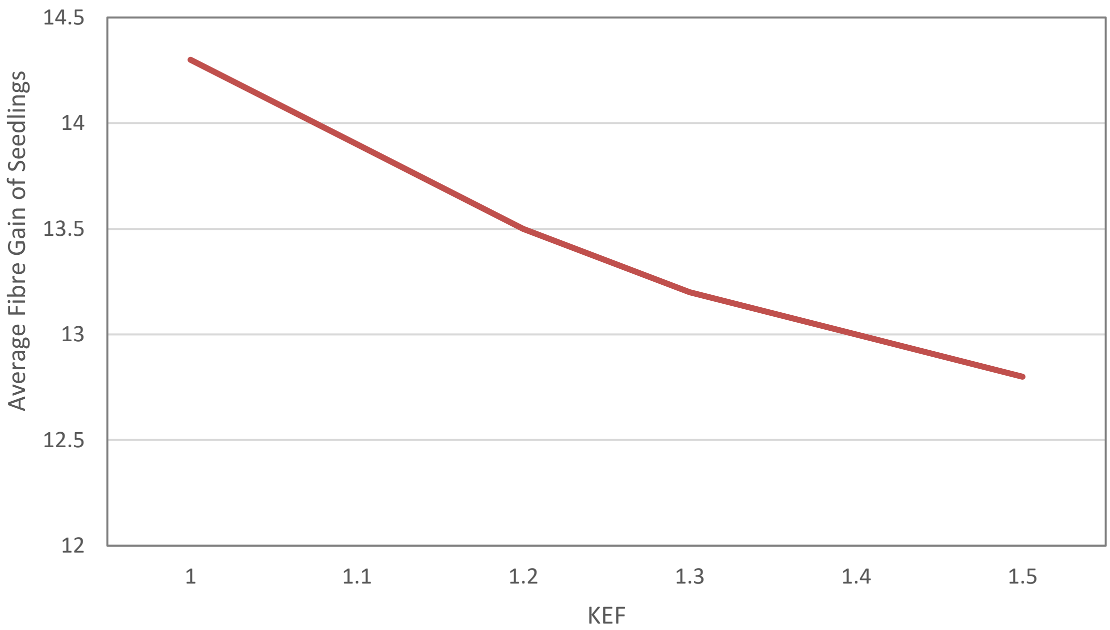

Figure 4.7. The impact of seed use efficiency (KEF) on timber yield (Fibre Gain).

A total of 30 million seedlings is sufficient to establish 15 000 hectares of seedlings at 2 000 seedlings per hectare. If Sappi's own seedling requirement is lower, at 8 500 hectares, as predicted for the next twenty years (some of Sappi Nursery grown seedlings are sold to private growers and out-growers), the impact of improved seed use efficiency is lower, at R 2 million.

4.3. Summary

Sappi's seed orchards were planted primarily in the early 1990s. They cover an area of 343.72 ha, and represent 25 different species. They generate direct annual costs of establishment (R 7 800 to R 16 900 / year), maintenance (around R 1000 / year) and overheads (R 3 m / annum) as well as indirect costs measured in terms of deferred timber production from the land they are sited on (R 19 m to R 40 m present value depending on calculation method.

Every year they generate income in direct seed sales (70 million viable seeds produced per annum, average income R 6.6 m), but also in increased timber production through the use of genetically improved seed (R 82 m in additional timber annually). Since inception, the Net Present Value of the seed orchard programme is estimated at over R0.5 bn, with a cost benefit ratio of 20.

Sappi's seedling nurseries currently have a seed use efficiency averaging 0.67 (KEF = 1.5, i.e. 1.5 viable seeds are used on average to produce one saleable seedling). An improvement in seed use efficiency from KEF 1.5 to KEF 1.2 (seed use efficiency from 67% to 83%) would save around 1 million rand a year in direct seed costs, but lead to increased income of R 2 to 8 million (depending on seedling numbers required) based on the more efficient use of scarce seed of the highest level of genetic improvement.

In the next chapter a discussion is made of these results, interpreting and explaining the results in the light of previous research on the topic conducted in other areas.

5. Chapter Five: Discussion

5.1. Introduction

This study aimed to identify and quantify the direct and indirect costs associated with seed production at Sappi and contrast this with the direct and indirect benefits of a seed orchard programme, including income from seed sales and increased timber production through the use of genetically improved seed. Based on the relative costs and benefits, has the seed orchard programme represented a good investment for Sappi? Should Sappi create new seed orchards given the gains in volume that are available from newer selections? What economic gains can be made in the nursery by improving seed use efficiency?

