THINNING COMPLIANCE AND ITS EFFECTS ON GROWTH, YIELD AND STEM QUALITY OF PINUS PATULA AT SAO HILL FOREST PLANTATION, MUFINDI DISTRICT, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN FORESTRY OF SOKOINE UNIVERSITY OF AGRICULTURE MOROGORO, TANZANIA.

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EXTENDED ABSTRACT

This study assessed the thinning compliance, effects of thinning on the growth, yield and stem quality of *Pinus patula* at Sao Hill Forest Plantation. Data were purposely collected from 285 circular plots of 0.03 ha (9.78 m radius) distributed randomly in 19 thinned compartments with the same site class and age. Fifteen plots were established in each purposely selected compartment where the adequacy of thinning for thinned compartments was determined by calculating the remaining number of stems per hectare and the deviation from scheduled values expressed in percentages. Thinning timing were obtained by deducting the age the compartment was supposed to be thinned as indicated in thinning schedule. One sampled t-test was used to compare if there were a significant difference between the number of remaining stems after thinning and those indicated in the thinning schedule. To assess the effect of thinning on growth, yield, and stem quality, three thinned and three unthinned compartments were purposely selected based on their compatibility in terms of site class and age. The height of three fattest trees, diameter at breast height (Dbh), and stem quality of all trees in a circular plot of 9.78 m were measured and recorded. An independent t-tests were used to test for significant difference between stand paramenters and Mann-Whitney U test were used to test stem quality between thinned and unthinned stands. A Mann-Whitney test was performed to assess if the stem quality of the thinned stands differs significantly from unthinned compartments. Thinned compartments were significantly overstocked and all compartment were not thinned on time as recommended in the thinning schedule. Thinning increased growth and yield of *Pinus patula*. Thinning improves stem quality by 9% resulting in trees having straight and good stem. Thinned stands have higher volume than unthinned stands. Therefore, this study recommended that pine plantations should be timely thinned as per used thinning schedule to ensure that more volume is attained.

DECLARATION

I, **Peter Christopher Nguyeje**, do hereby declare to the Senate of the Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor concurrently submitted to any other institution.

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DEDICATION

This work is dedicated to my beloved parents, Mr. Christopher Cornelio Nguyeje and Magdalena Bushiri Nguyeje, who wholeheartedly played a role in laying down the foundation for my education. Last but not least, I dedicate this work to my wife Vailet Aron Seth, and our children Joline, Joan, and Jovan Peter Nguyeje for their patience and understanding during my absence from home.

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LIST OF ABBREVIATIONS AND SYMBOLS

A.s.l	Above sea level
BA	Basal area (m^2)
Cm	Centimeter
Comp	Compartment
Dbh	Diameter at breast height (cm)
FAO	Food and Agriculture Organization of the United Nations
FBD	Forestry and Beekeeping Division
GDP	Gross Domestic Products
GVA	Gross Value Added
H	Height (m)
Ha	Hectare
Hdom	Dominant height (m)
M	Metre
MNRT	Ministry of Natural Resources and Tourism
MPM	Mufindi Paper Mills
N	Number of stems per hectare
No.	Number
SHFP	Sao Hill Forest Plantation
SNAL	Sokoine National Agricultural Library
SPH	Stems per hectare
SPM	Southern Paper Mills
TFS	Tanzania Forest Services Agency
TZS	Tanzanian Shillings
V	Volume per hectare (m^3/ha)

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

The total forest plantation area in Tanzania is 554,500 ha, of which 117,000 ha are managed by the Tanzania Forest Service Agency (TFS), and the rest are privately owned by individuals and companies (Malimbwi *et al*., 2016). The Sao Hill Forest Plantation (SHFP) is among 23 existing government forest plantations and was established in the 1950s to supply raw materials to Mgololo Southern Paper Mills (SPM) currently known as Mufindi Paper Mills (MPM), Sawmills and other wood-based industries. Another objective of the SHFP is to protect water catchment areas and prevent soil erosion, improve the local climate, and act as a buffer between local people and the natural forests (Ngaga, 2011).

Pinus patula is one of the most important plantation species in Eastern and Southern Africa planted mainly for timber production, paper manufacture, particle board, and wood-wool manufacture (Wormald, 1975). Other planted tree species in Tanzania include *P. elliottii, P. caribaea*, *Cupressus lusitanica*, *Eucalyptus sp* and *Tectona grandis*. *P. patula* is the most abundant with about 78% of the total area while the remaining 22% is shared among hardwoods and other softwood tree species (Ngaga, 2011). Its growth rate and yield vary considerably depend on site conditions as well as management techniques and the genetic quality of the planting stocks (Evans, 1996). Malimbwi (2016) showed that in Tanzania, plantation yield for Pines varied from 25 to 35 $m^3ha^{-1}year^{-1}$ during the first rotation for well thinned stands.

Forests are important in Tanzania due to the numerous goods and services they offer both to the national economy and society. The total Gross Value Added (GVA) by the forest sector was estimated to be approximately TZS 4.65 trillion which is equivalent to

3.3% of the total GDP contribution of the forest sector (MNRT, 2021). The estimation was based on several forest products in the forest sector which included charcoal, firewood, logs, poles, honey and beeswax, wild fruits, gums and resins, withies, seeds, and seedlings production (MNRT, 2021).

Thinning is defined as reducing the number of stems in a stand at any time between establishment and initiation of regeneration cutting or clear-felling (Chamshama and Malimbwi, 1999). Thinning is a silviculture tool to reduce competition among trees as trees grow with age. Thus, thinning results in greater availability of light, water and nutrients to the remaining trees. This contributes to accelerated diameter growth (Demers *et al.*, 2016 in Dangal and Das, 2018). The effect is more significant in younger stands where diameter at breast height (Dbh) increment is positively correlated with thinning intensity. However, based on diameter classes, thinning seems to promote the growth of large trees more strongly than that of small trees. This is because bigger trees are more capable of resources utilization in such a way that can take advantage of the increase in resource availability as a result of thinning and eventually to use these resources for growth (Kim *et al.*, 2016; Neumann and Hasenauer, 2021). For instance, the study done on *Pinus sylvestris L* over 12-year post-thinning period by Peltola *et al.* (2002) found out that the large trees (Dbh ≥10.5 cm) had the highest diameter growth in all the stand density classes while the medium-sized trees of 8–10.5 cm Dbh grew better in diameter than the small trees (Dbh 5.5–7.9 cm).

The stand basal area is directly related to stand volume as the gross volume increase with an increase in basal area (Malimbwi, 1997; Allen *et al.*, 2021). The effect of thinning on stand volume growth is strongly site dependent, but heavy thinning usually leads to a reduction in basal area and volume growth as compared with unthinned stand growing under similar site conditions (Skovsgaard, 2009). There is a general agreement that with increasing thinning intensity, there is an increasing shift of the dimension and volume from small and medium diameter classes into the higher diameter classes or right skewness (Radoglou and Raftoyannis, 2003).

Stem quality can be viewed in two ways: the external quality and internal quality. The study focused on external quality which includes dimensions like diameter and height, roundness, straightness of the stem, number and size of the branches (Kellomaki, 1980 in Mtakwa, 2014). Straightness is considered to be the most fundamental characteristic of stem quality across all the factors which help to determine the value of the product. Trees of greater diameter are considered to be of higher quality except for certain special uses such as pit props, poles and others. Apart from affecting the quantity of usable timber from a stand, thinning also affects the quality of tree. Removal of leaning, basal sweep or crooked stems trees reduces the amount of poor-quality wood remaining in the stand and the trees left to grow will have a higher percentage of utilization (Shepherd, 1986 in Gumadi, 2019). Stem quality is improved by thinning as poor-quality stems are removed during the operation (Piotto *et al., 2003;* Chamshama 2014).

It has been observed that thinning of softwood plantations in Tanzania among other plantations has been neglected resulting in lower standing volume being distributed into many small trees of poor form. However, little efforts have been made to show the effects of thinning on growth, yield and stem quality of unthinned compared to thinned trees in Tanzania. Gumadi (2019) and Zahabu *et al*. (2015) conducted research on the effects of thinning but they focused on different species such as *Tectona grandis* and different silviculture practice such as spacing.

1.2 Problem Statement and Study Justification

1.2.1 Problem statement

While the main sources of softwood raw materials in Tanzania are the industrial plantation forests, it has been observed that thinning of softwood plantations in Tanzania, among others has been neglected resulting in lower standing volume being distributed into many small trees rather than just a few with better form and size (Chamshama and Malimbwi, 1996). However, little efforts have been made to show the effects of thinning on growth, yield and stem quality of unthinned compared to thinned *Pinus patula* stands in Tanzania. Gumadi (2019) and Zahabu *et al*. (2015) conducted research on the effects of thinning but they focused on different species such as *Tectona grandis* and different silviculture practice such as spacing. This study aimed to fill the knowledge gap for *Pinus patula* grown at Sao Hill Forest Plantations.

1.2.2 Study justification

This study emphasized the importance of thinning *Pinus patula* at Sao Hill Forest Plantation because the species is dominant and generates more revenue than other species. The results can be useful to different stakeholders involving in *Pinus patula* management for sawntimber production.

1.3 Objectives

1.3.1 Main Objective

Assessment of thinning compliance and its effects on the growth, yield and stem quality of *Pinus patula* at Sao Hill Forest Plantation, Mufindi District, Tanzania.

1.3.2 Specific Objectives

The study specifically focused on the following objectives:

i. To assess compliance of *P. patula* thinning schedule at Sao Hill Forest Plantation;

ii. To assess the effects of thinning on the growth and yield of *P. patula* at Sao Hill Forest Plantation; and

iii. To assess the effects of thinning on stem quality of *P. patula* at Sao Hill Forest Plantation.

1.4 Dissertation Structure

The dissertation is developed in the format of publishable manuscripts comprising four main chapters. Chapter one consists of the introduction, which provides background information on the study, problem statement and justification together with study objectives. Chapter two is the first manuscript explaining the thinning compliance on *Pinus patula* at Sao Hill Forest Plantation, Mufindi District, Tanzania. Chapter three is the second manuscript which is about the effects of thinning on the growth, yield and stem quality of *Pinus patula* at Sao Hill Forest Plantation, Mufindi District, Tanzania. Chapter four summarizes the general conclusions and recommendations for this study.

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CHAPTER TWO

MANUSCRIPT ONE

2.0 THE THINNING COMPLIANCE ON PINUS PATULA AT SAO HILL FOREST PLANTATION, MUFINDI DISTRICT, TANZANIA

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Abstract

This study assessed the thinning compliance of *Pinus patula* at Sao Hill Forest Plantations. Data were purposely collected from 285 circular plots of 0.03 ha (9.78 m radius) distributed randomly in nineteen thinned compartments with the same site, age class and well thinned. Fifteen plots were established in each purposely selected compartment. Adequacy of thinning for thinned compartments was determined by calculating the remaining number of stems per hectare and the deviation from scheduled values expressed in percentages. Thinning timing was obtained by deducting the age the compartments were supposed to be thinned as indicated in thinning schedule from the actual thinning age using the information from Plantation Conservator and compartment register to determine whether the thinning was timely, earlier or delayed. One sample t-test was used to test whether stand density after thinning differs significantly from the scheduled density. The results show that all the thinned compartments surveyed were overstocked with stocking deviation ranging from 17% to 125%. A test statistic showed that the number of stems remaining after thinning was significantly high in the thinned compartments than the suggested in the thinning schedule for first and second thinning (p-value = 0.000 for all stands in the first and second thinning). It was revealed that about 68% of compartments were thinned earlier than the recommended time, 32% of compartments were delayed and there were no compartments thinned on time as recommended by thinning schedule. The study recommended all plantations should be thinned according to the government thinning schedule to attain desirable stand productivity.

Keywords: *Pinus patula*; Thinning; Thinned stand; Thinning adequacy: Thinning timing

2.1 Introduction

Thinning is defined as reducing the number of stems in a stand at any time between establishment and initiation of regeneration cutting or clear-felling. The net effect of thinning is the manipulation of tree growing space (Chamshama and Malimbwi, 1996). Thinning intensity is an important factor affecting forest density and influencing tree growth and yield depending on thinning schedule prescription. Thinning operations reduce stand density and modify its structure, consequently influencing subsequent medium and long-term stand development (Gadow and Hui, 1998). According to Niccoli *et al*. (2020), a very high selective thinning result is the most appropriate management practice, as it guarantees positive effects both in terms of growth and intrinsic water use efficiency. A study conducted by Saarinen *et al*. (2020) showed that intensive thinning resulted in more stem volume and therefore total biomass allocation and Carbon uptake compared to moderate thinning. Thus, thinning intensity, type, and the following growth effects have an impact on the post-thinning stem shape and size of Scots pine trees.

Thinning interval specifies the interval between successive thinning operations. The intervals between thinnings are either specified in terms of height growth or age. A height growth interval of 2 m is recommended (Hummel, 1954 in Chamshama, 2004). Many landowners plant Pines to harvest them within 15 to 20 years if markets and prices are favorable. However, when the Pine markets are down, longer rotations can bring higher financial returns on larger diameter trees if the landowners are willing to thin their stands when trees are 10 to 15 years old (Demers *et al*., 2007). Another thinning should be considered some years later before the trees become crowded again and the growth rate starts to slow down. First thinning is also an opportunity to remove vigorous, coarsely branched, or multiple-leader trees before they dominate too much and irreparably harm stand quality (Chamshama, 2004).

Varmola and Salminen (2004) revealed that, early thinning resulted in highest standing volume and amount of merchantable wood, and also in slightly accelerated height development. Punches (2004) in Dangal and Das (2018) found little effect on diameter increase in first thinning which was conducted around 10–11 years possibly due to very light mechanical thinning (10% of stems).

