AGROP-24

THE MINIMUM REQUIRED YIELD FOR PROFITABLE SAWTIMBER PRODUCTION FROM *PINUS PATULA* IN THE ESCARPMENT AREA OF MPUMALANGA

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by

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Thesis presented for the degree of Master of Science in Forestry at the University of Stellenbosch

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DECLARATION

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

Signature: MÁRIO PAULO FALCÃO .... Date: 20/11/98 ....

OPSOMMING

In hierdie studie word die minimum verlangde opbrengs, wat vereis word vir winsgewende produksie van *Pinus patula* saaghout in die platorand-gebied van Mpumalanga, bepaal. Netto Huidige Waarde en Interne Renteverdienste word as finansiële wingewendheidsmaatstawwe gebruik. Alle koste komponente is 1996 kostes wat verkry is uit die koste monitering-stelsel van Bosbou-Ekonomiese Dienste (FES, 1997). Die pryse van pulphout en saagblokke is 1996 pryse wat gebruik is in die betrokke studiegebied.

Die prima-oortrekkingskoers vir die tydperk 1978 tot 1997, soos gebruik deur Standard Bank, is gebruik om die Nominale Koste van Kapitaal te beraam as 17%. Deur gebruik te maak van regressie ontleding is die langtermyn inflasiekoers beraam as 13%. Gebaseer op hierdie twee beraamde koerse is die Reële Koste van Kapitaal bereken as 3,5% en in die studie gebruik.

Om die minimum vereiste opbrengsvermoë te bepaal, is ook twee ander scenarios gebruik ('n lae Reële Koste van Kapitaal van 2,0% en 'n hoë Reële Koste van Kapitaal van 5,0%). 'n Scenario-benadering is gevolg omdat hierdie studie nie bedoel is om op 'n spesifieke houtkweker in die studiegebied van toepassing te wees nie.

Deur gebruik te maak van die FINROT (FINansiële ROTasie) rekenaarprogram is 63 kontantstrome, waarvan die Gemiddelde Jaarlikse Aanwas op 20 jaar (GJA_{20}), wissel van 5 m^3/ha/jaar tot 25 m^3/ha/jaar, ontleed. Die resultate toon dat die minimum GJA_{20} wat vereis word vir winsgewende produksie van *Pinus patula* saaghout in die platorand-gebied van Mpumalanga, 14, 17 en 20 m^3/ha/jaar is teen 'n Reële Koste van Kapitaal van onderskeidelik 2,0%, 3,5% en 5,0%.

Die marginale GJA_{20} soos dit in hierdie studie bevind is, moet nie gesien word as iets wat vas of onveranderbaar is nie. Dit kan verminder as gevolg van die onderstaande faktore:

a) Jaarlikse stygings in die nominale pryse van saaghout wat tred hou met inflasie;

b) Ontginning van uitvoermarkte ten einde die produkte teen hoër pryse te verkoop;

c) Grondontledings van groeiplekke en toepaslike toediening van kunsmis;

d) Korrekte keuse van species vir groeiplekke; en

e) Effektiewe en doeltreffende uitvoering van aktiwiteite soos voorbereiding van groeiplek, plant, onkruidbestryding, snoei, dunning en kaalkap ten einde die optimale opbrengs op investerings te verdien.

ABSTRACT

This study establishes the minimum required yield for profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga. Net Present Value and Internal Rate of Return are used as financial profitability criteria. All cost components are 1996 costs derived from the cost monitoring system of Forestry Economics Services (FES, 1997). The prices of pulpwood and sawlogs are 1996 prices used in the escarpment area of Mpumalanga.

The prime overdraft rate from 1978 to 1997, used by Standard Bank, was used to estimate the Nominal Cost of Capital as 17%. By making use of regression analysis the long-term inflation rate was estimated as 13%. Based on these two estimated values for the Nominal Cost of Capital and the inflation rate, a Real Cost of Capital of 3,5% was calculated and used in the study.

Two other scenarios were also used (a low Real Cost of Capital of 2,0% and a high Real Cost of Capital of 5,0%) to determine the minimum required yield. A scenario approach was followed in the discounted cash flow analysis, because this study is not intended to be applicable to a specific timber grower in the escarpment area of Mpumalanga.

By means of the FINROT (FINancial ROTation) computer program 63 cash flows were analyzed. The result is that a minimum Mean Annual Increment at 20 years of age (MAI_{20}) of 14, 17 and 20 m^3/ha/*annum* is required for profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga at a Real Cost of Capital equal to 2,0%; 3,5% and 5,0% respectively.

The marginal MAI_{20} as found in this study must not be thought of as something fixed or immutable. It can be reduced by the following:

a) Annual increases in the nominal price of sawtimber which keep pace with inflation;

b) Exploitation of export markets in order to sell the products at higher prices;

c) Soil analysis of growing sites and appropriate fertilizer applications;

d) Effective matching of species to sites; and

e) Effective and efficient execution of activities such as soil preparation, planting, weeding, pruning, thinning and clearfelling in order to get the optimum yield on invested funds.

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LIST OF SYMBOLS AND ABBREVIATIONS

BCR	Benefit-Cost Ratio
CF	Clearfelling
COC	Cost of Capital
COMPAS	Computerised Plantation Analysis System
CPI	Consumer Price Index
CSS	Central Statistical Service
DNFFB	Direcção Nacional de Florestas e Fauna Bravia
E	Establishment
EAI	Equivalent Annual Income
E-Tvl	Eastern Transvaal
FES	Forestry Economics Services
FPI	Forestry Price Index
GAC	General Annual Cost
ha	Hectare
H_T	Total Height
IRR	Internal Rate of Return
LEV	Land Expectation Value
m	Meter
mm	Millimeter
m^2	Square meter
m^3	Cubic meter
MAI_{20}	Mean Annual Increment (m^3/ha/*annum*) at age 20 years

NPV	Net Present Value
NPVI	Net Present Value for Infinite series of rotations
P	Pruning
PPI	Production Price Index
PI	Profitability Index
R	Rotation Age (years)
RCOC	Real Cost of Capital
RDR	Real Discount Rate
RIRR	Real Internal Rate of Return
R/ha	Rand *per* hectare
R/ha/*annum*	Rand *per* hectare *per annum*
R/m^3	Rand *per* cubic meter
R/ton	Rand *per* ton
SA	South Africa
SATGA	South African Timber Growers' Association
SAFCOL	South African Forestry Company Limited
SPH	Stems *per* hectare
T	Thinning
tons	Metric ton (1 000 kg)
U Vol/ha	Utilisable volume *per* hectare
W	Weed control
W-Cape	Western Cape
Yr	Year

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1. INTRODUCTION

In South Africa, commercial tree growing is based mainly on introduced tree species. The species which are of major commercial value are *Pinus patula, Pinus elliottii, Pinus taeda, Pinus radiata, Pinus pinaster, Eucalyptus grandis* and *Acacia mearnsii.*

The commercial timber plantation area in 1996, in South Africa, was 1 486 923 ha. Pine and other softwood species occupied 53% of the total area under commercial plantations in 1996. The area distribution under pines was as follows: *Pinus patula* comprised 373 951 ha (49,3%), *Pinus elliottii* 219 342 ha (28,9%), *Pinus taeda* 63 541 ha (8,4%), *Pinus radiata* 67 809 ha (8,9%) and *Pinus pinaster* 33 851 ha (4,5%) (Department of Water Affairs and Forestry, 1997).

According to Hinze (1993), in South Africa there are mainly three basic management objectives for the growing of pine, namely:

a) Softwood sawlog and veneer production

b) Pine pole production

c) Pine pulpwood production

The main products generated by the timber processing industry in South Africa are structural timber, industrial timber, wooden poles, mining timber, wood-based panel products, woodpulp, paper and paperboard, matches as well as wood chips. In 1995/1996 the income generated from the sales and transfers of timber products in South Africa was R8 996 million, of which R6 947 million was generated from pulp, paper and paperboard and R904 million came from sawn timber (Department of Water Affairs and Forestry, 1997).

1.1 The statement of the problem

A forestry enterprise, like all other business enterprises, can only survive in the long term if it is profitable. One of the most important factors which determines profitability in forestry is the yield capacity of the growing site. The yield capacity of the growing site in forestry is indicated by the Mean Annual Increment of the trees at 20 years of age (MAI_{20}). It is measured in cubic meters of increment *per* hectare *per* year (m^3/ha/*annum*).

It is important for every timber grower to identify unprofitable stands in his plantation and also to identify unprofitable bare land on his estate if he wants to expand his plantation area. The required MAI_{20} for the profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga, one of the most important forestry areas in South Africa, is still unknown.

1.2 Sub-problems

It is necessary to solve a number of sub-problems before the problem stated in paragraph 1.1 can be solved.