In this study various economic analyses were conducted for the existing seed orchard programme at Sappi, and for a proposed new orchard. The costs incurred and benefits gained from existing and proposed new orchards were compared to the likely outcomes available using unimproved seed from wild sources or less improved seed respectively.

5.2. Seed orchard costs

Sappi’s seed orchard programme was initiated in the late 1980s when information about seed production and future demand were less well known than they are now, and when many species that are no longer commercially grown were still economically important. The legacy of these no longer needed orchards mean that Sappi still carries large areas of orchards for species that are of little or no economic value in South Africa. Some of the costs of these orchards can be offset by selling their seed to nurseries outside of the country, but costs are greatly increased by their presence.

Despite the addition of costs for large areas of now underutilised seed orchards, the overall costs of establishing and maintaining seed orchards comprises a fairly small proportion of the total costs of the seed orchard programme. A large proportion of total costs are represented by the overheads of running the programme, including salaries, equipment, buildings and maintenance. Sappi has a large facility at its Shaw Research Centre dedicated to the extraction, cleaning, processing, testing and sale of seed, which is often underutilised due to the seasonal nature of seed production.

It is difficult to assign costs accurately to the seed orchard programme, as researchers and facilities at the programme are used for tasks other than purely commercial seed harvest and sale. These include such tasks as running the pine controlled pollination project, conducting seed research, and assisting in the programmes of Tree Breeding and Tree Biotechnology among others. In this study, a value of 60% was estimated for the proportion of the Seed Technology budget spent on commercial seed delivery.

A more defined answer can be found to the question of the indirect costs of the seed orchard programme in the form of deferred timber production. Although the Seed Technology programme does not directly pay for the use of Sappi Land, the loss of timber is a cost to the business as a whole. In the study by Wu et al (2015), they note that other studies may need to include costs associated with land ownership, unlike in their case, where the land used for seed orchard development was provided free of charge, and would not otherwise have been utilised. This is not the case at Sappi Forests, where managing down the temporary unplanted area (TUP) is a major focus of forestry operations.

In our study, the indirect costs of placing seed orchards on productive forestry land were calculated in two methods, first using land expected value (LEV) and then by calculating the lost income of four rotations of ten years each, forty years being the estimated duration of a seed orchards presence on the land base. LEV is regularly used when analysing forestry management options (Cubbage et al., 2014), and is an extension of the net present value approach into perpetuity. LEV set an upper limit of the present value of the land used for the seed orchard programme at R 40 m, but the NPV of four rotations was significantly lower at around R 19 m. The seed orchard programme can increase its value (decrease costs) by promptly removing orchards that are no longer necessary and returning the land to commercial timber production.

In all discussions of costs, it must be noted that the method used in this study was to consider the current costs of establishment and maintenance, and then to deescalate these using historical CPI or escalate them by a fixed assumed future inflation rate of 5%. This approach could be fairly inaccurate in both directions, as past technology and techniques were simpler than those in use today, and labour costs were significantly less meaning that previous costs have possibly been overstated in this analysis. Future costs of course may grow at a rate considerably faster than 5%, or even decrease if efficiencies are found utilising new technologies.

Other research has included the costs associated with breeding to their analyses of seed orchard development (Wu et al., 2015, Restrepo and Orrego, 2015, Wang et al., 2014). Such an analysis was beyond the scope of this study, particularly given that rather than focussing on a single orchard and species as in previous studies, this study looked at orchards spread over 25 species, that are at various levels of genetic improvement and which rest on varying years of breeding effort, by various role-players including the South African government (SAFRI) and industry collectives such as the ICFR. If an orchard were to be developed based on a specific research programme, then durations and costs would increase substantially. This could be the case if a seed orchard was desired for a wholly new species to be established.

5.3. Seed orchard benefits

Key to this study is the assumption of the level of genetic improvement achievable at rotation age using the orchard seedlot rather than an unimproved seedlot. Here, a value of 10 % was used, which is comparable to other studies, such as those by Ahtikoski (Ahtikoski, 2000, Ahtikoski et al., 2012, Ahtikoski and Pulkkinen, 2003) which showed 7% yield improvement using orchard seed. Wu et al showed improvement of between 5 and 10% gains using orchard seed, while a recent review cited that tree breeding has increased volume growth in the range of 10 to 20% (Jansson et al., 2017). While the conclusions drawn in this research are affected in degree by the percentage improvement assumed, they are not affected in direction. i.e. NPVs are still positive, even assuming much lower percentage volume increase.