Technical Order No. 1 of 2003 (FBD, 2003) prescribes 2 thinnings for *Pinus patula* at 10 and 15 years with initial, first thinning and final stocking of 1111, 650 and 400 SPH respectively with the spacing of 3 m x 3 m and a rotation age between 25 and 30 years. The thinning schedule for a given species indicates ages and the number of stems to remove and retain as well as rotation age. The intensity of the thinning and the time since thinning, along with the inherent site quality, will determine the magnitude and duration of the thinning response (Zhang *et al*., 1997).

Most reports have found thinning schedules to be improperly carried out in many public plantations than in private sector plantations. Angyelile (2010) and Kiangi (2010) in Ngaga (2011) found no thinning was carried out at Sao Hill and Ukaguru plantations. The main reasons given for the neglect of thinnings were a shortage of funds, lack of markets for unsawn thinnings, lack of plantation management skills and experience, traditional attitude by foresters against waste and lack of processing plants (Chamshama, 2011 and Ngaga, 2011 in Gumadi, 2019). This study aimed to fill the knowledge gap for *Pinus patula* grown at Sao Hill Forest plantations. The results of this study will be used by Tanzania Forest Services Agency (TFS) and other stakeholders involved with *Pinus patula* management for sawntimber production.

2.2 Methodology

2.2.1 Study Area Description

This study was conducted at Sao Hill Forest Plantation. The plantation is found in the Mufindi District, Iringa within the Southern Highlands of Tanzania (Figure 1.2). Sao Hill Forest Plantation extends in several Divisions and Wards of Mufindi and it lies between 8°15’ – 8°41' S and 35°6'– 35°45' E. The altitudes range from 1400 m a.s.l to 2000 m a.s.l. The rainy season in Mufindi District starts from November to June with peak rainfall occurring in February and March. The area receives mean annual rainfall ranging from 750 to 2010 mm and temperature ranging from 15^0C to 25^0C per annum (Mgeni and Price, 1993; Ngaga, 2011). The plantation covers a total area of about 45,000 ha. The soil is moderately acidic, well-drained and of various types mainly dystric nitrosols in association with orthic acrisols (Ngaga, 2011). The natural vegetation adjacent to most of the compartments is the poorly stocked miombo woodland constituting grasslands with scattered trees and shrubs such as *Brachystegia spiciformis*, *Julbenadia globiflora*, *Dombeya rotundifolia*, *Erythrina caffra* and *Albizia antunesiana* (Mhando *et al*., 1993). The plantation is divided into Divisions I, II, III and IV which are under the management of Sao Hill Forest Plantation Headquarter. This study was conducted in Division II.

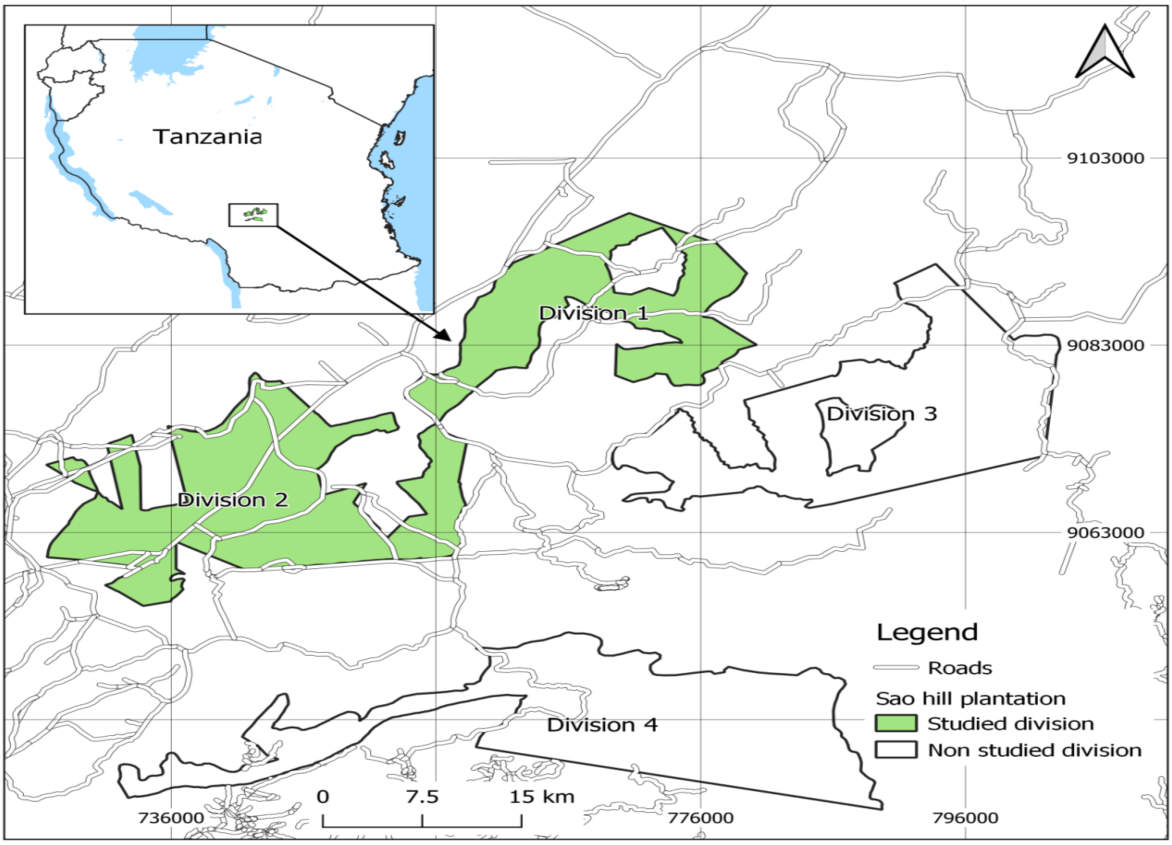

Figure 1.2: Map showing the location of Division I and Division II at Sao Hill Forest plantation

2.2.2 Study Design

The compartments information such as age, size, location, species planted, and the thinning status were obtained from the compartment register (Appendix 1). To assess the thinning compliance on *Pinus patula*, the compartments identified during the reconnaissance survey were purposely selected based on age and thinning performed. A total of 19 thinned compartments (3 first thinned and 16 second thinned) were selected and used for data collection (Table 1.2). In each compartment, 15 circular plots of 0.03 ha (9.78 m radius) were systematically established and used to count the number of stems that remained. The interval of 100 m from plot to plot and 100 m from transect to transect was used. In transect laying-out, the first transect was laid at half transect distance from the compartment border, this was also the case for the first plot.

Table 1.2: Compartments selected and used to assess thinning compliance to *P. patula* thinning schedule at Sao Hill Forest Plantation

SN.	Compartments Name/Number	Age	Site Index	Thinning status	Number of Plots
1	ID5B1_1	12	I	1st thinning	15
2	ID5B1_2	13	I	1st thinning	15
3	2/MT1/12	14	II	1st thinning	15
4	2/S16b/19	17	II	2nd thinning	15
5	2/S16b/20	17	III	2nd thinning	15
6	2/S16b/7	17	II	2nd thinning	15
7	2/S16b/6	17	II	2nd thinning	15
8	2/S16b/9	17	I	2nd thinning	15
9	2/S16b/8	17	I	2nd thinning	15
10	2/S16b/1a	18	III	2nd thinning	15
11	2/S16c/31	18	III	2nd thinning	15
12	2/S16b/4	18	III	2nd thinning	15
13	2/S16b/5	18	III	2nd thinning	15
14	2/S16b/10	18	II	2nd thinning	15
15	2/S16b/12	18	II	2nd thinning	15
16	2/KB2/26.2	19	II	2nd thinning	15
17	2/S16a/34	19	III	2nd thinning	15
18	2/S16b/32	19	II	2nd thinning	15
19	2/S16b/34	19	III	2nd thinning	15

2.2.3 Data Collection

To assess thinning compliance to *Pinus patula* thinning schedule, all the trees inside the radius of the established plot were counted and recorded.

2.2.4 Data Analysis

The number of stems per hectare that remained after thinning was obtained by dividing the number of stems in a plot by a plot area. Adequacy of thinning for thinned compartments was determined by calculating the remaining number of stems per hectare and the deviation from scheduled values expressed in percentages. Thinning timing was obtained by deducting the age the compartment was supposed to be thinned as indicated in thinning schedule from the actual thinning age using the information from the plantation conservator and compartment register to determine whether the thinning was timely, earlier or delayed. One sample t-test was used to test whether each compartment density after thinning differs significantly from the scheduled density in thinning schedule.

2.3 Results

2.3.1 Thinning Adequacy

The results show that all the thinned compartments surveyed were overstocked with stocking deviation ranging from 17% to 125% as shown in Appendix 3. The mean number of stems per hectare that remained after the first thinning was 1067 with a mean deviation of 40% while the second thinning had a mean number of stems per hectare of 685 remained with a mean deviation of 39% (Appendix 3). A test statistic showed that the number of stems that remained after thinning was significantly high (Figure 2.2) in the thinned compartments than suggested in the thinning schedule for first and second thinning with the p-value of 0.000 for every thinned compartment as indicated in Table 2.2.

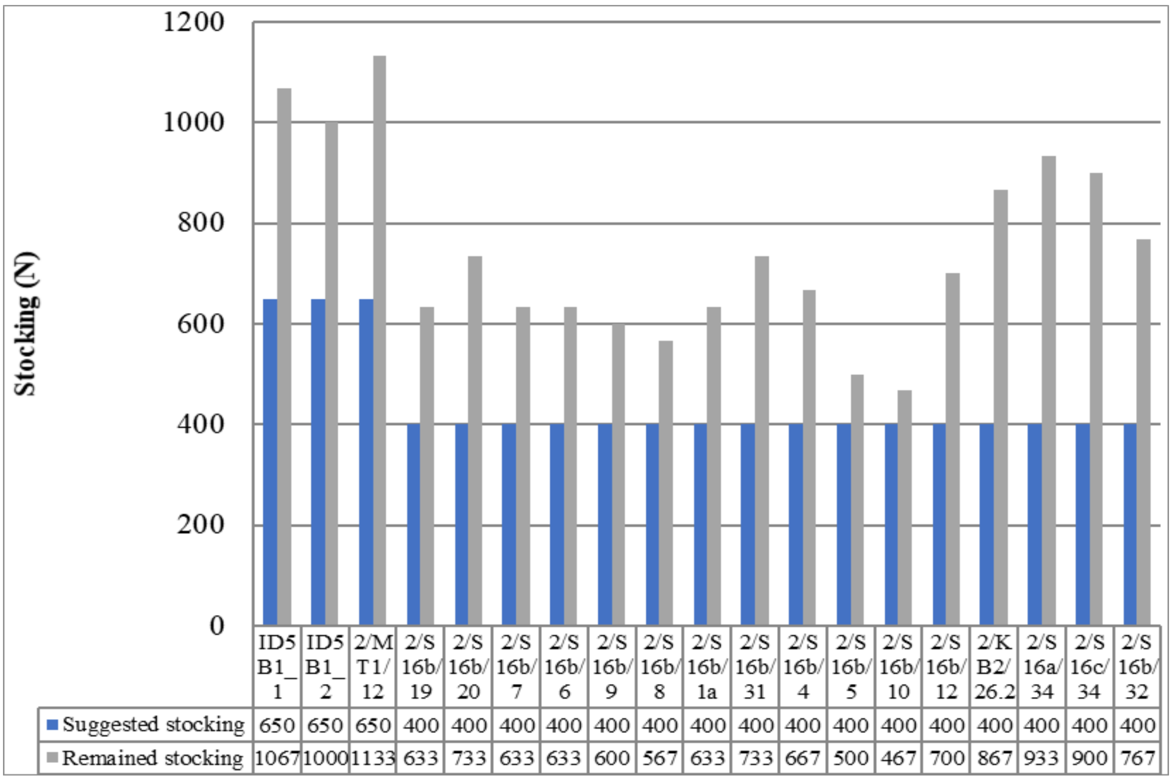

Figure 2.2: Number of stems per ha in thinned compartments against thinning schedule

2.3.2 Thinning timing

The results for thinned compartments revealed that about 68% were thinned earlier than the recommended time, and 32% of compartments were delayed as recommended by thinning schedule (Table 2.2). Results show that, in the first thinning operation, 67% of compartments were found to be delayed for 1 year and 33% were thinned late for two years. In the second thinning, 6% of thinned compartments were delayed for 1 year and 13% were delayed for two years while 81% were early thinned between 1 and 5 years.

Table 2.2: The difference between actual and scheduled time of performing thinning at operations at Sao Hill Forest Plantation

Compartment	Planting year	Compt. Age (years)	Actual stocking/ha (N/ha)	Actual thinning year	Scheduled thinning year	Thinning timing (years)	p-value
First thinning							
ID5B1_1	2009	12	1067	2020	2019	-1	0.000
ID5B1_2	2008	13	1000	2019	2018	-1	0.000
2/MT1/12	2007	14	1133	2019	2017	-2	0.000
Second thinning							
2/S16b/19	2004	17	633	2018	2019	1	0.000
2/S16b/20	2004	17	733	2014	2019	5	0.000
2/S16b/7	2004	17	633	2017	2019	2	0.000
2/S16b/6	2004	17	633	2017	2019	2	0.000
2/S16b/9	2004	17	600	2016	2019	3	0.000
2/S16b/8	2004	17	567	2016	2019	3	0.000
2/S16b/1a	2003	18	633	2015	2018	3	0.000
2/S16b/31	2003	18	733	2016	2018	2	0.000
2/S16b/4	2003	18	667	2017	2018	1	0.000
2/S16b/5	2003	18	500	2017	2018	1	0.000
2/S16b/10	2003	18	467	2016	2018	2	0.000
2/S16b/12	2003	18	700	2016	2018	2	0.000
2/KB2/26.2	2002	19	867	2019	2017	-2	0.000
2/S16a/34	2002	19	933	2019	2017	-2	0.000
2/S16c/34	2002	19	900	2018	2017	-1	0.000
2/S16b/32	2002	19	767	2016	2017	1	0.000

NB: Negative sign (-) in thinning timing indicates thinning delay and positive indicates early thinning.