1.2.1 Schedule of activities

A schedule of activities indicates activities and ages at which these activities take place. This schedule will be used to construct a cash flow table that shows the points in time (ages) when various activities take place, as well as the cost and/or income related with activities during the rotation period for MAI_{20} from 5 to 25 m^3/ha/*annum*.

a) Weed control

The frequency and timing of the application of weed control can differ from one region to another and also according to species. This sub-problem arises in determining when the weed control operations should be done and how many times during the rotation period it should be repeated.

b) Pruning and thinning regimes

The pruning schedules in South Africa have been changing since 1938 (Theron, 1997a). Determining how many pruning and thinning operations there should be and when these are supposed to be done during the rotation period, is a sub-problem in this study.

c) Clearfelling age

The clearfelling age is the actual age at which a stand is clearfelled and rotation is the planned period between the regeneration (or establishment) of a stand and its final harvesting. A sub-problem is how to determine the average clearfelling age which should be used in this study.

1.2.2 Determination of the financial yield

During the rotation period, activities such as thinning and clearfelling at rotation age will generate certain volumes of sawlogs and pulpwood. A sub-problem arises in determining the marketable yield (volume) obtained from thinning and clearfelling and also the prices and revenues from the sales of these volumes.

1.2.3 Determination of the cost component of cash flows

Forestry activities such as establishment, weed control, pruning, thinning, clearfelling, forest protection and conservation, administration and maintenance involve costs. A sub-problem arises in how to determine the cost *per* activity that should be used in the calculations.

1.2.4 Choice of a financial criterion

Many different financial criteria that can be used to evaluate forestry projects, for example, Net Present Value, Internal Rate of Return, Benefit-Cost Ratio, Profitability

Index, Land Expectation Value and Equivalent Annual Income are available. The most appropriate financial criterion to determine the minimum required yield potential for profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga must be identified.

1.2.5 Discount and inflation rates

Other sub-problems in this study are to decide which discount rate to use for discounting and how to deal with inflation.

1.2.6 Computer program

A number of computer programs that can be used for financial analysis of forestry investments are available (CASH, FINROT, BOSFIN, FAUST, FORVAL, Quick-Silver and YIELDplus). In this particular study, the most appropriate and most readily available computer program to determine the minimum required yield potential for profitable production of sawtimber from *Pinus patula* will be identified.

1.3 Objective and importance of the study

The main objective of this study is to determine the minimum required Mean Annual Increment at 20 years of age, for the profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga.

The availability of such a marginal MAI_{20} will help management to:

a) get insight into the required yield potential for profitable forestry;

b) apply measures such as fertilization to increase profitability;

c) decide on the termination of certain unprofitable forestry projects;

d) take decisions on the afforestation of fallow land on their estates; and

e) decide on the acquisition of new land.

1.4 Delimitation of the study

1.4.1 Region

In South Africa the commercial timber plantations are divided into 12 forestry zones: Northern Transvaal, Eastern Transvaal, Central Transvaal, South-Eastern Transvaal, Maputaland, Zululand, Natal Midlands, Northern Natal, Southern Natal, Eastern Cape, Southern Cape and Western Cape. The country is also divided into nine provinces (Northern Transvaal, Mpumalanga, Gauteng, North West, Free State, KwaZulu-Natal, Northern Cape, Eastern Cape and Western Cape) and the provincial borders do not coincide with the forestry zone borders.

The largest area of commercial timber plantations in Southern Africa is situated along the Mpumalanga escarpment north of Nelspruit (Schutz, 1990). According to the Department of Water Affairs and Forestry (1997), South Eastern and Eastern Transvaal (currently inside the Mpumalanga province) are the two biggest areas with *Pinus patula* plantations in South Africa, with a total of 179 271 ha of this species. Eastern Transvaal on the other hand, has the largest commercial timber plantations for the production of sawtimber (about 1 021 574 m^3/*annum*). It is also the third largest pulpwood production region (1 714 903 m^3/*annum*). For this reason the escarpment area of Mpumalanga (Eastern Transvaal which corresponds with zone 2 in Figure 1.1) is chosen as study area.

The commercial timber plantations in the escarpment area of Mpumalanga lies between 24°40' and 25°80' South latitude and between 31°00' and 32°00' East longitude. The plantations stretch from the Crocodile River near Nelspruit in the South, along the Mpumalanga escarpment to Mariepskop in the North. Most of the area lies within the Pilgrim's Rest magisterial district, but portions of the Witrivier, Nelspruit and Lydenburg magisterial districts are also included, but highveld areas of Mpumalanga are excluded.

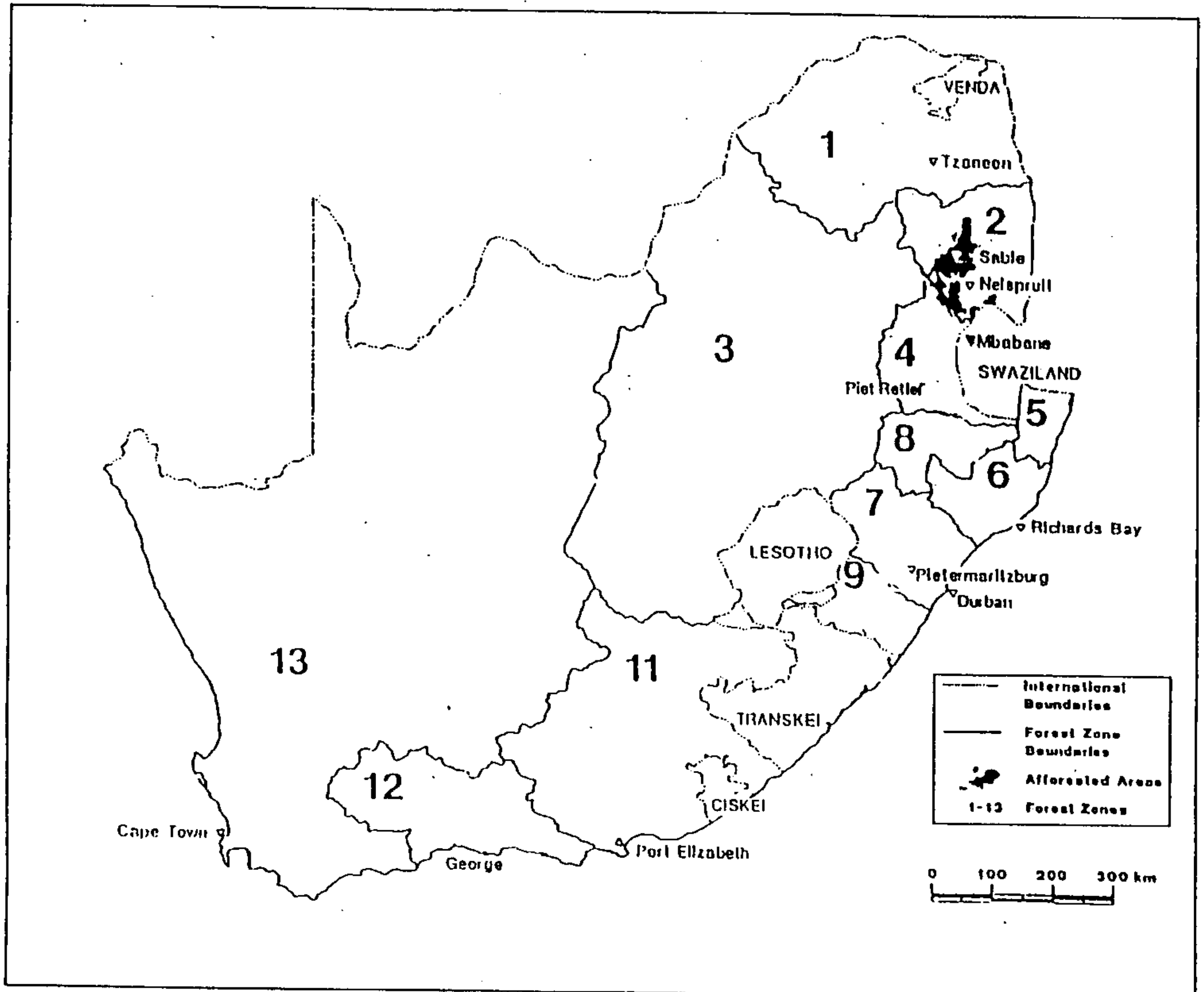

Figure 1.1: Map of forestry zones in South Africa showing afforested areas in the escarpment area of Mpumalanga (Source: Adapted from Directorate of Forestry, 1984)

1.4.2 Tree species

The escarpment area of Mpumalanga has the following commercial softwood species: *Pinus patula, Pinus elliottii* and *Pinus taeda*. In terms of commercial hardwood, *Eucalyptus grandis* is the species of major importance (Department of Water Affairs and Forestry, 1997 and Schutz, 1990).