In addition to the benefits of additional timber volume, there are many other benefits of improved material thanks to the breeding work that goes into making selections for new orchards that were not considered in this study. These benefits can include faster site capture, meaning lower silviculture costs, better pest and disease resistance, and superior nursery performance among others. Larger piece size in field from bigger trees also makes harvesting more efficient and increases utilisable volume. Increases in quality of timber can also result in higher prices at the mill. None of these harder to quantify benefits were included in our analysis.

The length of timber rotation is another key input in this study, where it has been assumed in most cases to be ten years. In reality this number will vary based on species, site, climate and timber requirements, as well as due to the impact of pests, diseases and disasters. One of the additional uncalculated benefits of faster volume growth through breeding is the possibility of reducing rotation length, which also decreases risk.

It was fortunate for this study that Sappi has accurate values for seed sale income. This is because although Sappi generates seed to provide its own nurseries, a decision was taken in the past that Nurseries would pay Seed Technology for the seed that they used, rather than simply transferring it internally without charging. South (1990) has pointed out the danger of providing seed internally free of charge, as it can lead to a careless approach to the use of the valuable seed resource.

This study has considered the benefit of the seed orchard programme primarily in terms of the additional volume growth offered by improved seedlings. It is assumed that if there was no seed orchard programme, unimproved ‘wild’ seed would be used instead. In reality, this wild seed might not be available. Collections of seed from, for example, Australia where *Eucalyptus* are native, are increasingly difficult to import into South Africa. The seed orchard programme, as well as providing improved seed, has had an added benefit of providing a constant and reliable seed source for Sappi Forests. If Sappi was dependent on the open market for seed supply, it is likely that there would be years where insufficient seed quantities were available for purchase. Most seed available would be improved to some degree, but costs would vary widely, making budgeting and planning difficult.

5.4. Cost benefit analysis of seed orchards

Previous studies on the economics of seed orchard development have shown that investment in the use of improved material produced in seed orchards in most cases results in better returns from plantation forestry, with benefits exceeding additional costs (O'Reilly, 2014, Ahtikoski et al., 2012). These benefits have been shown in some cases to be more costs effective than pursuing a vegetative propagation approach, which while it offers high levels of gain and uniformity, is much more expensive than a seedling approach (Lee and Watt, 2012).

The cost benefit ratios calculated in literature for projects of the type examined in this study have tended to vary widely, given that many of them are based on various assumptions, given the long term nature of tree improvement projects. Historical studies have shown BCRs that are greater than one only at certain, fairly low interest rates, and others that show gains of 2 – 5% would easily offset costs of producing genetically improved seeds, with others finding BCRs of more than 10%. The majority of studies show BCRs greater than 5 (Wu et al., 2015). As early as 1967, Davis opined that given the assumptions of the time that current investments in loblolly pine seed orchards fall well within the ballpark of financial justification, and time has proved him correct (Davis, 1967). All of these studies were performed on slow growing species in the Northern hemisphere with rotation lengths of 20 to 50 years, meaning returns in fast growing Southern hemisphere species are likely to be much higher.

Indeed, our study found that the seed orchard programme as a whole had a strongly positive net present value of over half a billion rand at an interest rate of 6% and remaining positive at a variety of interest rates, including 10% or 20%. At 6% interest rate, the internal rate of return was 62.5%. Our benefit cost ratio was 20 at an interest rate of 6%, significantly higher than those reported in literature. This can be expected given that costs tend to be lower in South Africa than those in mainly first world countries used in previous studies where land and labour are much more costly. Further, the benefits experienced in this study are received much earlier in the lifespan of the project given the shorter rotations in the Southern hemisphere using fast growing Eucalyptus trees.

The wide use of improved seed in reforestation (effectively all seedling plantings at Sappi since 1995) averaging almost 10 000 ha per annum is also responsible for part of the high BCR obtained. The more of the seed produced by the programme that is used in Sappi's own reforestation, the greater the returns, as the seed price supported by the market is not enough on its own to give the required returns. Sappi's vertical integration makes it possible for the seed orchard programme to be highly profitable.