2.4 Discussion

The overstocking trend of compartments from this study was observed due to inadequate thinning which limit trees to utilize the area for growth. The findings from this study differ from that of Akyoo (2017) who found an average stocking of 479 stems per hectare at Sao Hill Forest Plantation for thinned *Pinus patula* stands at an age of 15. The difference from the current study may be due to age, site class differences and fail to comply with the thinning schedule where by few trees were removed.

Nilsson (2010) reported that delaying the first thinning did not affect gross stem volume production for either Scots pine or Norway spruce. Gumadi (2019) reported delays in the first thinning for one and two years by 20% and 80% respectively on Teak plantations. The main reason for the delay in thinning at Sao Hill Forest plantation was due to the limited budget to conduct thinning in compartments that were ready for thinning and the limited market for thinning products for first thinning (Lupala, I. personal communication, 2021). Munishi and Chamshama (1994) revealed that the operations including thinning in many public plantations in Tanzania do not follow the prescribed schedules. This is in agreement with the results of this study and may be due to the lack of priority in planning and the shortage of funds to conduct thinning operations in compartments that are due for thinning.

2.5 Conclusion and recommendations

2.5.1 Conclusion

The study showed that the thinning operations were not conducted on time and compartments were overstocked as a result of not complying with thinning schedule.

2.5.2 Recommendation

The study recommends a close follow-up on the implementation and proper practices of Technical Order No. 1 of 2003 (currently Technical Order No. 1 of 2021) concerning thinning schedules. During each thinning, training and closer supervision should be given to field workers.

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CHAPTER THREE

MANUSCRIPT TWO

3.0 EFFECTS OF THINNING ON GROWTH, YIELD AND STEM QUALITY OF PINUS PATULA AT SAO HILL FOREST PLANTATION, MUFINDI DISTRICT, TANZANIA

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Abstract

Pinus patula is one of the most important plantation species grown in Eastern and Southern Africa. Its growth rate and yield vary considerably depending on site conditions, management techniques and genetic quality of the trees. It has been suspected that thinning of softwood plantations in Tanzania has been neglected resulting in lower standing volume being distributed into many small trees of poor form. This study assessed the effects of thinning on growth, yield and stem quality of *Pinus patula* at Sao Hill Forest Plantation located in Southern Highland part of Tanzania. In a systematically established plots; diameter of all trees, a total height of three trees and stem quality of four classes were recorded. An independent t-test was used to test for significant difference in stand parameters and Mann-Whitney U test was used to test stem quality between thinned and unthinned stand. Results showed that thinning significantly increased growth and yield of *Pinus patula*. Thinning improves stem quality by 9% resulting in trees having straight and good stem form. Thinned stands yielded higher volume than unthinned stands. Therefore, this study recommends that pine plantations should be timely thinned as per used thinning schedule to ensure that more volume is attained.

Keywords: Sao Hill Forest Plantation; *Pinus patula*; Thinned stand; Unthinned stand; Stem quality;

3.1 Introduction

Thinning is defined as reducing the number of stems in a stand at any time between establishment and initiation of regeneration cutting or clear-felling (Chamshama and Malimbwi, 1996). Thus, thinning results in greater availability of light, water and nutrients to the remaining trees. This contributes to accelerated diameter growth (Demers *et al.*, 2016 in Dangal and Das, 2018). The effect is more significant in younger stands where diameter at breast height (Dbh) is positively correlated with thinning intensity. However, based on diameter classes, thinning seems to promote the growth of large trees more strongly than that of small trees. This is because bigger trees are more capable of resources utilization in such a way that can take advantage of the increase in resource availability as a result of thinning and eventually to use these resources for growth (Kim *et al.*, 2016; Neumann and Hasenauer, 2021). For instance, the study done on *Pinus sylvestris L* over 12-year post-thinning period by Peltola *et al.* (2002) found out that the large trees (Dbh ≥10.5 cm) had the highest diameter growth in all the stand density classes while the medium-sized trees of 8–10.5 cm Dbh grew better in diameter than the small trees (Dbh 5.5–7.9 cm).

The stand basal area is directly related to stand volume as the gross volume increase with an increase in basal area (Malimbwi, 1997; Allen *et al.*, 2021). The effect of thinning on stand volume growth is strongly site dependent, but heavy thinning usually leads to a reduction in basal area and volume growth as compared with unthinned stand growing under similar site conditions (Skovsgaard, 2009). There is a general agreement that with increasing thinning intensity, there is an increasing shift of the dimension and volume from small and medium diameter classes into the higher diameter classes or right skewness (Radoglou and Raftoyannis, 2003).

Stem quality can be viewed in two ways: the external quality and internal quality. The study focused on external quality which includes dimensions like diameter and height, roundness, straightness of the stem, number and size of the branches (Kellomaki, 1980 in Mtakwa, 2014). Straightness is considered to be the most fundamental characteristic of stem quality across all the factors which help to determine the value of the product. Trees of greater diameter are considered to be of higher quality except for certain special uses such as pit props, poles and others. Apart from affecting the quantity of usable timber from a stand, thinning also affects the quality of tree. Removal of leaning, basal sweep or crooked stems trees reduces the amount of poor-quality wood remaining in the stand and the trees left to grow will have a higher percentage of utilization (Shepherd, 1986 in Gumadi, 2019). Stem quality is improved by thinning as poor-quality stems are removed during the operation (Piotto *et al., 2003;* Chamshama, 2014).

It has been observed that thinning of softwood plantations in Tanzania among other plantations has been neglected resulting in lower standing volume being distributed into many small trees of poor form. However, little efforts have been made to show the effects of thinning on growth, yield and stem quality of unthinned compared to thinned trees in Tanzania. Gumadi (2019) and Malimbwi *et al*. (1992) conducted research on the effects of thinning but they focused on different species such as *Tectona grandis* and different silviculture practice such as spacing. Therefore, aims of this study were to assess the effects of thinning on stand growth, yield and stem quality for *Pinus patula* grown at Sao Hill Forest Plantation. This study focused on *Pinus patula* because the species is dominant at Sao Hill Forest Plantation and generate more revenue compared to other species. The results of this study can be useful to different stakeholders involving in *Pinus patula* management for sawntimber production.

3.2 Methodology

3.2.1 Description of Study Area

This study was conducted at Sao Hill Forest Plantation. It is found in Southern highlands of Tanzania at Mufindi District (Figure 3.3). The plantation extends in several Divisions and Wards of Mufindi District and it lies between 8°15’ – 8°41’ S and 35°6’– 35°45’ E. The altitudes range from 1400 m a.s.l to 2000 m a.s.l. The rainy season at Mufindi District starts from November to June with peak rainfall occurring in February and March. The area receives mean annual rainfall ranging from 750 to 2010 mm and temperature ranging from 150C to 250C per annum (Mgeni and Price, 1993; Ngaga, 2011). The plantation covers a total area of about 45,000 ha. The soil is moderately acidic, well drained and of various types mainly dystric nitrosols in association with orthic acrisols (Ngaga, 2011). The natural vegetation adjacent to most of the compartments is the poorly stocked Miombo woodland constituting grasslands with scattered trees and shrubs such as *Brachystegia spiciformis*, *Julbemadia globiflora*, *Dombeya rotundifolia*, *Erythrina caffra* and *Albizia antunesiana* (Mhando *et al*., 1993).

The plantation is divided into four Divisions which are under management of Sao Hill Forest. Data for this study was collected on Division II which has a total land area of 11,169.8 ha and the total planted area is 10,239.18 ha. It is further divided into five Ranges namely: Sao Hill, Matanana, Nyololo, Kibidula/Mkewe and Makalala. The Division is bordered by a section of the famous little Ruaha river to the East beyond which is Division I; Nyololo and Nzivi villages on the South East; Kisada village on the South – West; and Kibidula Seventh Day Adventist Mission, Matanana, Mtula and Sao Hill villages on the West. The old Great North Road forms the plantation boundary on the North - West and to the North the Division is bordered by Mafinga National Service camp and Makalala Mission. The natural vegetation in the Division was originally typical montane open grasslands with occasional patches of Miombo clusters and riverine trees in the valleys. Sao Hill Forest Plantation was taken for study because they had compartments that met age and site class requirements for sampling.

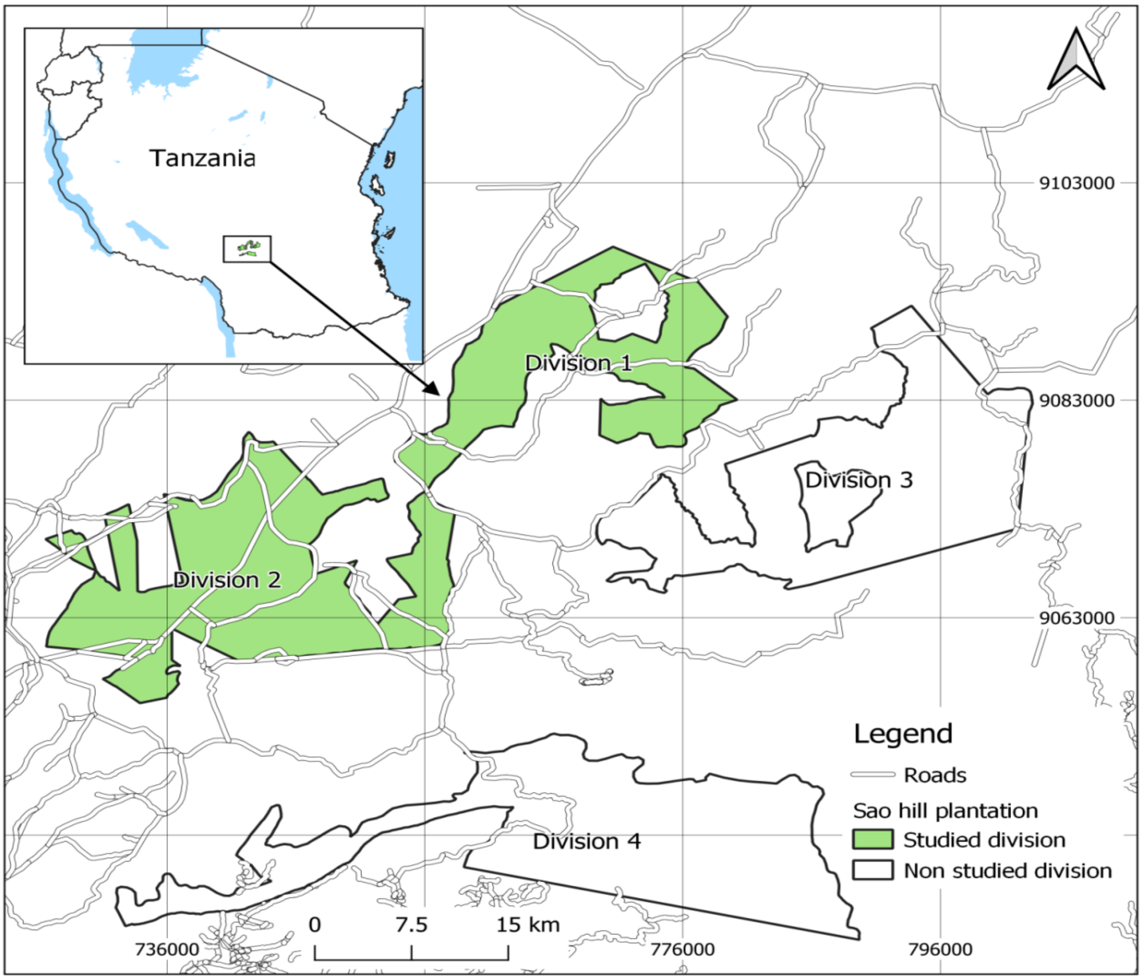

Figure 3.3: Map showing the location of Division I and II at Sao Hill Forest Plantation (Source: Author)

The plantation is divided into four Divisions which are under the management of Sao Hill Forest Plantation Headquarter. Division I have a total area of 17,140.13 ha and the total planted area is 12,829.00 ha. The Division is further divided into six ranges namely Gulusilo, Irundi, Mninga, Msiwasi, Nzivi, and Ruaha to ensure perfect execution and close follow-up on all the management activities. The predominant vegetation is grassland with trees widely scattered singly and in clumps. These clumps are found mainly around bushes, anthills, and valleys. The main species include Erythrina, Parinari, Cussonia, Apodytes, and Albizia. There are small patches of Brachystegia woodland.

Division II has a total land area of 11,169.8 ha and the total planted area is 10,239.18 ha. It is further divided into five Ranges namely: Sao Hill, Matanana, Nyololo, Kibidula/Mkewe and Makalala. The Division is bordered by a section of the famous little Ruaha river to the East beyond which is Division I; Nyololo and Nzivi villages on the South East; Kisada village on the South – West; and Kibidula Seventh Day Adventist Mission, Matanana, Mtula and Sao Hill villages on the West. The old Great North Road forms the plantation boundary on the North-West and to the North, the Division is bordered by Mafinga National Service camp and Makalala Mission. The natural vegetation in the Division was originally typical montane open grasslands with occasional patches of Miombo clusters and riverine trees in the valleys. The remaining patches of Miombo woodlands contain *Brachystegia spp* and *Julbernadia spp* that are bordered by bushes with species like *Syzygium spp, Parinari excelsa, P. Cussionia* and *P. spicata.*

3.2.2 Sampling procedures

3.2.2.1 Reconnaissance Survey

To be able to select the appropriate compartment for sampling, a reconnaissance survey was carried out in 16 unthinned and 26 thinned compartments (Appendix 2). The compartments information such as age, size, location, and species planted and the thinning status were obtained from the compartment register (Appendix 1). This was to ensure a fair comparison of compartments with similar site and age classes. In each compartment, seven plots with an area of 0.03 ha and 9.78 m radius delivered from plot area (Malimbwi *et al.*, 2016) each plot were laid out with a random start of the first plot at 50 m from a compartment boundary to avoid edge effects. In each plot, the height of the three largest trees in terms of diameter were measured.