Eucalyptus grandis and *Pinus patula* are the two main species in the Eastern Transvaal, with 98 957 ha of *Eucalyptus grandis* and 81 279 ha of *Pinus patula*. The majority of the *Eucalyptus grandis* plantations are managed to produce pulpwood and *Pinus patula* plantation areas are mainly managed to produce sawtimber. *Pinus patula* is the most widely planted softwood species not only within the study area, but also in the whole of Southern Africa. For this reason *Pinus patula* is chosen for this study.

1.4.3 Product

In this study, the main product of investigation is sawtimber produced from *Pinus patula* plantations in the escarpment area of Mpumalanga and pulpwood is considered a by-product.

According to Olivier (1993), sawlogs are classified in seven classes as a function of thin end diameter and length as indicated in Table 1.1.

Class	Diameter (cm)	Length (m)
A	13 - 17,9	1,8 - 3,3
B1	18 - 25,9	1,8 - 3,3
B2	18 - 25,9	>3,6
C1	26 - 33,9	1,8 - 3,3
C2	26 - 33,9	>3,6
D1	>34	1,8 - 3,3
D2	>34	>3,6

Table 1.1: Sawlog classification used in South Africa (Source: Olivier, 1993)

1.5 Assumptions in the study

The following assumptions are necessary for the purpose of the calculations in this study:

a) All costs of activities and the revenues from activities are calculated at 1996 prices (the latest available) and will be considered to be affected identically by inflation;

b) The market value of the land (R/ha) is the same for all the different MAI_{20} sites;

c) The establishment and pruning costs are the same for all the different MAI_{20} sites in the escarpment area of Mpumalanga;

d) All costs, revenues, discount rates and all other variables are known with certainty;

e) The outflows and inflows of cash take place at the end of the different years;

2. REVIEW OF THE RELATED LITERATURE

2.1 *Pinus patula*

Pinus patula originally from Mexico, grow to a height of 30 m or more and reach diameters of up to 1,2 m. It occurs naturally between 18° and 24° North over an elevation range of 1 650 m to 3 000 m. Annual rainfall ranges from 1 000 mm to 1 500 mm (Wormald, 1975).

This species is most frequently planted outside its natural growing area. It was first introduced to South Africa from Mexico in 1907 (Poynton, 1979). This was followed by further introduction, also from Mexico, up until 1928. Thereafter all seed was supplied by local sources which had started to become productive in the early 1920's (Wormald, 1975 and Poynton, 1979). The areas of *Pinus patula* for four other Southern African countries are indicated in Table 2.1, emphasizing the importance of *Pinus patula* in the region.

Country	Area (ha)
Swaziland	55 076 in 1972
Mozambique	23 000 in 1995
Zimbabwe	42 150 in 1975
Malawi	45 560 in 1998

Table 2.1: Pinus patula plantation areas in four Southern African countries (Source: Poynton, 1979, DNFFB, 1995 and Munthali and Stewart, 1998)

2.1.1 *Pinus patula* in South Africa

According to the Department of Water Affairs and Forestry (1997), South Africa in 1996 had 373 951 hectares of *Pinus patula* plantations. The public sector owned 34,8% of the area planted with *Pinus patula* and the private sector owned the rest

(65,2%). Table 2.2 indicates the *Pinus patula* plantation areas (ha), the ownership and the respective zones in South Africa in 1996.

Pinus patula produces a light softwood which is used mainly for structural purposes and for the manufacturing of pulp and paper (Keet, 1974). In South Africa, the wood from *Pinus patula* plantations is also used to produce furniture, laminates, mining timber, particle board, poles and droppers, matchwood, firewood and charcoal (Department of Water Affairs and Forestry, 1997).

2.1.2 *Pinus patula* in the escarpment area of Mpumalanga

The future of *Pinus patula* as a timber tree of major importance in the cooler, mist-belt regions of the summer rainfall area in South Africa seems guaranteed. This species has proved to be one of the most vigorous (Poynton, 1979). In the escarpment area of Mpumalanga, the plantation areas have increased during the period from 1991 to 1996 (refer to Figure 2.1).

Figure 2.2 shows the distribution of the commercial timber plantations in terms of softwood and hardwood in the escarpment area of Mpumalanga, in 1996. The softwood plantation area (186 016 ha) is approximately 1,8 times bigger than the hardwood plantation area (103 767 ha). The ownership of softwood plantations in the escarpment area of Mpumalanga, in 1996 is shown in Figure 2.3.

The percentage distribution of the three main pine species planted in the escarpment area of Mpumalanga in 1996 is illustrated in Figure 2.4. *Pinus patula* occupied 81 279 ha; *Pinus elliottii* comprised 68 394 ha; *Pinus taeda* constituted 29 106 ha and other species comprised 7 237 ha (Department of Water Affairs and Forestry, 1997).

Zones in South Africa	Ownership (ha)		Area (ha)	Percentage of the total area
	Private	Public		
Northern Transvaal	9 938	7 058	16 996	4,5
Eastern Transvaal	39 920	41 359	81 279	21,7
Central Transvaal	4 116	3 269	7 385	2,0
South-Eastern Transvaal	77 027	20 965	97 992	26,2
Zululand	3 098	951	4 049	1,1
Natal Midlands	49 961	4 266	54 227	14,5
Northern Natal	8 078	1 100	9 178	2,5
Southern Natal	26 395	8 046	34 441	9,2
Eastern Cape	23 695	43 054	66 749	17,9
Southern-Western Cape	1 625	30	1 655	0,4
Total	243 853	130 098	373 951	100,0

Table 2.2: Pinus patula plantation areas, in 1996, in different zones (Source: Department of Water Affairs and Forestry, 1997)

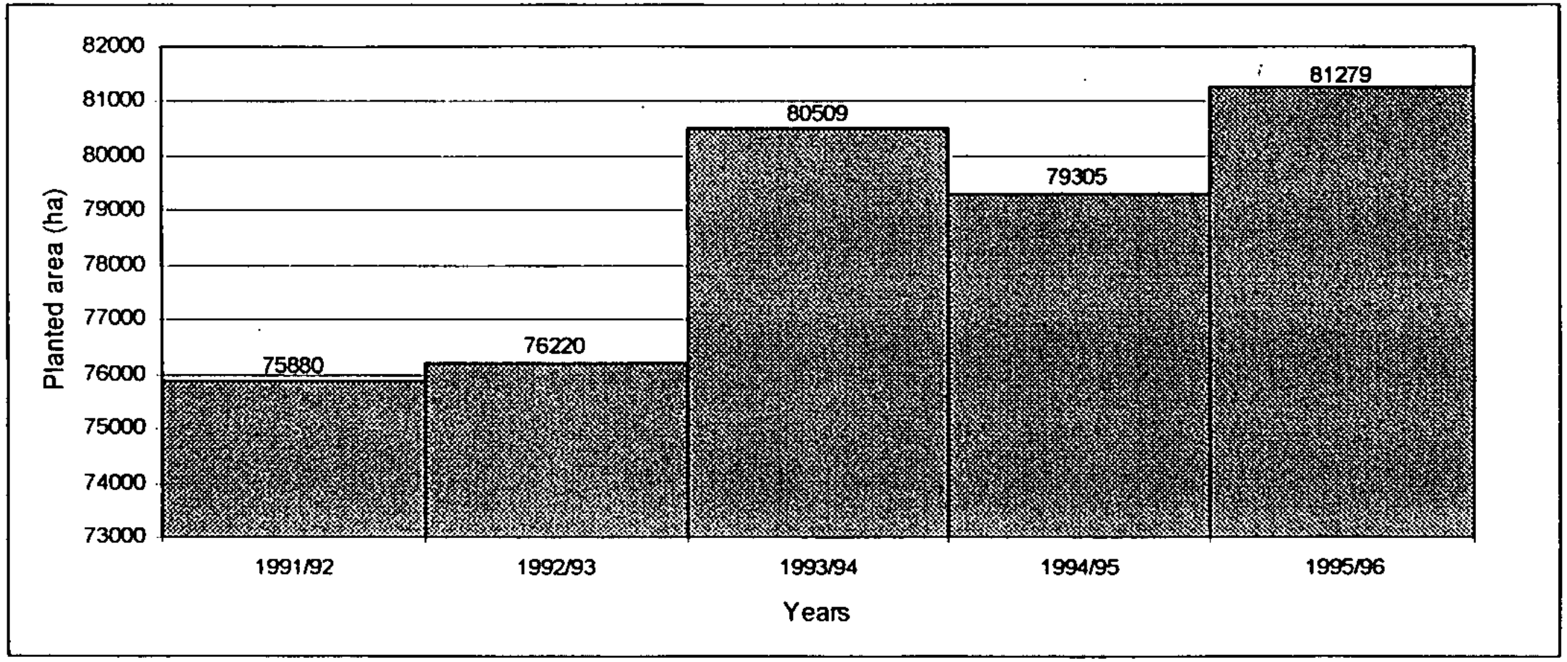

Figure 2.1: Pinus patula plantation area in the escarpment area of Mpumalanga since 1991/92 (Source: Department of Water Affairs and Forestry, 1993, 1994, 1995, 1996 and 1997)