Our results are in agreement with previous findings and show that in South Africa, even more so than in other countries, seed orchard development represents a valuable investment for forestry managers, even where volume gains are limited and interest rates are high. If assumed yield gain is decreased from 10% to a conservative 5% and interest rates increase from 6% to a much higher 15%, the project maintains a positive NPV of R 34 million.

The proposed new single *E. dunnii* orchard has a very high BCR of 122 at 6% interest. This is possible due to the fact that it is in effect an addition to the entire seed technology programme, and so adds significant benefit, at effectively no additional cost beyond establishment and maintenance. The cost that were incurred in identifying the superior new genotypes that would be grafted and put into production have already been covered by the Tree Breeding programme, and moving all of the top selections into a single orchard would actually lower Seed Technology costs, as it would require less travel to widely distributed orchards. The only risks with this approach are the possibility of losing the entire new orchard to a disaster such as a fire (hence high maintenance costs have been assigned to allow for additional fire preparation), or the risk that a new pest or disease makes the species redundant before the new seed is available for establishing plantations.

A key factor in determining net present values and BCRs is the chosen discount rate. The choice of an appropriate rate can be difficult to determine, and has a large effect on the outcomes of analyses (Griess et al., 2016). The higher the discount rate, the greater the impact of the early years of negative cash flow. In our study, the outcomes of the NPV are fairly resistant to changes in the discount rate, given that the project runs for many years, and returns positive cash flow from early on in the project. In this study, a rate of 6% has been used for most analyses, based on commonly used rates in South Africa (Forestry Economics Services, 2012), but the conclusions of the study remain unchanged even at much higher rates, including the highest rate of 12% seen in the literature for a similar study (Lopez et al., 2010).

Although risk evaluation is of great importance in forestry economics due to the long term nature of investments (Restrepo and Orrego, 2015), it was beyond the scope of this study to analyse the potential impact of fires, forced changes in species, climate change, future interest rate hikes, or commodity price changes. In South Africa political and legal risks can also affect forestry investments, such as in the case of land claims, arson and the threat of land expropriation without compensation. In general, investments in seed orchards can be seen as risk mitigating in the context of a forestry business as they offer fall back options and safety nets for when sudden changes in direction are necessary.

5.5. Seed use efficiency

The study also set out to examine the efficiency with which seed is used at Sappi seedling nurseries and calculate the increase in present value that can be obtained with increased seed use efficiency. Seed costs are a major component of Nursery budgets, representing a third of nursery costs. Given the high costs of seed, improvement in seed use efficiency can be justified simply by the decreased expenditure on seed itself, however, research by South (South, 1987, South, 1990) indicated the there are additional economic benefits that can be gained by increasing nursery seed use efficiency as the present value of improved seed often greatly exceeds the market value. South’s comments are supported by this study, which shows that seed sales alone are insufficient to cover the costs of the seed orchard programme, together with the costs of establishing and maintaining seed orchards.

Seed prices would need to increase by 16% to yield a positive net present value without considering the impact of improved timber yields.

The potential to improve timber yields by improving seed use efficiency in the nurseries is limited, however, by the small quantities of improved seed that are currently available. At present, the large majority of seed produced by the seed orchard programme is of a similar improvement level, and very little seed is highly improved. Of the seed harvested over the past eight years, 79% of it has an associated improvement level of 10 – 14%, with 13% of seed having a low improvement level of 5% and only 8% of seed harvested having a high level of improvement of 19% plus. The effect of this limited pool of highly improved seed is that even if seed use efficiency increases, it has a relatively limited impact, as the high value seed remains diluted by the much larger quantities of intermediate seed available. This situation could change in the future as additional effort is put into harvesting seed only from the best selections and creating new, more improved seed orchards.

Given the current distribution of seed improvement levels available, and the likely seedling demand for the next twenty years (8500 ha/yr), seed use efficiency increases will drive a fairly limited increased value of timber of around R 2 m per annum. This increase, however does represent twice as much as the direct savings in seed expenses. The value of increased timber is much higher when a wider planting area of 15 000 ha/yr is considered, rising to R 8 m. As with the benefits of greater timber volume, there are additional benefits to increased seed use efficiency that have not been considered in this study. These include decreased use of growing media in the nursery, fewer labourers required for consolidating seedlings, less water and fertiliser use, among others.