Table 3.3: The age class distribution of visited compartments during reconnaissance survey

Age class (Years)	Division		Thinning status	
	I	II	Thinned	Unthinned
12 - 15	10	4	5	9
16 - 20	0	28	21	7
> 20	0	0	0	0
Total	**10**	**32**	**26**	**16**

3.2.2.2 Site Class Determination

The dominant height data collected during the reconnaissance campaign were used to identify the site classes of the visited compartments. According to Malimbwi *et al.* (2016), there are four site classes at Sao Hill Forest Plantation namely I, II, III and IV (Figure 4.3) which vary depending on their dominant height (Hdom) and age. Productivity range in site classes from highest (site class I) to lowest (site class IV). The collected Hdom – Age data were compared to the site indices curves generated by Malimbwi *et al*. (2016) whereby the corresponding site class of that compartment was identified.

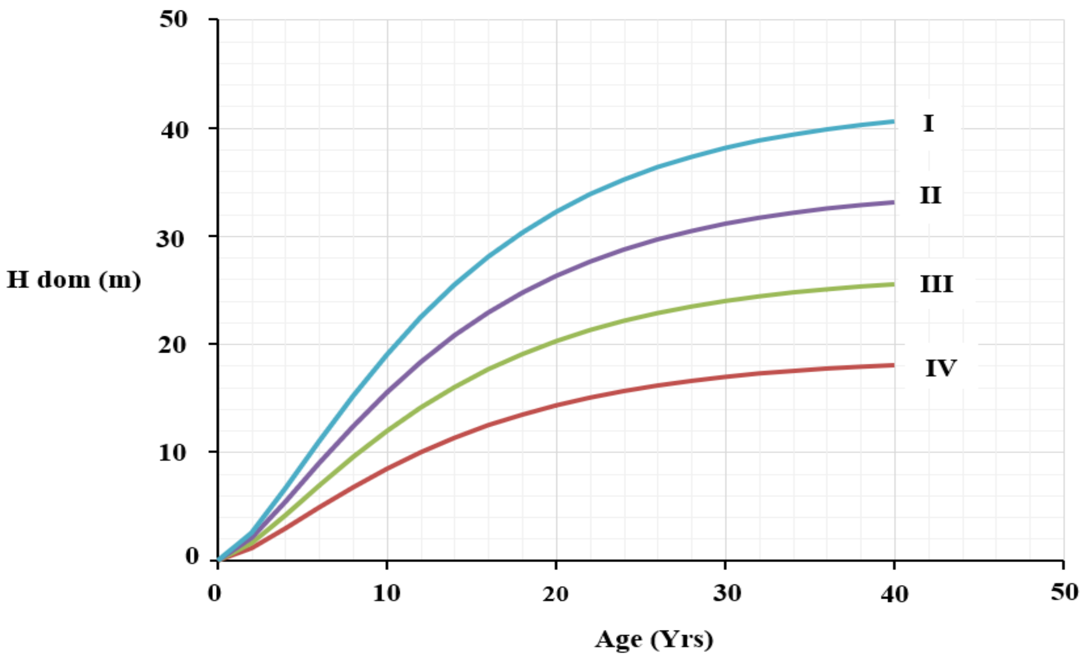

**Figure 4.3: Site index curve for *Pinus patula* at Sao Hill Forest Plantation **
***Source*:** Malimbwi *et al*., (2016)

3.2.2.3 Sampling Design

The compartment identified during reconnaissance survey were stratified based on thinning status, site class and age. Then the selection of thinned and unthinned compartments was done by considering their comparability in term of site class and age. The selected thinned compartments were well thinned so that the effect of thinning could be articulated. A total of 6 compartments which fit the criteria (Appendix 4) were selected and used in data collection. In each compartment, circular plots of 0.03 ha of radius 9.78 m delivered from plot area (Malimbwi *et al*., 2016) were systematically established at an interval in every compartment (Table 4.3). The dominant height (Hdom) is estimated using the hundred fattest trees (100 trees) in a ha. At a plot level, less than 100 trees are measured since a plot is smaller than a ha. Normally three (3) fastest trees corresponding to an area of 0.03 ha are selected for height measurement (Recall the above protocol, i.e., 100 trees in a ha). A plot with an area of 0.03 ha has a radius of 9.78 m delivered from the basal area formula. Plantation maps were used in transect layout and plot allocation prior to field work. In transect laying-out, the first transect was laid at half transect distance from the compartment border to avoid border effects, this was also the case for the first plot. The distance between transects and plots varied for different compartments as indicated in Table 4.3.

Table 4.3: Compartments selected and used to assess the effect of thinning on growth, yield and stem quality of *P. patula* at Sao Hill Forest Plantation

Compartment Name	Compartment size (ha)	Age (yr)	Hdom (m)	Thinning status	Distance between transect (m)	Distance between plots (m)	No. of plots
2/S16b/10	37.8	18	23.9	2nd thinning	100	100	30
2/MT5/31	50.9	18	25.6	Unthinned	150	100	30
2/S16a/34	33.5	19	22.9	2nd thinning	100	100	30
2/MT5/24	32.2	19	26.6	Unthinned	100	100	30
2/S16a/31	21.6	19	25.0	2nd thinning	100	50	30
2/MT5/34.2	19.5	19	25.6	Unthinned	100	50	30

3.2.3 Data Collection

3.2.3.1 To assess the effect of thinning on the growth and yield of *Pinus patula* at Sao Hill Forest Plantation

Direct field measurement was used to measure the Dbh of all trees in the plot to the nearest 10^{th} of a cm by using a caliper. The total tree height for three trees (one small, one medium and one fattest diameter tree) were measured by using a Suunto hypsometer.

2.2.3.2 To assess the effect of thinning on stem quality of *Pinus patula* at SHFP

On each plot, the stem quality class of all trees was determined by using subjective ranking using four quality classes 1, 2, 3 and 4 adopted from Mugasha *et al*. (1996) (Table 5.3).

Table 5.3: Stem quality classification

Description	Stem quality class
a). Straight to the top and good stem form b). Straight and good stem form but with one slight bend less than 1m in length	1
a). Straight to the top and good stem form but with one slight bend less than 1 m in length b). Straight to the top and good stem form but with slight bend less than 1 m in length or crooked mid top forks c). Straight to the top and good stem form with buttresses within 1 m height.	2
a). Straight bends less than 1 m at the bottom and at top with straight middle part b). One slight bend more than 1 m in length c). Slight crook, slight taper, buttressed within 2 m height	3
a). Seriously crook, excess taper and buttressed beyond 2 m height	4

Source: Mugasha *et al*. (1996)

3.2.4 Data Analysis

3.2.4.1 Growth and yield for thinned and unthinned *Pinus patula* trees

The stand parameters used to describe growth and yield were Quadratic Mean Diameter (cm), basal area per hectare (m^2/ha) and volume per hectare (m^3/ha). Quadratic Mean Diameter (QMD) was used instead of arithmetic mean diameter (Dbh) because it gives greater weight to larger trees and it is equal to or larger than the arithmetical mean diameter at an amount that depends on the variance (Curtis and Marshall, 2000).

The Quadratic mean diameter (QMD) was computed as a square root of the arithmetic mean of squared value (Curtis and Marshall, 2000). It was estimated by using Equation 1.

QMD = $\sqrt{(\Sigma di^2)/n}$ ……………………………………………… Equation 1

The input in this equation is Dbh in cm and the output is QMD in cm.

Where: QMD is the quadratic mean diameter in cm,

di is the diameter at breast height of i^{th} tree and

n is the total number of trees.

The tree basal areas (BA) in a compartment were estimated by using the standard formula (Equation 2) and results were divided by plot area (ha) to obtain basal area per hectare (m^2/ha).

$\boldsymbol{BA = \pi \times \frac{dbh^2}{4\,x\,10{,}000}}$ …………………………. Equation 2

The input in this equation is Dbh in cm and the output is BA in $m^{2.}$

Where: Dbh in Diameter at the Breast Height (cm), and

BA is a basal area (m^2)

The estimation of Height (H) for trees that were measured for Dbh alone was done by using the equation developed from the Regression equation. The resulting logarithmic equation was:

$$\mathbf{H = 9.2357ln(dbh) - 4.7924}$$ ……………………………………………. Equation 3

The following performance and characteristics were obtained; R^2 = 0.96; n = 537 observations and SE = 2.38. The input in this equation is Dbh (cm) and the output is the height (m) where H is the height and Dbh is the diameter at breast height.

The basal area was divided by plot area to obtain basal area per hectare (m^2/ha).

Tree volume was estimated using the equation developed by Malimbwi *et al.* (2016). The inputs to the volume equation are tree height (m) and diameter at breast height (cm), and the output is a volume in m^3/ha.

$$\boldsymbol{V = exp(-9.04925 + 1.114781 x ln(height) + 1.5496 ln(dbh))}$$ ……Equation 4

Where; V is tree volume (m^3) and dbh is the diameter at breast height (cm).

The volume was divided by plot area to obtain volume per hectare (m^3/ha).

Comparison of growth and yield parameters between thinned and unthinned compartments was firstly done by using deviations percent between thinned and unthinned for each age and site class. An independent t-test was used to determine whether the mean values between thinned and unthinned stands differ significantly.

3.2.4.2 Stem quality of *Pinus patula* in thinned and unthinned stands

The percentage of trees in each of the four quality classes was computed. A Mann-Whitney U test was performed to assess whether the stem quality of thinned stands is significantly different from unthinned stands.

3.3 Results

3.3.1 Quadratic Mean Diameter

Thinned compartments had a higher Quadratic Mean Diameter (QMD) compared to unthinned compartments that ranged from 11% to 18% percentage deviation (Table 6.3). Results in Table 6.3 indicated that thinned compartments were significantly different from unthinned compartments with p-values of 0.02 and 0.01 but thinned compartment 2/S16a/34 were not significantly different to unthinned compartment 2/MT5/24 with p-value of 0.19.

Table 6.3: Summary of stand Dbh for thinned and unthinned *Pinus patula* at Sao Hill Forest Plantation

Thinning status	Compartment	Age (year)	Dbh (cm)	Deviation (cm)	Deviation %	p-value
2nd Thinning	2/S16b/10	18	25.9 ± 0.3	4.5	17%	0.01*
Unthinned	2/MT5/31	18	21.4 ± 0.4			
2nd Thinning	2/S16a/34	19	27.6 ± 0.6	4.9	18%	0.19
Unthinned	2/MT5/24	19	22.7 ± 0.01			
2nd Thinning	2/S16a/31	19	23.5 ± 0.4	2.6	11%	0.02*
Unthinned	2/MT5/34.2	19	21.0 ± 0.4			

***Significant at p = 0.05**

2.3.2 Stand Basal Area

Thinned compartments had higher basal area values than unthinned compartments. The basal area per hectare results indicated that only thinned compartment 2/S16a/34 had no significant different from unthinned compartment 2/MT5/24 with p-values of 0.18 (Table 7.3).

Table 7.3: Summary of stand basal area per ha for thinned and unthinned *Pinus patula* at Sao Hill Forest plantation

Thinning status	Compartment	Age (years)	Basal area/ha (m²/ha)	Deviation (m²/ha)	Deviation %	p-value
2nd Thinning	2/S16b/10	18	48.46 ± 0.01	7.9	16%	0.02*
Unthinned	2/MT5/31	18	40.59 ± 0.02			
2nd Thinning	2/S16a/34	19	50.01 ± 0.02	6.9	14%	0.18
Unthinned	2/MT5/24	19	43.12 ± 0.01			
2nd Thinning	2/S16a/31	19	43.88 ± 0.02	3.6	8%	0.0001*
Unthinned	2/MT5/34.2	19	40.31 ± 0.02			

***Significant at p = 0.05**

3.3.3 Stand Volume

Thinned compartments had high volume per ha values compared to unthinned compartments (Table 8.3). The mean deviation percentage ranged from 20% to 33%. The mean volume per ha of thinned stands ranged from 537.75 ± 0.61 m3/ha to 743.22 ± 0.98 m3/ha and unthinned stands were from 429.65 ± 0.58 m3/ha to 500.59 ± 0.38 m3/ha. Results indicated that volume per hectare of thinned compartments were significantly different from unthinned compartments with p-values of 0.01, 0.001 and 0.04

Table 8.3: Summary of stand volume per ha for thinned and unthinned *Pinus patula* at Sao Hill Forest Plantation

Thinning status	Compartment	Age (years)	Volume/ha (m^3/ha)	Deviation	Deviation %	p-value
2nd Thinning	2/S16b/10	18	656.63 ± 0.54	211.5	32%	0.001*
Unthinned	2/MT5/31	18	445.13 ± 0.48			
2nd Thinning	2/S16a/34	19	743.22 ± 0.98	242.6	33%	0.001*
Unthinned	2/MT5/24	19	500.59 ± 0.38			
2nd Thinning	2/S16a/31	19	537.75 ± 0.61	108.1	20%	0.04*
Unthinned	2/MT5/34.2	19	429.65 ± 0.58			

***Significant at p = 0.05**

3.3.4 Effect of Thinning on Stem Quality

The thinned and unthinned compartments assessed were dominated mostly by trees which are straight to the top and good stem form at 76% for thinned compartment compared to 67% of unthinned compartments (Figure 5.3). This means, thinned stands had an advantage of improving quality of trees by increasing straightness by 9%. About 19% of trees in thinned compartments are straight to the top and good stem form but with one slight bend or buttresses less than 1 m in height compared to 21% of trees for unthinned compartments. About 5% of trees in thinned compartments and 12% of trees in unthinned compartments are slightly crooked, slightly taper and buttressed within 2 m height. Almost, less than 1% of trees in thinned and unthinned compartments have serious crook, excess taper and buttressed beyond 2 m height. Thinning tends to increase straightness to the trees and reduce serious crooked, excess taper and buttressed trees when it is done properly. A statistical test for stem quality of thinned compartments showed that they were significantly different to unthinned compartments with p = 0.000.