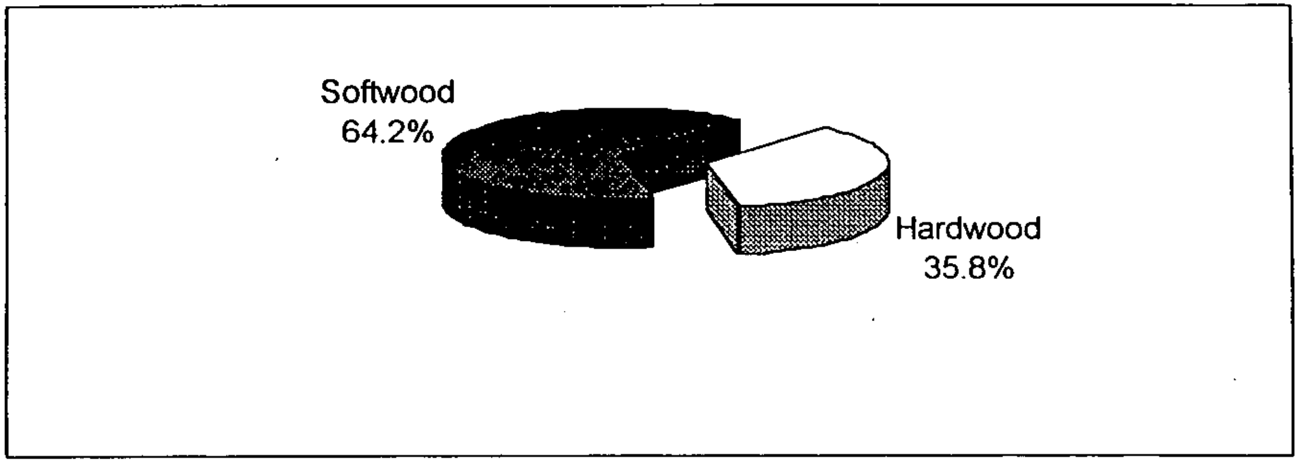

Figure 2.2: Plantation distribution in the escarpment area of Mpumalanga (Source: Department of Water Affairs and Forestry, 1997)

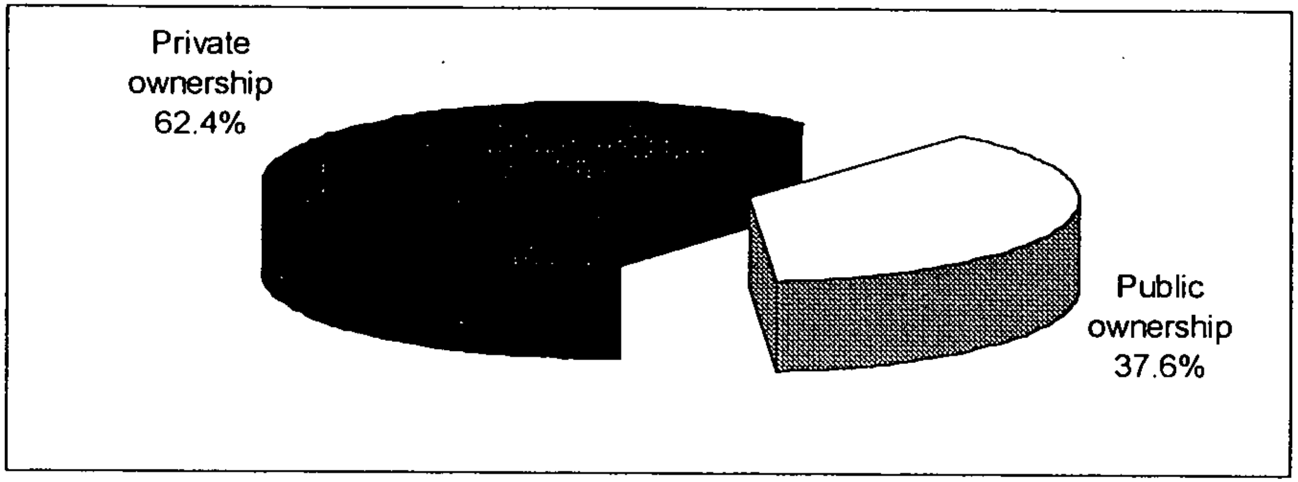

Figure 2.3: Ownership of the plantations of softwood in the escarpment area of Mpumalanga (Source: Department of Water Affairs and Forestry, 1997)

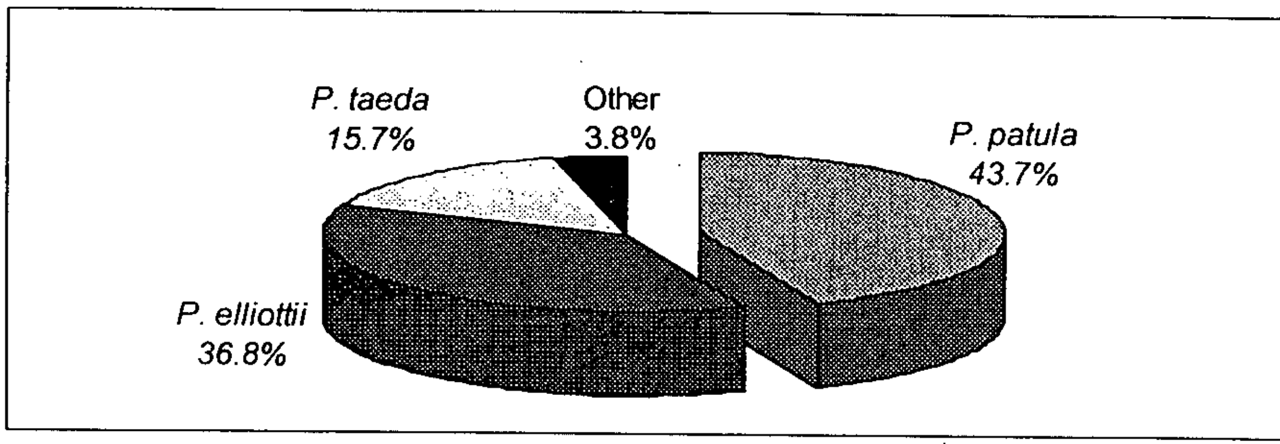

Figure 2.4: Pine distribution in the escarpment area of Mpumalanga (Source: Department of Water Affairs and Forestry, 1997)

2.1.3 Pruning and thinning regimes

The recommended pruning regimes, in 1993, for the major pine species, i.e. *Pinus patula*, *Pinus elliottii*, *Pinus taeda*, *Pinus radiata* and *Pinus pinaster* are given in Table 2.3.

Approximate age (years)	Dominant height (m)	Pruning height (m)
3 – 5	3,0 - 4,0	1,0 - 1,5
5 – 8	6,0 - 7,0	2,5 - 3,0
8 – 10	9,0 - 10,0	5,0
10 – 12	12,0 - 13,0	7,0

Table 2.3: Pruning regimes for pines in South Africa (Source: Hinze, 1993)

According to Theron (1997a), the current pruning schedules for SAFCOL, one of the major forestry companies in South Africa, excluding *Pinus radiata* is as indicated in Table 2.4.

Dominant Tree height (m)	Pruning height (m)	Stems *per* ha pruned	Age of *Pinus patula* on average site (yr)	Diameter of knotty core (cm)
3,5+	1,5	all**	3,0	-
6,0	3,0	(±1 330 sph)	5,0	11,2
9,0	5,0	all**	7,0	13,6
12,0++	7,0	all** (usually 650)	9,5	14,1
16,0*	10,5	400	13,5	-

Table 2.4: Pruning schedule used by SAFCOL (Source: Theron, 1997a)

\+ This pruning may probably not be required for stands originating from improved *Pinus elliottii* and *Pinus taeda* seed.

++ This pruning should only be carried out if the stand is younger than 13 years or else permission must be obtained from Headquarters.

* Only under the following conditions:

(i) Fast and medium-fast growing species and species which present problems with knots;

(ii) On accessible sites and on site index I. Special permission must be obtained.