This study indicates that Sappi should seriously consider changes to nursery practices that increase seed use efficiency, even when those changes appear to be too expensive to pursue. This approach has been followed at Sappi's new Ngodwana nursery where a large germination room was installed at considerable cost in an effort to improve seed germination and hence seed use efficiency.

5.6. Summary

Similarly to previous research, this study finds that seed orchards represent a positive investment for forestry managers, as the direct and indirect benefits of planting improved seedlings outweigh the direct and indirect cost of establishing and maintaining orchards. This is true both on a wide scale, looking at entire programmes of seed orchard development, and on a smaller scale, looking at proposed new single orchards, where even a small increase in volume gain from improved seed can justify the production of new production capacity, provided the area destined for planting is large enough. The study has also shown that an increase in seed use efficiency in the nursery is valuable both for the direct savings in seed costs, but also for the resulting increase in timber yields, although those are constrained by the limited availability of the most improved seed. In the next and concluding chapter of this dissertation, the objectives of the study are held up against the findings, and implications of the research discussed, as well as recommendations made for future studies.

6. Chapter Six: Conclusions and recommendations

6.1. Introduction

This chapter concludes the study by describing the implications of the research, and providing recommendations for future studies.

6.2. Conclusion

Based on the findings of this study, it can be concluded that while establishing and running a seed orchard programme contributes significant costs to a business, in the form of deferred timber production and the direct costs of establishing and maintaining orchards and running a seed centre to harvest, process and test seed, the benefits of the programme, both in terms of direct seed sales and in increased timber production greatly outweigh the costs. In the South African environment where timber rotations are short, interest rates are around 6% and costs of land and labour are relatively low, a net present value for Sappi's seed orchard programme was estimated at over half a billion rand, with a BCR of 20. The study emphasises that new orchard development (which add little or no costs to fixed programme overheads) are a profitable investment, even where there is limited genetic gain, and relatively small areas of plantation. For a species like E. dunnii which has selections available with high genetic gain over current orchards, and which is widely planted, new orchard development is an imperative, with NPVs of over R 100 m possible.

6.3. Implications of this research

This study has shown that while the up-front costs of orchard development and the ongoing costs of maintenance and lost timber production potential are not insignificant, the benefits of a seed orchard programme including the direct income from seed sales and particularly the indirect benefit of additional timber production can far outweigh these costs, making genetically improved seed orchard development an attractive investment opportunity for forestry managers. New orchard development is strongly encouraged by the results of this study.

The findings relating to the increased net present value by improving seed use efficiency of scarce, highly improved seed resources, can be applied by giving a value which can be spent on nursery improvements to increase seed use efficiency – this is of particular interest to nursery managers, who must justify and control costs. This study suggests that spending R 2 m on improving seed use efficiency from KEF 1.5 to KEF 1.2 would be justified by a single year of increased net present value of timber production. The data generated in this study will be of interest to seed sellers in South Africa, as the benefits of sowing improved seed can be used to justify the cost of improved seed.

6.4. Limitations of this study

Forestry economics is a complex field with many variables that can greatly influence the final outcome of whether or not a project will have a positive net present value. In this study, certain variables were either disregarded, simplified, or assumptions made, given the scope of the project and the lack of data in certain areas. In the discussion section, mention is made of various costs that were not considered (such as breeding costs) and benefits that were ignored (such as the increase in utilisable volume from improved seedlings). These factors and others like them could have a large impact on the output of the analyses. The lack of actual values for Rands spent per orchard will also limit the accuracy of this study.

6.5. Recommendations to solve the research problem

The research problem set out at the beginning of this study was that while the majority of South African plantation forestry is established using seedlings grown from seed orchard derived seed, the economic feasibility of these orchards is based on little to no published data with regards to their costs, seed yields, and benefits, or the impact that seed use efficiency in the nursery can have on timber production in the plantations.

The data from this study adds to the body of research on this topic in a South African context. It can clearly be seen from these findings that given the assumptions made here the benefits of a seed orchard programme greatly exceed the costs.

Based on the results of this study, several direct recommendations can be made. New orchards should be urgently pursued where a species has selections available with genetic gain greater than selections in currently used orchards, particularly where large areas of plantation are planned for the species in question. Increasing seed yield and reducing duration to first significant seed harvest are both techniques that will increase the net present value of a new seed orchard project. The number of active seed orchards should be decreased where possible by returning old orchards that are no longer needed back to plantation forestry – this has a dual effect of lowering costs of seed orchard maintenance and decreasing indirect costs of deferred timber.