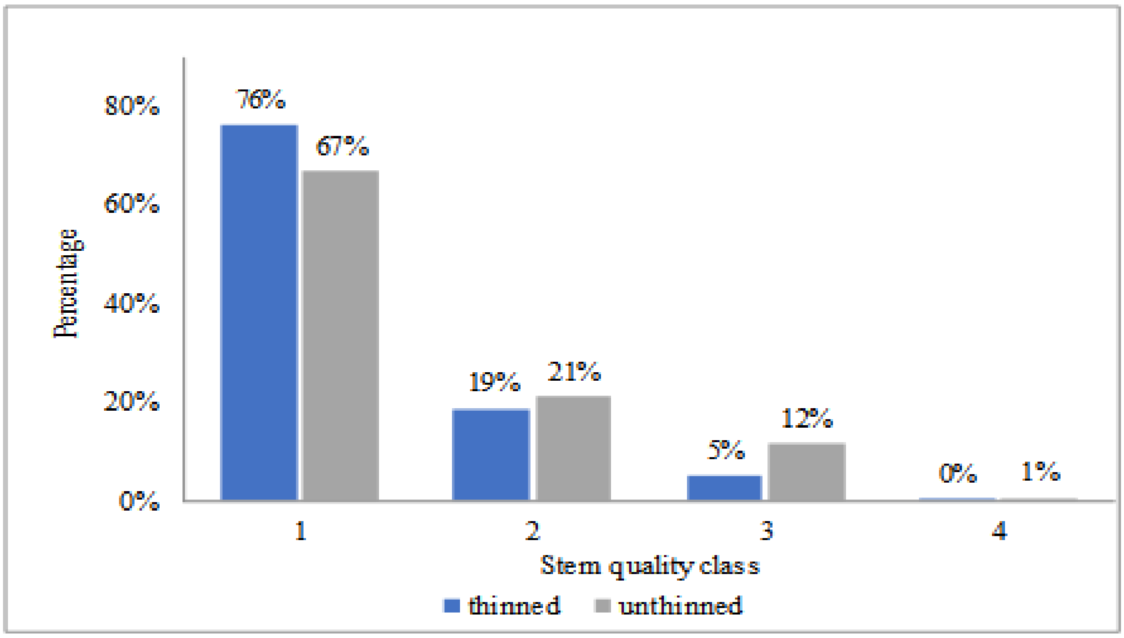

Figure 5.3: Percentage of stem quality classification on thinned and unthinned compartments at Sao Hill Forest Plantation

3.4 Discussion

The simulated Dbh results by Malimbwi *et al*. (2016) for thinned compartments at age 18 and 19 years were 27.8 and 28.4 cm respectively which are higher than 25.9 cm and 23.5 – 27.6 cm for 18 and 19 years respectively obtained in this study. The reason is due to inadequate thinning observed which limits the space for diameter growth meaning that proper thinning was needed to reduce the trees competition for light, water and nutrients in order to increase tree diameter growth in stands (Hitsuma *et al*., 2021). Likewise, Malimbwi *et al*. (2016) found out that Dbh results for unthinned compartments at an age 18 and 19 years were higher than those obtained in this study because of overstocking in unthinned stands in this study as diameter increases with decrease on stand density (Makinen and Isomaki, 2004). This situation possibly was the result of delayed thinning as trees fail to show difference in diameter within a time after thinning. However, given the higher stem density of the thinned compartment compared to the density directed by the Technical Order No. 1 of 2003; there is a possibility to attain more size of diameter on trees if thinning could have been performed properly (Radoglou and Raftoyannis, 2003).

The results on basal area contradict with other studies conducted by Malimbwi *et al*. (2016) on *Pinus patula* and Skovsgaard (2009) on Scots pine that reported basal area to be high in unthinned compared to thinned compartments. The reason for the difference may be due to inadequate thinning performed, high level of fertility and availability of soil water in thinned stand that contributed to the observed difference (Makinen and Isomaki, 2014). For a given site condition and a given spacing or initial stem number at stand establishment, the unthinned stand will support the highest possible basal area of live trees at any stage of stand development (Skovsgaard, 2009).

The volume per ha results obtained are also in contrary to other studies conducted by Akyoo (2017) and Elia (2014) who reported the average volume per ha in unthinned stand to be higher than in thinned compartments. The high volume in thinned compartments is associated with large tree Dbh in thinned compartments. The large tree Dbh is caused by enough space between trees that trigger the tree to increase in width (Makinen and Isomaki, 2014). Also, the study results implied that there was a possibility of many small-sized diameter trees in unthinned compartments causing standing volume to be distributed in many small trees (Chamshama and Malimbwi, 1996) resulting to smaller volume/ha than corresponding thinned compartments.

The relative high number of straight stems in thinned compartments could primary be associated with selective removal of crooked stems during thinning operations. Some studies found out that, there were a high percentage of a good quality stem aligned the stem form to increase with decreasing in stand density (Chamshama and Phillip, 1980; Pérez and Kanninen, 2005; Saarinen *et al*., 2020). Furthermore, thinning operation if not properly carried out, will increase spacing and stem straightness to the most widely spaced trees having the worst mean stem straightness (Erasmus *et al*., 2018). However, the comparative low percent of straight trees in unthinned compartments could be due to low quality of tree seeds and high competition of nutrients when the unthinned stand density was higher. There is low competition in thinned stands which can allow a tree to attain its desired diameter and stem form (Pérez and Kanninen, 2005). The presence of few stems with defects observed in thinned compartments possibly were due to inadequate thinning, lack of serious quality consideration during thinning and cattle grazing in young stands resulted in seedling damage and poor stem quality in general for *Pinus patula* (Okama and Chamshama, 1988; Maliondo and Chamshama, 1996). The trees with low stem qualities were found in compartments which have not been properly maintained. So, quality of stands can be improved by establishing them in the good sites and using proper tending techniques (Mwasomola, 2008).

3.5 Conclusions and recommendations

3.5.1 Conclusions

Thinning practice increase the stand mean diameter, basal area and volume per hectare as the study showed. This has positive effect on timber volume and revenue collection of final products. Thinned compartments were dominated by trees with straight and good stem form by difference of 9% compared to unthinned compartments which means Sao Hill Forest Plantation has suitable trees that can be sold at 9% more of the market price if silvicultural practices will be maintained and properly implemented.

3.5.2 Recommendations

To ensure high growth and yield of *Pinus patula* at Sao Hill Forest Plantation, it is recommended that the *Pinus patula* plantation to be thinned according to the government thinning schedule as stated in used Technical Order to encourage large diameter growth that can produce different sizes of timber to suit local and international demand.

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CHAPTER FOUR

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Thinning is an important silviculture activity that led to growth, yield increment and stem quality improvement of *Pinus patula* stands at Sao Hill Forest Plantation. Based on the findings, the present study concluded that; thinning has an effect on stand quadratic mean dbh, basal area per hectare and volume per hectare for *Pinus patula* grown at Sao Hill Forest Plantation. There is a significantly higher growth and yield on thinned compartments compared to unthinned compartments. Stem quality of thinned compartments were significantly higher than unthinned compartments and dominated by straight trees with a good stem form. The thinning operations were not conducted on time and compartments were overstocked because the thinning schedule were not complied.

4.2 Recommendations

In view of the conclusions above, it is therefore recommended that:

i. To ensure high growth and yield of *Pinus patula* at Sao Hill Forest Plantation, the *Pinus patula* plantations to be thinned according to existing government thinning schedule to encourage large diameter trees that can produce different sizes of timber to suit local and international market demand.

ii. Sufficient funds should be allocated and disbursed on time for thinning and other silvicultural activities to minimize thinning delay and encourage growth and yield of plantation.

iii. A close follow up on the implementation and training should be given to field workers on proper practices of Technical Order No. 1 of 2003 (currently technical order No. 1 of 2021) with regard to thinning schedules.

iv. Further studies are recommended at Sao Hill Forest Plantations focusing on improvement on the productivity of stands. In this study only *Pinus patula* species was considered but it is possible to expand the study with other species or silviculture practices.

APPENDICES

Appendix 1: Sao Hill Forest Plantation (Division I & II) compartment register

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
I	GULUSILO	G3_25	22.58	Pinus patula	1979	42
I	GULUSILO	G4_10	15.76	Pinus patula	1980	41
I	GULUSILO	G4_11	28.91	Pinus patula	1980	41
I	GULUSILO	G4_12	26.12	Pinus patula	1980	41
I	GULUSILO	G4_13	57.00	Pinus patula	1980	41
I	GULUSILO	G4_14	43.79	Pinus patula	1980	41
I	GULUSILO	G4_15	23.04	Pinus patula	1980	41
I	GULUSILO	G4_16	42.05	Pinus patula	1985	36
I	GULUSILO	G4_17	33.77	Pinus patula	1985	36
I	GULUSILO	G4_18	41.82	Pinus patula	1985	36
I	GULUSILO	G4_19	25.35	Pinus patula	1985	36
I	GULUSILO	G4_2	28.96	Pinus patula	1986	35
I	GULUSILO	G4_22	19.06	Pinus patula	1985	36
I	GULUSILO	G4_24	27.86	Pinus patula	1980	41
I	GULUSILO	G4_26	31.69	Pinus patula	1980	41
I	GULUSILO	G4_27	22.73	Pinus patula	1980	41
I	GULUSILO	G4_29	34.64	Pinus patula	1980	41
I	GULUSILO	G4_3	33.18	Pinus patula	1986	35
I	GULUSILO	G4_30	21.21	Pinus patula	1980	41
I	GULUSILO	G4_4	9.48	Pinus patula	1986	35
I	GULUSILO	G4_5	30.10	Pinus patula	1986	35
I	GULUSILO	G4_6	12.19	Pinus patula	1986	35
I	GULUSILO	G4_6A	6.00	Pinus patula	2006	15

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
I	GULUSILO	G4_8	40.56	Pinus patula	1980	41
I	GULUSILO	G4_9	39.25	Pinus patula	1980	41
I	IRUNDI	IR2B1	12.69	Pinus patula	1986	35
I	IRUNDI	IR2B4	17.61	Pinus pa	2007	14

				tula		
I	IRUNDI	IR3B1	12.80	Pinus patula	1982	39
I	IRUNDI	IR3B2	13.80	Pinus patula	1982	39
I	IRUNDI	IR3B3	16.63	Pinus patula	1992	29
I	IRUNDI	IR3B4	11.42	Pinus patula	2003	18
I	IRU	IR3B	11	Pi	20	18

	NDI	5	.72	nuspatula	03	
I	IRUNDI	IR3B6	12.35	Pinuspatula	2003	18
I	IRUNDI	ID1A2	59.95	Pinuspatula	1988	33
I	IRUNDI	ID1A3	17.61	Pinuspatula	2007	14
I	IRUNDI	ID1B	81.20	Pinuspatu	1983	38

				la		
I	IRUNDI	ID2_Bi	36.14	Pinus patula	2005	16
I	IRUNDI	ID2A4	23.04	Pinus patula	2001	20
I	IRUNDI	ID2B	58.52	Pinus patula	2000	21
I	IRUNDI	ID2B2	56.25	Pinus patula	1997	24
I	IRUND	ID3B1A	11.8	Pinu	2008	13

	I		5	spatula		
I	IRUNDI	ID3B2	6.69	Pinus spatula	2009	12
I	IRUNDI	ID3C2	15.65	Pinus spatula	2005	16
I	IRUNDI	ID3C3	48.80	Pinus spatula	2009	12
I	IRUNDI	ID3C4	46.44	Pinus spatula	2005	16

I	IRUNDI	ID3C5	68.42	Pinus patula	2009	12
I	IRUNDI	ID3D	7.68	Pinus patula	1987	34
I	IRUNDI	ID4AI	40.67	Pinus patula	1993	28
I	IRUNDI	ID4AII	19.69	Pinus patula	1998	23
I	IRUNDI	ID4AIII	21.03	Pinus pa	2006	15

				tula		

Division	**Block**	**Compartment**	**Area (ha)**	**Species**	**Planting year**	**Age (years)**
I	IRUNDI	ID4AIV	4.41	Pinus patula	2008	13
I	IRUNDI	ID4AVI	14.12	Pinus patula	2009	12
I	IRUNDI	ID4AVII	42.62	Pinus patula	2009	12

I	IRUNDI	ID4AVIII	48.62	Pinuspatula	2008	13
I	IRUNDI	ID4B	77.36	Pinuspatula	1993	28
I	IRUNDI	ID4BI2	3.14	Pinuspatula	2008	13
I	IRUNDI	ID4BI3	40.42	Pinuspatula	2008	13
I	IRUNDI	ID4bi4	9.69	Pinuspatula	2006	15