** Excluding those which are suppressed and will obviously be removed during the early thinning.

In 1977 the thinning regimes for *Pinus patula*, *Pinus elliottii*, *Pinus taeda*, *Pinus radiata* and *Pinus pinaster* were revised. According to Loveday and Kassier (1993), thinning in 1993 was done at ages 8, 13 and 18 years. Table 2.5 indicates the thinning regime for Pines species.

Year	Stems *per* hectare
0	1 200
8	650
13	400
18	250
25+	0

Table 2.5: Thinning regime for pine species (Source: Loveday and Kassier, 1993)

2.1.4 Costs in *Pinus patula* plantations

The standard forestry costs recommended for use in South Africa are the costs published by the Forestry Economics Services (FES), formerly the economics division of the South African Timber Growers' Association (SATGA) titled "Forestry costs in South Africa".

Forestry Economics Services has produced annual reports on production costs in South African forestry since 1978 (FES, 1997). The data in the reports is collected

from a wide spectrum of growers, from major forestry corporations to small family farmers and covers Pine, Gum and Wattle planted for commercial purposes in Natal, Transvaal (Northern and Eastern), South-eastern Transvaal, Zululand, Southern Cape, Western Cape and an average for South Africa (SATGA, 1995 and FES, 1996).

The FES publication include information related to financial analysis, annual profit potential, sales and costs (establishment, re-establishment, tending, harvesting, loading and transport, forest protection and conservation, overheads, labour and forest machine costs).

In this study, the costs from the FES (1997) publication will be used. This publication covers the year 1996 and 65% of the 1 307 million hectares plantation area in South Africa. Statistics concerning the data in the report for 1996 are indicated in Table 2.6.

Item	Magnitude
Plantation area	844 603 ha
Production	9 747 157 tons
Turnover	R1 279 172 820
Total expenditure	R1 183 158 531

Table 2.6: Coverage of the 1996 FES report (FES, 1997)

2.1.5 Pulpwood in the escarpment area of Mpumalanga

According to Department of Water Affairs and Forestry (1997), all plantation areas in the escarpment area of Mpumalanga, which are managed to produce pulpwood, are privately owned. Table 2.7 shows the areas of different types of plantations for pulpwood production in the escarpment area of Mpumalanga in 1996.

In the escarpment area of Mpumalanga, 7 457 873 tons were sold as pulpwood in 1994/1995 and 9 088 645 tons in 1995/1996. The main purpose for which *Pinus patula* are grown in the escarpment area of Mpumalanga is sawtimber production and in this study, pulpwood is considered a by-product. Pulpwood volumes from thinning and clearfelling are determined using yield tables (refer to Appendix A).

Item	Area (ha)	Percentage of the total
All softwood species	29 243	78,9
Eucalyptus grandis	7 451	20,1
Other Gum species	169	0,5
Wattle species	201	0,5
Total	37 064	100,0

Table 2.7: Pulpwood plantation areas in the escarpment area of Mpumalanga (Source: Department of Water Affairs and Forestry, 1997)

2.2 Required yield for profitability

Only a few studies addressed this problem for South African conditions. Olivier (1993) established the Mean Annual Increment required for profitable sawtimber production from *Pinus patula* in Natal by using Net Present Value and Internal Rate of Return as financial criteria. The study covers softwood sawtimber production (two or three thinnings) and softwood pulpwood production in Zululand. The cost component was derived from the 1989 cost monitoring system of the South African Timber Growers' Association (SATGA). In the study 2,65% was used as the Real Cost of Capital. The results show that the MAI required for profitable sawtimber production from *Pinus patula* in Natal is 17 m^3/ha/*annum* regardless of the thinning regime.

Du Toit (1992) using Net Present Value and Internal Rate of Return as financial criteria for 4 different silvicultural regimes, found that 16 m^3/ha/*annum* is the minimum yield required for profitable *Pinus radiata* sawlog production in the Western Cape. He used 0,89% as a Real Discount Rate.

Eucalyptus plantations which are grown for sawtimber production should have a Mean Annual Increment of at least 20 m^3/ha/*annum* at 10 years of age to be profitable (Schönau, Stubbings and Norris, 1993).

In another study, Schönau and Stubbings (1987) state that the minimum required yield potential for profitable timber production in South Africa, at 10 years of age, is 15 m^3/ha/*annum*.

According to Stratten (1985), a minimum required MAI for profitability in South Africa for timber delivered over a distance of 100 km is equal to 15 m^3/ha/*annum* and for a distance of 250 km, the minimum MAI will increase to 25 m^3/ha/*annum*.

The breakeven MAI to cover costs for pine plantations according to FES (1997) was as follows: Eastern Transvaal 9,84 m^3/ha; Natal 13,79 m^3/ha; South-Eastern Transvaal 8,54 m^3/ha; Zululand 7,24 m^3/ha; Cape Province 8,12 m^3/ha and South Africa 9,76 m^3/ha. These values are required to cover silvicultural costs (establishment, tending and forest protection) and overhead costs. The study does not take the time value of money into account and does not include the land value.

2.3 Financial criteria

A number of financial criteria for the valuation of forestry projects are available. They all take account of the time value of money which is important in forestry due to the long production periods. These criteria are Net Present Value, Internal Rate of Return, Benefit-Cost Ratio, Equivalent Annual Income, Land Expectation Value and Profitability Index.

2.3.1 Net Present Value (NPV)

The NPV is the present value of the anticipated annual net cash flow that will be generated by the project and is a function of the magnitude of the periodic net cash flow and its duration (Shashua and Goldschmidt, 1983 and Irvin, 1978).

NPV may be referred to by any of these names: Net Present Worth (Davis and Johnson, 1987), Present Net Worth (Gittinger, 1982 and Anon., 1988), Discounted Cash Flow (Brigham and Gapenski, 1991 and Gregory, 1972) and Net Discounted Revenue (Grut, 1977). The term used in this study is Net Present Value with the abbreviation NPV. In formula form NPV is (Leuschner, 1984):

$$NPV = \sum_{t=0}^{n} (R_t - C_t) \frac{1}{(1+i)^t} \qquad (2.1)$$

where

NPV	=	Net Present Value
R_t	=	revenues or positive cash flows in year t
C_t	=	cost or negative cash flows in year t
t	=	year in which the cash flow occurs
i	=	discount rate, usually the alternative rate of return or the Cost of Capital
n	=	number of periods involved

The greatest advantage of NPV is that it gives an unambiguous answer when maximising returns from investments. A disadvantage of NPV is that it is sometimes difficult to determine which discount rate to use (Klemperer, 1996 and Gregersen and Contreras, 1979) and a comparison between alternative investment proposals can be carried out only for equal life spans. This fact reduces the applicability of the method (Shashua and Goldschmidt, 1983).

NPV is the best-known and most-used financial criterion. A project is acceptable if NPV is zero or greater. Project with a Net Present Value smaller than zero is unacceptable (Klemperer, 1996 and Shashua and Goldschmidt, 1983).

2.3.2 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is the discount rate which gives a particular cash flow an NPV of zero (Leuschner, 1984 and Klemperer, 1996). This criterion is called Internal Rate of Return because it is a return internal to the project, calculated independently of a discount rate (Mao, 1969). To calculate the value of IRR, we can find the value of the interest rate *(i)* that causes the following equation to be true:

$$\sum_{t=0}^{n} R_t \frac{1}{(1+i)^t} = \sum_{t=0}^{n} C_t \frac{1}{(1+i)^t} \qquad (2.2)$$

where the symbols have the same meaning as in Equation (2.1).

Other names used are True Rate of Return (Riggs, 1982), Discounted Cash Flow Return (Merrett and Sykes, 1966), Return on Investment or Rate of Return (Leuschner, 1984) and Financial Yield (Openshaw, 1980).

The concept of IRR assumes that all net cash flows generated by the investment are reinvested at rate *i*. If the rate at which net cash flows is reinvested is not equal to *i*, then the derived *i* (IRR) is not a correct statement of the realisable rate of return (Klemperer, 1981).

IRR can often be more useful in communicating information, since some people find it more intuitively understandable than the Net Present Value (Solomon and Pringle, 1977).

A project is acceptable if its Internal Rate of Return is equal to or greater than the minimum acceptable rate of return or Cost of Capital. Projects with an Internal Rate of Return smaller than the minimum acceptable rate of return are unacceptable (Klemperer, 1996).

2.3.3 Benefit-Cost Ratio (BCR)

Many Government agencies are required by law to use the benefit-cost ratio when evaluating investment projects (Clutter *et al.*, 1983). The calculation of a BCR is expressed in terms of the ratio of the present value of total benefits over the present value of total cost (Gregersen and Contreras, 1979 and Klemperer 1996). It is formulated as follows:

$$BCR = \frac{NPV_{REVENUES}}{NPV_{COSTS}} = \frac{\sum_{t=0}^{n} \frac{R_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}} \tag{2.3}$$

where

BCR = Benefit-Cost Ratio.