Finally, based on the results of this study, it can be seen that improvements in seed use efficiency in the nursery can be funded both by reduced direct seed costs, and by increased timber production. A project that improved seed use efficiency at the cost of a million Rand annually, through improved nursery methods, could be justified based on a positive net present value.

6.6. Recommendations for future studies

The current study is based on data available from Sappi Forests, only one of the major forestry companies in South Africa. Additional data on topics including seed production, seed orchard costs, and so on from other forestry companies including Mondi, Hans Merensky, Safcol, NCT and others would add robustness to the results.

Due to the limited scope of this study, not all potential factors were included in the analyses conducted, future research could add to the complexity of this study, bringing the recommendations closer to actual costs and benefits, as this study will necessarily have a fairly wide degree of potential error. More focused studies on individual species, with levels of improvement, seed production and seed production area for that species would be valuable, as would studies that incorporate the cost of genetic gain trials to identify new selections for advanced generation seed orchards.

This research has not considered costs for individual orchards in the seed orchard programme, some of which are highly productive, while others have never had seed harvested from them. These underutilised seed orchards are currently considered as an insurance policy against species changes in the future, but the costs and benefits of this approach, particularly as part of a risk management programme are not known.

There are a number of potential future focus areas that this study was not able to examine, these included specific recommendations for how to improve seed use efficiency, the cost benefits of seed orchard treatments that increase flowering and seed production, and the impact of orchard siting on seed production.

6.7. Summary

This study set out to accurately account for the costs that surround Sappi Forest's seed orchard programme. Establishment costs were estimated at R 10 000 / ha, while routine maintenance costs were calculated at R 1 000 per year. The indirect cost of lost timber production potential was estimated at between R 18 and 40 million depending on the method. Harvesting costs and the costs of running a seed centre, including pro rata costs of salaries were estimated as making up 60% of the Seed Technology programme and set at R 3 m per year.

Despite the high costs associated with the seed orchard programme, it was noted that direct income from the programme was as high as R 6 m per year in the form of seed sales, although this figure represents a small proportion of the total benefit, with the indirect benefits of increased timber production estimated at more than ten times this amount, or around R 60 m a year, taking into account various factors including mill delivered costs of timber, average MAI and length of timber rotations.

Based on the findings above, and examination of cash flows for the seed orchard programme over time, this study concludes that the seed orchard programme has a very positive impact on Sappi Forest's business, contributing half a billion rand in net present value since inception of the project.

While the future of forestry in South Africa is tending towards greater use of cuttings, seedlings will still represent a portion of new plantings for the foreseeable future, and as such the development of new orchards can still be economically viable, provided that new selections of improved genetic gain are available, and that there is a large enough demand for seed of that species. Before developing new orchards it is important to take into account what the predicted gain over existing seed sources is, what seed production is forecast, what seed use efficiency can be achieved, and what areas of the species are to be planted. Existing orchards have the benefit of already being sexually mature, and those orchards that are well sited and which produce large quantities of seed should be protected going forward.

A research question posed by this study was to determine the difference in the net present value of seed use efficiency increases which would make better use of scarce best available seed at Sappi's seedling nursery. It was found that increasing seed use efficiency will lead to savings both in direct seed costs and in the form of increased timber production worth between R 2 to 8 million a year depending on the level of seedling demand.

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8. Appendices

8.1. Appendix A: Excel spreadsheet of calculations

See digital copy Appendix A.xlsx

8.2. Appendix B: Ethical clearance certificate

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04 July 2018

Mr Owen Luke Solomon (211558256)
Graduate School of Business & Leadership
Westville Campus

Dear Mr Solomon,

Protocol reference number: HSS/0625/018M
Project Title: A cost benefit analysis of forestry seed orchard establishment in Sappi Forests, South Africa

Approval Notification – Expedited Application

In response to your application received 18 June 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

[redacted]

Professor Shenuka Singh (Chair)

/ms

Cc Supervisor: Professor Mabutho Sibanda
Cc Academic Leader Research: Professor Muhammad Hoque
Cc School Administrator: Ms Zarina Bullyraj

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8.3. Appendix C: Turnitin Summary Report

A cost benefit analysis of forestry seed orchard establishment in Sappi Forests, South Africa

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