I	IRUNDI	ID4BI6	68.65	Pinuspatula	2008	13
I	IRUNDI	ID5A1	31.92	Pinuspatula	2009	12
I	IRUNDI	ID5A2	30.11	Pinuspatula	2009	12
I	IRUNDI	ID5A3	44.00	Pinuspatula	2009	12
I	IRUNDI	ID5A4	6.11	Pinuspatula	2008	13

I	IRUNDI	ID5B1_1	9.93	Pinus patula	2008	13
I	IRUNDI	ID5B1_2	40.42	Pinus patula	2008	13
I	IRUNDI	IDID	11.82	Pinus patula	1998	23
I	IRUNDI	R5BI	9.74	Pinus patula	2005	16
I	IRUNDI	S4A	4.11	Pinus patula	2008	13

I	MSIWASI	G1_3	61.52	Pinus patula	2005	16
I	MSIWASI	G2_34	17.00	Pinus patula	1979	42
I	MSIWASI	G2_8	16.02	Pinus patula	2003	18
I	MSIWASI	G3_28	22.41	Pinus patula	1979	42
I	MSIWASI	G3_29	23.60	Pinus patula	1979	42

I	MSIWASI	G3_30	32.14	Pinus patula	1979	42
I	MSIWASI	G3_32	21.36	Pinus patula	1979	42
I	MSIWASI	G3_34	16.41	Pinus patula	1979	42
I	MSIWASI	MS11	26.68	Pinus patula	1997	24
I	MSIWASI	MS12	12.59	Pinus patula	1996	25

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
I	MSIWASI	MS13	48.69	Pinus patula	2007	14
I	MSIWASI	MS4Ci	21.46	Pinus patula	2007	14
I	NZIVI	NZ8D	29.63	Pinus patula	2004	17
I	NZIVI	R10_1	48.48	Pinus patula	1998	23
I	NZIVI	R10_3	77.53	Pinus patula	2004	17
I	NZIVI	R11_1	26.26	Pinus patula	2002	19
I	NZIVI	R11_10	10.39	Pinus patula	2002	19
I	NZIVI	R11_2	28.56	Pinus patula	2002	19
I	NZIVI	R11_3	29.38	Pinus patula	2002	19
I	NZIVI	R11_4	17.62	Pinus patula	2002	19
I	NZIVI	R11_5	13.29	Pinus patula	2002	19
I	NZIVI	R11_6	4.00	Pinus patula	2002	19
I	NZIVI	R11_7	17.48	Pinus patula	2002	19
I	NZIVI	R11_8	10.90	Pinus patula	2002	19
I	NZIVI	R11_9	11.02	Pinus patula	2007	14
I	NZIVI	R12ai2	56.27	Pinus patula	1998	23
I	NZIVI	R12Ai3	19.30	Pinus patula	1999	22
I	NZIVI	R12Ai4	189.30	Pinus patula	2001	20
I	NZIVI	R12Ai5	29.06	Pinus patula	2002	19
I	NZIVI	R12Ai6	36.12	Pinus patula	2003	18
I	NZIVI	R12B1	18.87	Pinus patula	2002	19
I	NZIVI	R12B2	23.51	Pinus patula	2002	19
I	NZIVI	R12B3	7.17	Pinus patula	2003	18
I	NZIVI	R12B4	21.24	Pinus patula	2000	21
I	NZIVI	R12B5	25.87	Pinus patula	2000	21
I	NZIVI	R12B6	19.87	Pinus patula	2000	21
I	NZIVI	R12B7	43.06	Pinus patula	2000	21

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
I	NZIVI	R13Ai1	7.00	Pinus patula	2004	17
I	NZIVI	R13Ai2	255.12	Pinus patula	1999	22
I	NZIVI	R13Aii2	6.30	Pinus patula	2002	19
I	NZIVI	R13Aii2A	94.60	Pinus p	2005	16

				atula		
I	NZIVI	R13B1	15.88	Pinus patula	2004	17
I	NZIVI	R13B10	28.13	Pinus patula	2000	21
I	NZIVI	R13B12	24.96	Pinus patula	2000	21
I	NZIVI	R13B13	18.38	Pinus patula	2000	21
I	NZIVI	R13B14	19.23	Pinus p	2000	21

				atula		
I	NZIVI	R13B15	35.62	Pinus patula	2000	21
I	NZIVI	R13B16	22.16	Pinus patula	2000	21
I	NZIVI	R13B17	5.27	Pinus patula	2000	21
I	NZIVI	R13B18	2.78	Pinus patula	2000	21
I	NZIVI	R13B2	28.66	Pinus p	2004	17

				atula		
I	NZIVI	R13B3	32.50	Pinus patula	2004	17
I	NZIVI	R13B4	35.68	Pinus patula	2004	17
I	NZIVI	R13B5	35.78	Pinus patula	2004	17
I	NZIVI	R13B6	35.44	Pinus patula	2004	17
I	NZIVI	R13B7	38.74	Pinus p	2004	17

				atula		
I	NZIVI	R13B8	42.98	Pinus patula	2002	19
I	NZIVI	R13B9	55.22	Pinus patula	2002	19
I	NZIVI	R14B1	24.06	Pinus patula	2000	21
I	NZIVI	R14B10	28.17	Pinus patula	2000	21
I	NZIVI	R14B2	28.01	Pinus p	2000	21

				atula		
I	NZIVI	R14B3	31.20	Pinus patula	2000	21
I	NZIVI	R14B4	34.19	Pinus patula	2000	21
I	NZIVI	R14B5	33.78	Pinus patula	2000	21
I	NZIVI	R14B6	28.69	Pinus patula	2000	21

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
I	NZIVI	R14B7	28.19	Pinus patula	2000	21
I	NZIVI	R14B8	28.31	Pinus patula	2000	21
I	NZIVI	R14B9	25.56	Pinus patula	2000	21
I	NZIVI	Z9A1	42.68	Pinus patula	1990	31

I	RUAHA	R14A1	202.15	Pinus patula	2009	12
I	RUAHA	R14C2	12.03	Pinus patula	2007	14
I	RUAHA	R14E	12.23	Pinus patula	2009	12
I	RUAHA	R14E2	16.10	Pinus patula	2004	17
I	RUAHA	R14E3	17.38	Pinus patula	2002	19

I	RUAHA	R14E4	59.73	Pinus patula	2003	18
I	RUAHA	R16C37	41.10	Pinus patula	2003	18
I	RUAHA	R16C38	37.10	Pinus patula	2003	18
I	RUAHA	R5A1	30.00	Pinus patula	2005	16
I	RUAHA	R5b2_1	30.54	Pinus patula	2008	13

I	RUAHA	R5Bi	13.00	Pinus patula	2008	13
I	RUAHA	R5C	13.65	Pinus patula	1995	26
I	RUAHA	R6A2	24.79	Pinus patula	1996	25
I	RUAHA	R6A3	35.58	Pinus patula	1996	25
I	RUAHA	R6A4	33.91	Pinus patula	2005	16

I	RUAHA	R6 Bii 2	193.00	Pinus patula	2009	12
I	RUAHA	R6 Bii 3	6.63	Pinus patula	2007	14
I	RUAHA	R6 C D	29.35	Pinus patula	2005	16
I	RUAHA	R6 F	57.50	Pinus patula	1994	27
I	RUAHA	R7 Ai	129.42	Pinus patula	2009	12

I	RUAHA	R7Ai1	25.00	Pinus patula	1998	23
I	RUAHA	R7Ai2A	23.86	Pinus patula	2006	15
I	RUAHA	R7Ai2B	17.18	Pinus patula	2006	15

Division	**Block**	**Compartment**	**Area (ha)**	**Species**	**Planting year**	**Age (years)**
I	RUAHA	R7Ai3	60.23	Pinus patula	2007	14
I	RUAHA	R7Ai4	211.41	Pinus patula	2006	15
I	RUAHA	R7Aii2	58.87	Pinus patula	1997	24
I	RUAHA	R7B1	90.25	Pinus patula	2003	18
I	RUAHA	R7B2	197.51	Pinus patula	2006	15
I	RUAHA	R7B3_2	19.11	Pinus patula	2006	15

I	RUAHA	R7B3B	46.97	Pinus patula	2006	15
I	RUAHA	R8A	191.82	Pinus patula	1997	24
II	KIBIDULA	KB1_3.2	15.20	Pinus patula	1978	42
II	KIBIDULA	KB2_23.1	14.00	Pinus patula	2003	17
II	KIBIDULA	KB2_23.2	17.02	Pinus patula	2001	19
II	KIBIDULA	KB2_24	53.17	Pinus patula	2002	18
II	KIBIDULA	KB2_25.1	6.70	Pinus patula	2002	18
II	KIBIDULA	KB2_26.1	30.06	Pinus patula	2003	17
II	KIBIDULA	KB2_27	29.30	Pinus patula	2003	17
II	KIBIDULA	KB2_28	49.01	Pinus patula	2002	18
II	KIBIDULA	KB2_30.1	32.80	Pinus patula	2003	17
II	KIBIDULA	KB2_30.2	9.58	Pinus patula	1986	34
II	KIBIDULA	KB1-5	46.46	Pinus patula	1986	34
II	KIBIDULA	KB1-9	20.42	Pinus patula	1986	34
II	KIBIDULA	KB2-26.2	16.59	Pinus patula	1986	34
II	KIBIDULA	MT5_8	17.14	Pinus patula	1986	34
II	KIBIDULA	MT5_35	12.50	Pinus patula	1986	34
II	MATANANA	MT1_1	30.40	Pinus patula	2008	12
II	MATANANA	MT1_11.2	18.20	Pinus patula	2007	13
II	MATANANA	MT1_12	55.30	Pinus patula	2007	13
II	MATANANA	MT1_13	57.00	Pinus patula	2008	12

Division	**Block**	**Compartment**	**Area (ha)**	**Species**	**Planting year**	**Age (years)**

II	MATANANA	MT1_14	12.00	Pinus patula	2008	12
II	MATANANA	MT1_15	100.52	Pinus patula	2007	13
II	MATANANA	MT1_16	25.03	Pinus patula	2006	14
II	MATANANA	MT1_18	13.88	Pinus patula	2006	14
II	MATANANA	MT1_19	56.15	Pinus patula	2006	14

II	MATANANA	MT1_20	31.16	Pinus patula	2006	14
II	MATANANA	MT1_21	23.36	Pinus patula	2005	15
II	MATANANA	MT1_22	28.51	Pinus patula	2006	14
II	MATANANA	MT1_8	10.23	Pinus patula	2008	12
II	MATANANA	MT1_9.1	20.86	Pinus patula	2008	12

II	MATANANA	MT2_2	42.00	Pinus patula	2008	12
II	MATANANA	MT2_3	53.30	Pinus patula	2008	12
II	MATANANA	MT2_5	16.30	Pinus patula	1998	22
II	MATANANA	MT2_7	39.07	Pinus patula	2008	12
II	MATANANA	MT2_9	29.00	Pinus patula	2008	12

II	MATANANA	MT3_1.1	9.20	Pinus patula	2007	13
II	MATANANA	MT3_1.2	30.87	Pinus patula	2008	12
II	MATANANA	MT3_10	26.82	Pinus patula	2007	13
II	MATANANA	MT3_11	65.80	Pinus patula	2007	13
II	MATANANA	MT3_12.1	54.59	Pinus patula	2007	13

II	MATANANA	MT3_12.2	31.80	Pinuspatula	2008	12
II	MATANANA	MT3_13	88.88	Pinuspatula	2007	13
II	MATANANA	MT3_14	82.90	Pinuspatula	2007	13
II	MATANANA	MT3_15	62.70	Pinuspatula	2007	13
II	MATANANA	MT3_17	37.12	Pinuspatula	2007	13

II	MATANANA	MT3_2	50.30	Pinuspatula	2008	12
II	MATANANA	MT3_3	75.02	Pinuspatula	2008	12

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
II	MATANANA	MT3_4	57.42	Pinus patula	2008	12
II	MATANANA	MT3_5	11.35	Pinus patula	2007	13
II	MATANANA	MT3_6.1	48.62	Pinus patula	2008	12
II	MATANANA	MT3_7	81.10	Pinus patula	2008	12
II	MATANANA	MT3_8.2	29.00	Pinus patula	2007	13
II	MATANANA	MT3_9.1	47.50	Pinus patula	2007	13
II	MATANANA	MT4_1	54.25	Pinus patula	1998	22
II	MATANANA	MT4_2	25.20	Pinus patula	1998	22
II	MATANANA	MT4_3	45.25	Pinus patula	1998	22
II	MATANANA	MT4_4	36.62	Pinus patula	1998	22
II	MATANANA	MT5_1	9.11	Pinus patula	1986	34
II	MATANANA	MT5_16.1	48.03	Pinus patula	1986	34
II	MATANANA	MT5_16.2	4.60	Pinus patula	2002	18
II	MATANANA	MT5_17.1	44.92	Pinus patula	1986	34
II	MATANANA	MT5_17.2	1.47	Pinus patula	2002	18
II	MATANANA	MT5_18.1	52.19	Pinus patula	1986	34
II	MATANANA	MT5_18.2	1.47	Pinus patula	2002	18
II	MATANANA	MT5_2	87.73	Pinus patula	1986	34
II	MATANANA	MT5_21	12.41	Pinus patula	2002	18
II	MATANANA	MT5_22	33.85	Pinus patula	1986	34
II	MATANANA	MT5_23	27.73	Pinus patula	2002	18
II	MATANANA	MT5_24	32.20	Pinus patula	2002	18
II	MATANANA	MT5_25	51.49	Pinus patula	2003	17
II	MATANANA	MT5_28	6.13	Pinus patula	2003	17
II	MATANANA	MT5_29	10.12	Pinus patula	2002	18
II	MATANANA	MT5_30	33.50	Pinus patula	2003	17
II	MATANANA	MT5_31	99.97	Pinus patula	2003	17