Other symbols have the same meaning as in Equation (2.1).

The BCR is an index that shows the relative productivity of each dollar spent (Davis and Johnson, 1987). Several alternative forms of BCR's are in use. Formula 2.3 is the most commonly used one and is a ratio of the NPV of all benefits to the NPV of all costs (Gregersen and Contreras, 1979).

If the NPV of revenues exceed the NPV of costs, the BCR must be greater than 1 and if the NPV of revenues do not exceed the NPV of costs, then the BCR must be smaller than 1. Projects are acceptable when their BCR's are 1 or greater, and unacceptable when their BCR's are smaller than 1 (Klemperer, 1996). The BCR gives the same accept/reject decision as the NPV approach, because a negative

NPV makes the BCR smaller than 1 (Klemperer, 1996 and Gregersen and Contreras 1979). According to Rose *et al.* (1988), a natural symmetry exists between NPV, IRR and BCR as shown in Table 2.8 below (i is the discount rate or Cost of Capital).

NPV			IRR		BCR
If	> 0	then	$> i$	and	> 1
If	< 0	then	$< i$	and	< 1
If	$= 0$	then	$= i$	and	$= 1$

Table 2.8: Natural symmetry between NPV, IRR and BCR (Source: Rose et al., 1988).

The BCR is a dimension-free quantity. The NPV is measured in monetary units and IRR in percentages, but the BCR has no unit attached to it which increases the usefulness of the BCR for projects that differ greatly in size (Clutter *et al.*, 1983).

2.3.4 Equivalent Annual Income (EAI)

Equivalent Annual Income (EAI) is calculated by converting NPV to an annual value paid at the end of each year over the life of the investment with interest calculated at the appropriate discount rate (Rose *et al.*, 1988). It is also termed Equal Annual Equivalent, Equivalent Annual Annuity and Equivalent Annual Worth (Rose *et al.*, 1988 and Riggs, 1982). The EAI is calculated using the formula:

$$EAI = NPV \frac{i(1+i)^n}{(1+i)^n - 1} \tag{2.4}$$

where

EAI = Equivalent Annual Income

Other symbols have the same meaning as in Equation (2.1).

According to Klemperer (1996), the project which has the highest value for the Equivalent Annual Income, is chosen. The EAI decision rule is as follows:

EAI > 0: accept the project

EAI < 0: reject the project

The EAI allows competing projects of different lives to be compared and is especially useful when comparing forestry activities with farming or other land uses with annual income (Bullard and Straka, 1994).

2.3.5 Land Expectation Value (LEV)

The Land Expectation Value is another criterion that is known by several names. The most well known is the Faustmann formula, but the terms land rent, economic land value, bare land value, maximum discounted economic rent, maximum land rent and soil expectation value are also used (Klemperer, 1996 and Schönau, 1982).

According to Uys (1988), the traditional Faustmann formula can be written as:

$$LEV = \frac{\sum_{t=0}^{n} P_t (1+i)^{n-t}}{(1+i)^n - 1} - \frac{E}{i} \qquad (2.5)$$

where

LEV = Land Expectation Value

P_t = net cash flow in year t (land cost and general annual cost excluded)

E = general annual cost

n = rotation age

Other symbols have the same meaning as in Equation (2.1).

The decision rules are as follows:

LEV > market value of land: accept the project

LEV < market value of land: reject the project

Land Expectation Value can be interpreted as the maximum price that can be paid for a tract of land for growing timber, if one can expect to earn a rate of return greater than or equal to the discount rate used to calculate the LEV. This criterion is most appropriate for selecting the optimal rotation age and management regime for timber on a particular tract of land because it considers all of the present and expected future income and costs on a property (Bullard and Straka, 1994).

Land Expectation Value is a special case of NPV that has certain restrictive assumptions made about it. These are: (1) land value is zero; (2) the land has no residual stand; (3) the land will be forested in perpetuity and (4) the cash flows from the forest will be the same in perpetuity (Leuschner, 1984).

The greatest disadvantage of the LEV is that the assumption of constant cash flows is inappropriate and unrealistic in the modern dynamic financial environment (Uys, 1989).

2.3.6 Profitability Index (PI)

According to Van Horne (1977), the Profitability Index is calculated using the following formula:

$$PI = \frac{\sum_{t=1}^{n} \frac{R_t}{(1+i)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}{|C_o|} \tag{2.6}$$

where

R_t = revenue in year t

C_t = cost in year t

C_o = initial cash outlay at stage 0

Other symbols have the same meaning as in Equation (2.1).

The following decision rules apply:

PI > 1: accept the project

PI < 1: reject the project

The use of the PI is limited by the fact that it is not appropriate for investments that are carried out in one lump sum. Further, it is often difficult to distinguish between investment cost and other outlays included in the cash flow from which the net cash inflow is calculated (Shashua and Goldschmidt, 1983).

The Profitability Index as well as the Benefit-Cost Ratio are ratios and consequently these two financial criteria provide dimension-free quantities (Davis and Johnson, 1987).

2.4 Cost of Capital and inflation rate

2.4.1 Cost of Capital

Cost of Capital is also known as: discount rate, rejection rate, required rate of return, alternative rate, trade-off rate, target rate, hurdle rate, cut-off rate and guiding rate. Cost of Capital is the price that a company pays for funds which are obtained from its capital suppliers (Klemperer, 1996).

According to Uys (1997) the capital structure of a company can consist of the following forms of financing: common shares, preference shares, retained earnings, debentures, short-term loans, long-term loans, and bank overdrafts. Each of these

forms can have a different cost (rate). In order to decide on a single rate, the weighted average Cost of Capital is calculated using the following formula:

$$C = \sum_{j=1}^{m} W_j C_j \tag{2.7}$$

where

C	=	weighted average Cost of Capital
W_j	=	percentage of the total capital structure provided by the j-th source of capital
C_j	=	cost of the j-th source of capital
m	=	number of capital sources

If an individual in the forestry industry obtains the capital for his total operation from just a single loan, the borrowing rate is considered to be the Cost of Capital. When the entire operation is financed with own funds, the highest rate which can be earned in an alternative investment with similar risk, must be used as the Cost of Capital. If the State is the investor, the opportunity cost model is used to determine the discount rate (Bullard and Straka, 1994).

2.4.2 Inflation rate

Inflation is defined in terms of the general level of prices and it is measured by the changes in general price indices, such as the Consumer Price Index (CPI) or the Production Price Index (PPI) (Leuschner, 1984).

During inflation, the evaluation of investments become more complicated because some cash-flow items are affected by inflation and others are not. Forestry investments have often been sold short because of a failure to distinguish between real and current prices or a failure to uniformly take inflation into account. Financial analyses involve two types of price changes, a price change which results from

general inflation and a real price change for each individual item in a cash flow (Gregersen, 1975 and Shashua and Goldschmidt, 1983).

According to Buongiorno and Gilles (1987), Equation (2.8) is used to describe the relationship between the nominal and real discount rates and the inflation rate:

$$(1+k)=(1+i)(1+f) \tag{2.8}$$

where

k = nominal discount rate

i = real discount rate

f = inflation rate according to a general price index.

The effect of inflation can be avoided by estimating the rate of inflation and assuming it to be identical for cost and revenue items and by "adding" it to the appropriate Real Discount Rate or by expressing all cash flows in constant prices before discounting. But it is not usually the case that cost and revenue will be identically affected by inflation (Irvin, 1978).

Equal application of inflation to costs and returns would not change the final decision, because even the best return can be eaten up by unrealistic combinations of inflation, price increases and interest rates. It is important that all assumptions be as realistic as possible (Rose *et al.,* 1988).

2.5 Computer programs

Complex and tedious mathematical calculations undoubtedly discouraged Discounted Cash Flow analysis in the past and were easily subjected to arithmetic errors. For that reason, microcomputer programs for investment analysis have been developed and they simplify the task of calculating the different financial criteria. Some of the available financial computer programs according to Nodine (1994) and

Uys (1997) are CASH, FAUST, INVEST, FINROT, BOSFIN, FORVAL, Quick-Silver, YIELDplus and FINAL.

In this paragraph two computer programs (FINROT and CASH) are described. These two programs are described because both programs can be used to do a financial analysis for this particular study problem and they are readily available.

2.5.1 FINROT program

FINROT (FINancial ROTation) is a microcomputer program in GW-BASIC, with easy data editing facilities and it was designed to determine optimal financial rotations for forestry projects. The FINROT program was developed by the Faculty of Forestry at the University of Stellenbosch.

The FINROT program can calculate the NPV for a single rotation according to Equation (2.1), the IRR according to Equation (2.2), the BCR according to Equation (2.3); the EAI according to Equation (2.4); the LEV according to Equation (2.5); the PI according to Equation (2.7); the Net Present Value for Infinite series of rotations (NPVI) according to Equation (2.9) and the Real Internal Rate of Return for an infinite series of rotations (RIRRI) according to Equation (2.10) (Uys, 1997).

The *NPVI* is calculated as follows:

$$NPVI = \frac{\sum_{t=0}^{n} A_t (1+i)^{n-t}}{(1+i)^n - 1} - \frac{E}{i} \qquad (2.9)$$

Where

$NPVI$ = Net Present Value for an Infinite series of rotations

A_t = net cash flow item in year t, expressed in today's prices (general annual cost is excluded);

n = duration of the project (rotation);

E = general annual cost, expressed in today's prices;

Other symbols have the same meaning as in Equation (2.1).

The RIRRI of a project is represented by that i, say i* which will result in:

$$\frac{\sum_{t=0}^{n} A_t (1+i^*)^{n-t}}{(1+i^*)^n - 1} - \frac{E}{i} = 0 \tag{2.10}$$

Where other symbols have the same meaning as in Equation (2.9).

The convention used by the FINROT program is based on the principle that all activities occur at the end of the year or period and the project starts at the zero point in time.

2.5.2 CASH program

This cash flow and sensitivity analysis program is a menu-driven, user-friendly microcomputer program written in Microsoft basic for application on personal computers. It is a decision aid which makes it possible to rank alternative investments based on several investment analysis criteria. It may be used for any type of investment alternative: forestry, agriculture, engineering, home economics and marketing. For each alternative the program calculates cash flows by period for an analysis of up to 120 periods (years) plus various economic measures of investment performance. In addition, it conducts a sensitivity analysis on the discount rate and each activity included in the analysis (Blinn and Rose, 1986).

It was developed at the University of Minnesota and includes the following financial criteria of project performance:

a) Net Present Value according to Equation (2.1)

b) Equivalent Annual Income according to Equation (2.4)

c) Land Expectation Value according to Equation (2.5)

d) Benefits over cost according to Equation (2.3)

e) Internal Rate of Return according to Equation (2.2)

f) Payback period

This program uses a convention where all activities occur at the beginning of the specified years or periods. The initial investment period is designated as "1" and all cash flows are then discounted to this point.

3. RESEARCH DATA

The research data necessary for this study is primarily intended to solve the sub-problems that were listed in Paragraph 1.2.

3.1 Schedule of activities

a) Weed control

According to Olivier (1997) and Theron (1997b), SAFCOL, the most important producer of *Pinus patula* sawtimber in the study area, is doing three weed control operations during the rotation for a *Pinus patula* stand in the escarpment area of Mpumalanga. The first weed control operation occurs in the first year after planting, the second one two years after planting and the third one three years after planting. This schedule for weed control application will be used in this study.

b) Pruning and thinning

The current pruning schedule (refer to Table 2.4) and thinning schedule (refer to Appendix A), both used by SAFCOL will be used in this study. The thinning schedule in Appendix A is unpublished COMPAS output where the thinning regime prescribed use three thinning operations from MAI_{20} = 20 m^3/ha/*annum* to MAI_{20} = 25 m^3/ha/*annum*.

c) Clearfelling

According to FES (1997), the average age of clearfelling for pine plantations in South Africa varies from 26 years in the escarpment area of Mpumalanga to 33,7 years in the Cape Province. The average age of clearfelling in the escarpment area of Mpumalanga is 28,2 years. For the purposes of this study a clearfelling age of 28 years will be used.

The timing of activities such as establishment, weed control, pruning, thinning and clearfelling according to different MAI_{20} classes during the rotation is indicated in Table 3.1.

Age	MAI$_{20}$																				
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
1	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
2	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
3	W	W	W	W	W	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP	WP
4	P	P	P	P	P										P	P	P	P	P	P	P
5					P	P	P	P	P	P	P	P	P	P							P
6	P	P	P	P								P	P	P	P	P	P	P	P	P	
7							P	P	P	P	P									P	P
8	T	T	T	PT	PT	PT	T	T	T	T	T	T	T	T	PT	PT	PT	PT	PT	T	T
9		P	P								P	P	P	P							
10	P							P	P	P											
11					P	P	P														
12				P																	
13	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
14																					
15																					
16																					
17																					
18																T	T	T	T	T	T
19-27																					
28	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF	CF

Table 3.1: Timing of all activities for different MAI$_{20}$ classes during the rotation (Source: Table 2.4 and Appendix A)

3.2 Financial yield

The volumes from activities such as thinning and clearfelling is determined using yield tables from SAFCOL, which were generated with the aid of the growth models used in Computerised Plantation Analysis System (refer to Appendix A).

The Computerised Plantation Analysis System (COMPAS) was designed mainly to improve silvicultural management, planning and control of exotic plantations in Southern Africa. This is an integrated system, which comprises a whole range of interlinked computer programs, which can be categorised roughly as a growth model, data editing and processing programs, a discounted cash flow model and a series of working plan report-writing programs (Kassier, 1980). The COMPAS system is well known and used in all the forestry areas in South Africa to forecast yields.

The prices of pulpwood (by-product) and the prices of different sawlog classes on roadside that are used in this study to determine the revenues obtained from thinnings and clearfelling are indicated in Table 3.2.

Pulpwood and sawlog classes	Price (R/m^3)
Pulpwood	86,40
Class A	60,21
Class B	89,67
Class C	138,87
Class D	176,30

Table 3.2: Prices of pulpwood and sawlogs used in 1996 in the escarpment area of Mpumalanga (Source: Möller, 1997)

The total revenue obtained from pulpwood and sawlogs delivered on roadside is calculated using formula (3.1):

$$R_t = P_s V_s + \sum_{i=A}^{D} P_i V_i \tag{3.1}$$

where

R_t	=	Total revenue per activity (thinning or clearfelling) (R/ha)
P_s	=	Price for pulpwood on roadside (R/m^3)
V_s	=	Volume of pulpwood (m^3/ha)
P_i	=	Price (R/m^3) for different sawlog classes (A, B, C and D) on roadside
V_i	=	Volume (m^3/ha) of different sawlogs classes (A, B, C and D)

The total revenue (R/ha) according to formula (3.1) for thinning at 8; 13 and 18 years of age, and clearfelling at 28 years of age, for different MAI_{20} classes is indicated in Table 3.3.

3.3 Cost component of cash flows

In this study all cost components are 1996 costs derived from the cost monitoring system of the Forestry Economics Services (FES, 1997). According to Marwick (1994), these costs are consistent with efficient forestry practice and the most comprehensive available on plantation forestry in South Africa.

3.3.1 Value of land and infrastructure

Land in addition to the trees is the basic capital in a forestry investment. In this study, land is valued at market value on the basis of the 1996 cost of bare, unimproved and afforestable land. Fixed improvements include all buildings (houses, offices, sheds, garages and workshops) and other permanent improvements such as dams, fire towers, water supplies and fences. The value of land and infrastructure at 1996 prices in the escarpment area of Mpumalanga is

R2 202/ha and this value will be used in the calculations. The composition of the land and infrastructure value is shown in Table 3.4.

MAI_{20} (m^3/ha/*annum*)	Activity and age (years)			
	T 8	T 13	T 18	CF 28
5	605	906	0	9 083
6	751	1 086	0	11 351
7	984	1 383	0	13 796
8	1 071	1 593	0	16 171
9	1 217	1 803	0	18 910
10	1 364	1 953	0	21 815
11	1 571	2 163	0	24 612
12	1 631	2 703	0	27 398
13	1 838	2 642	0	30 447
14	1 898	2 735	0	33 542
15	2 105	2 975	0	36 813
16	2 165	3 304	0	39 897
17	2 375	3 483	0	43 379
18	2 582	3 752	0	46 860
19	2 642	4 082	0	50 203
20	2 852	4 261	6 116	45 712
21	2 913	4 530	6 573	48 462
22	3 123	4 799	6 891	51 396
23	3 183	5 068	7 348	54 457
24	3 393	5 247	7 805	57 391
25	3 543	5 655	8 173	60 275

Table 3.3: Revenue in R/ha from thinnings and clearfellings during the rotation (Source: Appendix A, Table 3.2 and Equation 3.1)

Item	Cost (R/ha)
Land	1 125
Fixed improvements	258
Roads	819
Total (land and infrastructure value)	2 202

Table 3.4: Composition of land and infrastructure value at 1996 prices in the escarpment area of Mpumalanga (Source: FES, 1997)

3.3.2 General Annual Cost

All forestry investments include General Annual Cost (GAC), which are costs related to administration (labour, machinery, vehicles, radios, office expenses and depreciation), protection, conservation, maintenance (of roads, buildings and other improvements), tax and management costs.