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
II	MATANANA	MT5_32	45.28	Pinus patula	2003	17
II	MATANANA	MT5_33	5.62	Pinus patula	2003	17
II	MATANANA	MT5_34	19.51	Pinus patula	2002	18
II	MATANANA	MT5_38	41.00	Pinus patula	2009	11
II	MATANANA	MT5_6	31.26	Pinus patula	1986	34
II	MATANANA	MT5_7.1	42.35	Pinus patula	1986	34
II	MATANANA	MT5_7.2	60.13	Pinus patula	2003	17
II	MATANANA	MT5_9.B	35.73	Pinus patula	1986	34
II	MATANANA	MT5_27	8.83	Pinus patula	1986	34
II	MATANANA	NZ 11B	81.80	Pinus patula	2008	12
II	NYOLOLO	NY_34	26.96	Pinus patula	1991	29
II	NYOLOLO	NY_36	40.71	Pinus patula	1991	29
II	NYOLOLO	NZ_11A	272.40	Pinus patula	2008	12
II	SAO HILL	S15B_15	55.96	Pinus patula	1991	29
II	SAO HILL	S15b_16	26.83	Pinus patula	1991	29
II	SAO HILL	S15b_17	40.84	Pinus patula	1991	29
II	SAO HILL	S15b_18	23.89	Pinus patula	1991	29
II	SAO HILL	S15b_19	52.24	Pinus patula	2003	17
II	SAO HILL	S15B_20	63.44	Pinus patula	2006	14
II	SAO HILL	S15b_21	43.27	Pinus patula	2002	18
II	SAO HILL	S15b_25	11.19	Pinus patula	2002	18
II	SAO HILL	S15b_26	53.15	Pinus patula	2002	18
II	SAO HILL	S15b_27	21.79	Pinus patula	2002	18
II	SAO HILL	S15B_28	50.38	Pinus patula	2002	18
II	SAO HILL	S15b_6.2	8.42	Pinus patula	2008	12
II	SAO HILL	S15B13	74.60	Pinus patula	1991	29
II	SAO HILL	S15b2	15.37	Pinus patula	1991	29

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
II	SAO HILL	S15B22	44.46	Pinus patula	2002	18
II	SAO HILL	S15B23	56.56	Pinus patula	2002	18
II	SAO HILL	S15B24	21.79	Pinus patula	2002	18
II	SAO HILL	S16a_30	7.83	Pinus patula	2006	14
II	SAO HILL	S16a_32	31.41	Pinus patula	2002	18
II	SAO HILL	S16a_33	30.42	Pinus patula	2002	18
II	SAO HILL	S16a_34	33.48	Pinus patula	2002	18
II	SAO HILL	S16a_36	53.83	Pinus patula	2002	18
II	SAO HILL	S16A_37	28.75	Pinus patula	2005	15
II	SAO HILL	S16a_40	24.80	Pinus patula	2002	18
II	SAO HILL	S16a_41	30.30	Pinus patula	2002	18
II	SAO HILL	S16a_42	33.14	Pinus patula	2002	18
II	SAO HILL	S16a_43	42.44	Pinus patula	2002	18
II	SAO HILL	S16a_44	10.22	Pinus patula	2002	18
II	SAO HILL	S16A_45	75.15	Pinus patula	2002	18
II	SAO HILL	S16A29	38.43	Pinus patula	2002	18
II	SAO HILL	S16A31	21.63	Pinus patula	2002	18
II	SAO HILL	S16a35	35.19	Pinus patula	2005	15
II	SAO HILL	S16A38	46.74	Pinus patula	2005	15
II	SAO HILL	S16a39	21.70	Pinus patula	2005	15
II	SAO HILL	S16b_10	37.77	Pinus patula	2003	17
II	SAO HILL	S16b_11	14.44	Pinus patula	2002	18
II	SAO HILL	S16b_16	16.21	Pinus patula	1997	23
II	SAO HILL	S16b_17	16.63	Pinus patula	2004	16
II	SAO HILL	S16B_18	14.36	Pinus patula	2008	12
II	SAO HILL	S16b_19	41.36	Pinus patula	2004	16
II	SAO HILL	S16b_2	18.71	Pinus patula	2003	17

Division	Block	Compartment	Area (ha)	Species	Planting year	Age (years)
II	SAO HILL	S16B_20	35.55	Pinus patula	2004	16
II	SAO HILL	S16b_22	39.53	Pinus patula	2005	15
II	SAO HILL	S16b_24	47.10	Pinus patula	2008	12
II	SAO HILL	S16B_26	72.30	Pinus patula	2008	12

II	SAO HILL	S16b_27	10.33	Pinus patula	2008	12
II	SAO HILL	S16b_6	16.57	Pinus patula	2004	16
II	SAO HILL	S16B1	22.23	Pinus patula	2003	17
II	SAO HILL	S16B12	28.66	Pinus patula	2003	17
II	SAO HILL	S16B13	14.67	Pinus patula	2003	17

II	SAO HILL	S16B15	38.24	Pinus patula	1997	23
II	SAO HILL	S16B21	51.10	Pinus patula	2008	12
II	SAO HILL	S16B25	41.45	Pinus patula	2004	16
II	SAO HILL	S16B3	13.46	Pinus patula	2003	17
II	SAO HILL	S16B4	30.91	Pinus patula	2003	17

II	SAO HILL	S16B5	27.90	Pinus patula	2003	17
II	SAO HILL	S16B7	9.52	Pinus patula	2004	16
II	SAO HILL	S16B8	21.22	Pinus patula	2004	16
II	SAO HILL	S16B9	16.32	Pinus patula	2004	16
II	SAO HILL	S16C_31	40.45	Pinus patula	2003	17

II	SAO HILL	S16C_32	19.12	Pinus patula	2002	18
II	SAO HILL	S16C33	6.44	Pinus patula	2002	18
II	SAO HILL	S16C34	13.54	Pinus patula	2002	18
II	SAO HILL	S16C35	20.09	Pinus patula	2002	18
II	SAO HILL	KB1-1	19.40	Pinus patula	1986	34

II	SAO HILL	KB1-2	26.17	Pinus patula	1986	34

Appendix 2: List of surveyed compartments during the reconnaissance survey

Division	Block	Compartment	Planting year	Area (ha)	Age (yrs)	Dominant height (m)	Site class	Thinning status
II	Kibidula	2/KB2/23.1	2003	14.00	18	27.6	II	Thinned
II	Kibidula	2/KB2/26.2	2002	30.60	19	26.7	II	Thinned
II	Kibidula	2/KB2/28	2002	49.01	19	26.7	II	Thinned
II	Kibidula	2/KB2/29	2003	29.70	18	27.5	II	Unthinned
II	Kibidula	2/KB2/30.2	2003	32.80	18	28.9	II	Thinned
II	Matanana	2/MT 1/12	2007	55.30	14	22.6	II	Thinned
II	Matanana	2/MT 1/13	2008	57.00	13	21.3	II	Unthinned
II	Matanana	2/MT 1/18	2006	25.03	15	26.0	II	Thinned
II	Matanana	2/MT 1/22	2006	28.51	15	23.8	II	Thinned
II	Matanana	2/MT 5/30	2003	33.50	18	19.7	III	Unthinned
II	Matanana	2/MT 5/31	2003	50.90	18	20.7	III	Unthinned
II	Matanana	2/MT 5/32	2003	45.28	18	20.6	III	Unthinned
II	Matanana	2/MT 5/34.2	2002	19.51	19	25.6	II	Unthinned
II	Sao Hill	2/S16a/31	2002	21.63	19	25.0	II	Unthinned
II	Sao Hill	2/S16a/34	2002	33.48	19	22.9	III	Thinned
II	Sao Hill	2/S16a/36	2002	53.83	19	22.1	III	Thinned

II	Sao Hill	2/S16a/40	2002	24.80	19	24.5	II	Thinned
II	Sao Hill	2/S16b/10	2003	37.77	18	23.9	II	Thinned
II	Sao Hill	2/S16b/12	2003	28.66	18	23.0	II	Thinned
II	Sao Hill	2/S16b/19	2004	41.36	17	25.9	II	Thinned
II	Sao Hill	2/S16b/1a	2003	22.23	18	21.9	III	Thinned
II	Sao Hill	2/S16b/20	2004	35.55	17	21.1	III	Thinned
II	Sao Hill	2/S16b/25	2004	41.45	17	21.2	III	Thinned
II	Sao Hill	2/S16b/4	2003	30.91	18	22.8	III	Thinned
II	Sao Hill	2/S16b/6	2004	16.57	17	24.3	II	Thinned
II	Sao Hill	2/S16b/7	2004	23.14	17	22.3	II	Thinned
II	Sao Hill	2/S16b/8	2004	21.22	17	28.8	II	Thinned
II	Sao Hill	2/S16b/9	2004	16.32	17	27.1	II	Thinned

Division	Block	Compartment	Planting year	Area (ha)	Age (yrs)	Dominant height (m)	Site class	Thinning status
II	Sao Hill	2/S16c/31	2003	40.45	18	20.8	III	Thinned
II	Sao Hill	2/S16c/32	2002	19.12	19	24.6	II	Thinned
II	Sao Hill	2/S16c/34	2002	13.54	19	23.7	III	Unthinned
II	Sao Hill	2/S16c/35	2002	20.09	19	20.8	III	Thinned
I	Irundi	ID3C3	2009	48.80	12	16.0	III	Unthinned
I	Irundi	ID3C5	2009	68.42	12	19.7	II	Unthinned
I	Irundi	ID4AVII	2009	42.62	12	16.9	III	Unthinned
I	Irundi	ID4BI3	2008	40.42	13	22.3	II	Unthinned
I	Irundi	ID5A1	2009	31.92	12	17.4	III	Unthinned
I	Irundi	ID5A2	2009	30.11	12	15.4	III	Unthinned
I	Irundi	ID5A3	2009	44.00	12	21.6	II	Unthinned
I	Irundi	ID5B1_1	2008	9.93	13	22.1	II	Thinned
I	Irundi	ID5B1_2	2008	40.42	13	23.2	II	Thinned
I	Nzivi	R14C2	2007	22.03	14	22.1	II	Unthinned

Appendix 3: Adequacy of thinning for Thinned stands at Sao Hill Forest Plantation

SN	Compartment	Compt. Age (years)	Scheduled stocking	Present stocking	Stocking deviation (SPH)	Stocking deviation (%)
			First thinning			
1	ID5B1_1	12	650	1067	-417	39%
2	ID5B1_2	13	650	1000	-350	35%
3	2/MT1/12	14	650	1133	-483	43%
	Average		**650**	**1067**	**-417**	**39%**
			Second thinning			
4	2/S16b/19	17	400	633	-233	37%
5	2/S16b/20	17	400	733	-333	45%
6	2/S16b/7	17	400	633	-233	37%
7	2/S16b/6	17	400	633	-233	37%
8	2/S16b/9	17	400	600	-200	33%
9	2/S16b/8	17	400	567	-167	29%
10	2/S16b/1a	18	400	633	-233	37%
11	2/S16b/31	18	400	733	-333	45%
12	2/S16b/4	18	400	667	-267	40%
13	2/S16b/5	18	400	500	-100	20%
14	2/S16b/10	18	400	467	-67	14%
15	2/S16b/12	18	400	700	-300	43%
16	2/KB2/26.2	19	400	867	-467	54%
17	2/S16a/34	19	400	933	-533	57%
18	2/S16c/34	19	400	900	-500	56%
19	2/S16b/32	19	400	767	-367	48%
Average			**400**	**685**	**-285**	**40%**

NB: Negative sign **(-)** in stocking deviation indicates an overstocking

Appendix 4: Compartments summary for thinned and unthinned Pinus patula at Sao Hill Forest Plantation

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/S16b/10	1	18	29.4	1.5314	18.9678	633	Thinned
2/S16b/10	2	18	30.1	2.2463	27.9169	433	Thinned
2/S16b/10	3	18	30.8	2.0846	25.8144	467	Thinned
2/S16b/10	4	18	31.5	1.7831	22.1995	433	Thinned
2/S16b/10	5	18	32.3	1.6222	19.9763	667	Thinned
2/S16b/10	6	18	33.0	1.5685	19.3031	467	Thinned
2/S16b/10	7	18	33.7	1.6322	20.1187	633	Thinned
2/S16b/10	8	18	34.4	1.8706	23.2080	433	Thinned
2/S16b/10	9	18	35.2	1.5124	18.6812	567	Thinned
2/S16b/10	10	18	35.9	1.3249	16.2020	500	Thinned
2/S16b/10	11	18	25.6	1.7173	21.2386	467	Thinned
2/S16b/10	12	18	24.8	1.6084	19.8875	600	Thinned
2/S16b/10	13	18	30.2	2.3852	29.7690	367	Thinned
2/S16b/10	14	18	26.8	1.8750	23.2319	567	Thinned
2/S16b/10	15	18	26.7	1.8586	23.0073	533	Thinned
2/S16b/10	16	18	23.5	1.4450	17.7024	667	Thinned
2/S16b/10	17	18	26.7	1.8707	23.0978	633	Thinned
2/S16b/10	18	18	24.8	1.6031	19.6780	533	Thinned
2/S16b/10	19	18	24.4	1.5545	19.1398	500	Thinned
2/S16b/10	20	18	27.4	1.9591	24.2406	500	Thinned
2/S16b/10	21	18	28.4	2.1085	26.1974	533	Thinned
2/S16b/10	22	18	25.2	1.6577	20.3913	400	Thinned
2/S16b/10	23	18	26.1	1.7786	21.8707	500	Thinned
2/S16b/10	24	18	26.8	1.8781	23.1786	567	Thinned
2/S16b/10	25	18	24.5	1.5721	19.3395	400	Thinned
2/S16b/10	26	18	26.0	1.7727	21.9758	500	Thinned
2/S16b/10	27	18	25.5	1.6964	20.9549	433	Thinned
2/S16b/10	28	18	26.1	1.7812	21.9403	400	Thinned
2/S16b/10	29	18	25.2	1.6617	20.4313	500	Thinned
2/S16b/10	30	18	27.1	1.9233	23.9042	433	Thinned
		18	28.3	52.8832	653.5648	509	

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/MT5/31	1	18	20.6	1.1117	13.5950	900	Unthinned
2/MT5/31	2	18	21.7	1.2355	15.1531	1333	Unthinned
2/MT5/31	3	18	21.4	1.1986	14.6786	833	Unthinned
2/MT5/31	4	18	22.3	1.3053	16.0663	1200	Unthinned
2/MT5/31	5	18	18.1	0.9592	11.7964	900	Unthinned
2/MT5/31	6	18	22.3	1.2994	15.9673	1333	Unthinned
2/MT5/31	7	18	19.4	0.9809	12.0054	933	Unthinned
2/MT5/31	8	18	20.0	1.0415	12.7842	1067	Unthinned
2/MT5/31	9	18	22.1	1.2738	15.6645	1033	Unthinned
2/MT5/31	10	18	22.7	1.3538	16.7242	867	Unthinned
2/MT5/31	11	18	21.5	1.2120	14.9079	1000	Unthinned
2/MT5/31	12	18	24.5	1.5746	19.6922	900	Unthinned
2/MT5/31	13	18	20.8	1.1371	13.9011	767	Unthinned
2/MT5/31	14	18	19.3	0.9792	11.9978	800	Unthinned
2/MT5/31	15	18	19.2	0.9645	11.8570	1033	Unthinned
2/MT5/31	16	18	19.2	0.9695	11.9079	1100	Unthinned
2/MT5/31	17	18	21.0	1.1501	14.0748	900	Unthinned
2/MT5/31	18	18	23.2	1.4044	17.3251	700	Unthinned
2/MT5/31	19	18	22.6	1.3342	16.3507	800	Unthinned
2/MT5/31	20	18	23.1	1.3973	17.3053	800	Unthinned
2/MT5/31	21	18	24.3	1.5495	19.0237	533	Unthinned
2/MT5/31	22	18	24.0	1.5085	18.5387	767	Unthinned
2/MT5/31	23	18	17.8	0.8260	10.1407	1133	Unthinned
2/MT5/31	24	18	19.5	0.9924	12.1617	1200	Unthinned
2/MT5/31	25	18	23.2	1.4144	17.3652	600	Unthinned
2/MT5/31	26	18	24.6	1.5866	19.6786	1133	Unthinned
2/MT5/31	27	18	21.2	1.1746	14.5162	900	Unthinned
2/MT5/31	28	18	19.9	1.0317	12.6927	1067	Unthinned
2/MT5/31	29	18	23.4	1.4307	17.6654	1067	Unthinned
2/MT5/31	30	18	18.8	0.9265	11.3530	1167	Unthinned
Total		18	20.8	40.1546	446.8906	959	

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/S16a/34	1	19	26.1	1.7802	22.2328	633	Thinned
2/S16a/34	2	19	22.7	1.3475	16.4836	700	Thinned
2/S16a/34	3	19	22.0	1.2716	15.6113	800	Thinned
2/S16a/34	4	19	24.0	1.5083	18.6431	767	Thinned
2/S16a/34	5	19	26.0	1.7746	21.9216	633	Thinned
2/S16a/34	6	19	29.9	2.3321	29.2134	500	Thinned
2/S16a/34	7	19	22.8	1.3631	16.7317	767	Thinned
2/S16a/34	8	19	26.7	1.8596	23.1278	633	Thinned
2/S16a/34	9	19	33.2	2.8794	36.6744	367	Thinned
2/S16a/34	10	19	30.6	2.4552	30.9672	400	Thinned
2/S16a/34	11	19	27.1	1.9240	23.9892	733	Thinned
2/S16a/34	12	19	33.5	2.9435	37.5161	333	Thinned
2/S16a/34	13	19	32.8	2.8196	35.9842	400	Thinned
2/S16a/34	14	19	29.6	2.2924	28.8658	467	Thinned
2/S16a/34	15	19	29.0	2.2021	27.5265	567	Thinned
2/S16a/34	16	19	30.7	2.4740	31.2689	367	Thinned
2/S16a/34	17	19	28.0	2.0488	25.3791	533	Thinned
2/S16a/34	18	19	27.4	1.9621	24.2912	467	Thinned
2/S16a/34	19	19	25.7	1.7257	21.3371	633	Thinned
2/S16a/34	20	19	24.6	1.5862	19.6046	833	Thinned
2/S16a/34	21	19	24.7	1.6010	19.7179	933	Thinned
2/S16a/34	22	19	26.8	1.8829	23.4986	433	Thinned
2/S16a/34	23	19	24.5	1.5661	19.2940	633	Thinned
2/S16a/34	24	19	30.6	2.4462	30.8151	400	Thinned
2/S16a/34	25	19	29.6	2.2872	28.7786	600	Thinned
2/S16a/34	26	19	29.7	2.3137	28.9152	600	Thinned
2/S16a/34	27	19	26.8	1.8784	23.5496	500	Thinned
2/S16a/34	28	19	26.6	1.8461	23.0217	600	Thinned
2/S16a/34	29	19	27.9	2.0385	25.4147	567	Thinned
2/S16a/34	30	19	28.6	2.1460	26.9845	500	Thinned
2/S16a/34		19	27.6	60.5561	757.3593	577	Thinned

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/MT5/24	1	19	20.6	1.1146	13.6556	933	Unthinned
2/MT5/24	2	19	23.2	1.4110	17.3717	833	Unthinned
2/MT5/24	3	19	24.3	1.5447	18.9410	933	Unthinned
2/MT5/24	4	19	22.3	1.3055	15.9978	1000	Unthinned
2/MT5/24	5	19	21.4	1.2030	14.7521	967	Unthinned
2/MT5/24	6	19	21.9	1.2590	15.4731	900	Unthinned
2/MT5/24	7	19	19.8	1.0256	12.5419	900	Unthinned
2/MT5/24	8	19	23.8	1.4874	18.2876	867	Unthinned
2/MT5/24	9	19	22.8	1.3560	16.6219	967	Unthinned
2/MT5/24	10	19	21.6	1.2220	15.0163	867	Unthinned
2/MT5/24	11	19	24.1	1.5217	18.7932	800	Unthinned
2/MT5/24	12	19	21.4	1.1942	14.6596	933	Unthinned
2/MT5/24	13	19	21.8	1.2393	15.2110	967	Unthinned
2/MT5/24	14	19	22.7	1.3454	16.5066	900	Unthinned
2/MT5/24	15	19	23.4	1.4366	17.6391	933	Unthinned
2/MT5/24	16	19	22.0	1.2662	15.5942	967	Unthinned
2/MT5/24	17	19	19.6	1.0060	12.3075	867	Unthinned
2/MT5/24	18	19	21.7	1.2266	14.9931	1000	Unthinned
2/MT5/24	19	19	22.5	1.3250	16.3117	867	Unthinned
2/MT5/24	20	19	24.1	1.5171	18.7036	767	Unthinned
2/MT5/24	21	19	23.9	1.4927	18.2621	800	Unthinned
2/MT5/24	22	19	22.7	1.3534	16.5527	867	Unthinned
2/MT5/24	23	19	23.2	1.4086	17.2609	800	Unthinned
2/MT5/24	24	19	22.4	1.3090	16.0362	767	Unthinned
2/MT5/24	25	19	23.1	1.3915	17.1325	900	Unthinned
2/MT5/24	26	19	25.3	1.6684	20.5883	833	Unthinned
2/MT5/24	27	19	24.4	1.5592	19.2048	900	Unthinned
2/MT5/24	28	19	21.7	1.2328	15.0620	900	Unthinned
2/MT5/24	29	19	24.1	1.5217	18.7284	800	Unthinned
2/MT5/24	30	19	24.6	1.5873	19.5623	933	Unthinned

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/S16a/31	1	19	21.3	1.1900	14.6545	1067	Thinned
2/S16a/31	2	19	26.5	1.8311	22.7714	1100	Thinned
2/S16a/31	3	19	22.5	1.3304	16.4292	767	Thinned
2/S16a/31	4	19	23.1	1.4002	17.3197	833	Thinned
2/S16a/31	5	19	20.3	1.0778	13.2208	867	Thinned
2/S16a/31	6	19	22.7	1.3480	16.6126	733	Thinned
2/S16a/31	7	19	26.6	1.8583	23.2241	600	Thinned
2/S16a/31	8	19	23.9	1.4953	18.4882	933	Thinned
2/S16a/31	9	19	22.4	1.3113	16.1933	733	Thinned
2/S16a/31	10	19	24.9	1.6265	20.0778	600	Thinned
2/S16a/31	11	19	25.7	1.7282	21.3525	600	Thinned
2/S16a/31	12	19	20.0	1.0471	12.7746	633	Thinned
2/S16a/31	13	19	22.6	1.3378	16.6008	533	Thinned
2/S16a/31	14	19	27.7	2.0053	24.8464	667	Thinned
2/S16a/31	15	19	22.6	1.3307	16.3188	867	Thinned
2/S16a/31	16	19	22.9	1.3694	16.8252	833	Thinned
2/S16a/31	17	19	19.1	0.9549	11.6644	900	Thinned
2/S16a/31	18	19	24.5	1.5713	19.3121	833	Thinned
2/S16a/31	19	19	21.5	1.2040	14.7139	967	Thinned
2/S16a/31	20	19	21.2	1.1812	14.4916	1033	Thinned
2/S16a/31	21	19	21.8	1.2487	15.3270	833	Thinned
2/S16a/31	22	19	24.3	1.5401	19.1189	833	Thinned
2/S16a/31	23	19	25.7	1.7228	21.3596	800	Thinned
2/S16a/31	24	19	23.2	1.4106	17.3339	800	Thinned
2/S16a/31	25	19	22.4	1.3108	16.1827	867	Thinned
2/S16a/31	26	19	25.2	1.6594	20.5941	500	Thinned
2/S16a/31	27	19	24.4	1.5576	19.3703	500	Thinned
2/S16a/31	28	19	25.0	1.6307	20.1669	700	Thinned
2/S16a/31	29	19	24.1	1.5252	18.8928	967	Thinned
2/S16a/31	30	19	27.9	2.0304	25.3019	633	Thinned
		19	23.5	43.8350	541.5399	784	

Compartment	Plot No.	Age (yrs)	Quadratic mean diameter (QMD)	Basal area/ha (m^2/ha)	Volume/ha (m^3/ha)	Stocking (N)	Thinning status
2/MT5/34.2	1	19	21.7	1.2269	15.0219	1033	Unthinned
2/MT5/34.2	2	19	21.4	1.1944	14.6203	833	Unthinned
2/MT5/34.2	3	19	22.9	1.3778	16.8309	767	Unthinned
2/MT5/34.2	4	19	23.7	1.4663	18.0832	700	Unthinned
2/MT5/34.2	5	19	21.0	1.1492	14.0924	1233	Unthinned
2/MT5/34.2	6	19	23.7	1.4648	18.0781	800	Unthinned
2/MT5/34.2	7	19	21.0	1.1500	14.0515	867	Unthinned
2/MT5/34.2	8	19	19.0	0.9421	11.5220	1167	Unthinned
2/MT5/34.2	9	19	18.0	0.8522	10.4338	1433	Unthinned
2/MT5/34.2	10	19	18.4	0.8846	10.8200	1200	Unthinned
2/MT5/34.2	11	19	19.8	1.0259	12.5435	967	Unthinned
2/MT5/34.2	12	19	21.9	1.2553	15.4469	700	Unthinned
2/MT5/34.2	13	19	21.3	1.1868	14.6495	1100	Unthinned
2/MT5/34.2	14	19	21.2	1.1806	14.4847	800	Unthinned
2/MT5/34.2	15	19	18.0	0.8445	10.3341	1233	Unthinned
2/MT5/34.2	16	19	20.2	1.0628	13.0951	1100	Unthinned
2/MT5/34.2	17	19	22.7	1.3532	16.6492	867	Unthinned
2/MT5/34.2	18	19	19.1	0.9544	11.6874	867	Unthinned
2/MT5/34.2	19	19	21.6	1.2249	15.0146	1033	Unthinned
2/MT5/34.2	20	19	24.8	1.6033	19.8084	533	Unthinned
2/MT5/34.2	21	19	26.5	1.8309	22.6302	433	Unthinned
2/MT5/34.2	22	19	20.0	1.0441	12.7945	1267	Unthinned
2/MT5/34.2	23	19	21.7	1.2280	15.0783	933	Unthinned
2/MT5/34.2	24	19	25.2	1.6594	20.4576	600	Unthinned
2/MT5/34.2	25	19	20.7	1.1232	13.8028	867	Unthinned
2/MT5/34.2	26	19	18.2	0.8697	10.6231	1133	Unthinned
2/MT5/34.2	27	19	19.0	0.9399	11.5024	633	Unthinned
2/MT5/34.2	28	19	19.1	0.9588	11.7294	1233	Unthinned
2/MT5/34.2	29	19	18.3	0.8755	10.6804	1200	Unthinned
2/MT5/34.2	30	19	18.7	0.9137	11.1530	867	Unthinned
		19	21.0	34.8433	427.7192	947	