In this study, forestry overhead cost (R475,70/ha) plus cost of forest protection and conservation (R149,58/ha) will be included in the value of GAC at 1996 prices. Forest protection includes control of pests and noxious weeds, fire protection and insurance. Conservation includes clearing and rehabilitating streams and rivers, managing wetlands and indigenous areas on the estate, establishing hiking trails or picnic areas and protecting wildlife from poaching. The GAC at 1996 prices in the escarpment area of Mpumalanga is R625,28/ha (refer to Table 3.5) and this value will be used in the calculations.

3.3.3 Establishment cost

Establishment cost for pine plantations includes the cost of activities such as land preparation, planting, blanking and fertilising. Land preparation includes the clearing of indigenous and exotic plants, the clearing of the remains of a previous crop, destumping, all methods of mechanical cultivation, ring weeding planting spots before planting, marking planting spots and preparing planting holes. Land preparation is complete when planting holes are ready to receive the young trees.

Planting includes seedling transport, watering, applying insecticides or moisture absorbing gels, and planting the seedlings. Blanking includes seedling transport, watering and replanting gaps. Fertilising includes both transport of the fertiliser and its application.

Activity	Cost (R/ha)
Control of pests and noxious weeds	41,87
Fire protection	96,27
Conservation	11,44
Hand tools	2,65
Road maintenance	25,55
Building maintenance	4,48
Administration	406,49
Community development	2,31
General Annual Cost	625,28

Table 3.5: Components of GAC at 1996 prices in the escarpment area of Mpumalanga (Source: FES, 1997)

According to FES (1997), the establishment cost at 1996 prices in the escarpment area of Mpumalanga is R1 658,48 *per* hectare (refer to Table 3.6). This value will be used in this study and it is assumed to be constant for different MAI_{20} classes.

Activity	Cost (R/ha)
Land preparation	681,19
Planting	718.44
Blanking	216,76
Fertilising	208,35
Total (Establishment cost)	1 658,48

Table 3.6: Composition of establishment cost at 1996 prices in the escarpment area of Mpumalanga (FES, 1997)

3.3.4 Weed control cost

Weed control operations refers to hoeing, discing and herbicide spraying with the object of protecting the young plants and minimising loss of moisture and fertiliser to weed growth. The weed control cost *per* operation for pine plantations in the escarpment area of Mpumalanga in 1996 was R296,33/ha (FES, 1997). This cost for weed control will be considered the cost for an average site (MAI_{20} = 15 m^3/ha/*annum*).

The weeding intensities do not really differ on different site qualities, i.e., the number of weedings applied by SAFCOL on sites of different quality are the same. It is possible to consider that fewer weeds on poorer sites (low MAI_{20}) will reduce the weed control cost *per* hectare by about 5 percent for every 5 m^3 reduction in MAI_{20} and on good sites will increase it by 5 percent (Olivier, 1997 and Theron, 1997b). Table 3.7 indicates percentage changes in the weed control cost as a function of the different MAI_{20} classes and the standard weeding cost. For example for MAI_{20} = 8 m^3/ha/*annum*, the weed control cost will be R266,70/ha (=296,33*0.9).

MAI_{20} classes (m^3/ha/*annum*)	Adjustment factor	Weed control cost (R/ha)
5 to 9	0,90	266,70
10 to 14	0,95	281,51
15 to 19	1,00	296,33
20 to 25	1,05	311,15

Table 3.7: Percentage increase or decrease of weeding cost for different MAI_{20} classes

3.3.5 Pruning cost

The current pruning schedule for SAFCOL (Table 2.4) will be used to determine when the different pruning operations should be carried out. The pruning cost in 1996, according to FES (1997), is shown in Table 3.8.

Pruning height (m)	Cost (R/ha)
1,5	174
3,0	179
5,0	169
7,0	173

Table 3.8: Pruning cost of pine plantations, in 1996, in the escarpment area of Mpumalanga (Source: FES, 1997)

3.3.6 Thinning cost

The thinning cost on roadside for sawtimber production includes the marking of trees to be thinned and the harvesting cost (felling, crosscutting, debranching, stacking brushwood between tree rows and stacking the logs to be extracted). This cost is indicated in Table 3.9.

Activity	Cost (R/m^3)
Marking of trees to be thinned	108,82
Harvesting of pulpwood	21,48
Harvesting of sawlogs	22,85

Table 3.9: Thinning cost for pine plantations, in 1996, in the escarpment area of Mpumalanga (Source: FES, 1997)

In this study the current thinning regime for SAFCOL will be used, where thinnings is applied at ages 8, 13 and 18 (refer to yield tables in Appendix A). Stands with an MAI_{20} = 19 and lower receive only two thinnings at ages 8 and 13. Thinning cost is calculated according to Equation (3.2):

$$C_{thn} = M_c + H_s V_s + H_c \sum_{i=A}^{D} V_i \tag{3.2}$$

where

C_{thn} = cost of thinning (R/ha)

M_c = cost of marking trees to be thinned (R/ha)

H_c = harvesting cost of sawlogs (R/m^3)

H_s = harvesting cost of pulpwood (R/m^3)

Other symbols have the same meaning as in Equation (3.1).

The thinning cost for different Mean Annual Increment classes at 20 years of age, expressed in 1996 values, is shown in Table 3.10.

3.3.7 Clearfelling cost

The harvesting cost for pulpwood and sawlogs are shown in Table 3.11.

The clearfelling cost at rotation age includes the harvesting cost of pulpwood and sawlogs to roadside. The total clearfelling cost is calculated using formula (3.3). The total clearfelling cost for different MAI_{20} classes is indicated in Table 3.12.

$$C_c = H_s V_s + H_c \sum_{i=A}^{D} V_i \tag{3.3}$$

where

C_c = Clearfelling cost (R/ha)

The other symbols have the same meaning as in Equation (3.2).

The completed cash flows, according to 1996 prices, which indicate age, activity, cost and revenue, appear in Appendix B for MAI_{20} classes ranging from 5 m^3/ha/*annum* to 25 m^3/ha/*annum*.

MAI_{20} (m^3/ha/*annum*)	Age (years)		
	T 8	T 13	T 18
5	259	373	0
6	304	442	0
7	369	532	0
8	391	601	0
9	435	670	0
10	479	715	0
11	547	783	0
12	569	852	0
13	637	920	0
14	660	945	0
15	727	1 013	0
16	750	1 105	0
17	818	1 150	0
18	885	1 219	0
19	908	1 310	0
20	977	1 356	1 680
21	1 000	1 425	1 771
22	1 068	1 493	1 840
23	1 091	1 562	1 931
24	1 159	1 607	2 023
25	1 205	1 699	2 091

Table 3.10: Thinning cost for pine plantations, in R/ha, for different MAI_{20} classes

Activity	Cost (R/m^3)
Harvesting for pulpwood	21,48
Harvesting for sawlogs	22,85

Table 3.11: Clearfelling cost for pine plantations, in 1996, in the escarpment area of Mpumalanga (FES, 1997)

MAI_{20} (m^3/ha/*annum*)	Clearfelling cost (R/ha)
5	2 454
6	2 957
7	3 460
8	3 939
9	4 465
10	4 990
11	5 493
12	5 974
13	6 477
14	6 980
15	7 505
16	7 985
17	8 511
18	9 036
19	9 539
20	7 876
21	8 242
22	8 630
23	9 042
24	9 430
25	9 819

Table 3.12: Clearfelling cost for pine plantations, in 1996, for different MAI_{20} classes

3.4 Choice of financial criteria

NPV and IRR are the financial criteria that will be used to determine the marginal MAI_{20} in this study due to the reputation of these two criteria in financial literature (see Paragraphs 2.3.1 and 2.3.2), as well as in the forest industry. Olivier (1993) and Du Toit (1992) also used these two criteria in studies similar to this one.

3.5 Choice of a discount rate

Inflation can be dealt with in several ways, but the most effective way to use in the case of forestry projects is to use a real approach (Uys, 1997). In a real approach, present prices are used to estimate future revenues and costs and a real discount rate is used. The real discount rate or Real Cost of Capital is a function of the Nominal Cost of Capital and the inflation rate (refer to Equation 2.8).

3.5.1 Determination of the Nominal Cost of Capital

The prime overdraft rate will be used in this study to estimate the Nominal Cost of Capital. The prime overdraft rate used by Standard Bank from 1978 to 1997 is indicated in Table 3.13. The course of the prime overdraft rate during this period is indicated in Figure 3.1.

Regression analysis and the data from Table 3.13 were used to establish the trend of the prime overdraft rate in South Africa. Table 3.14 indicates three types of regression models and their respective coefficients of determination. From this table it is possible to see that the coefficients of determination for all the regression models are less than 32 percent, which means that none of the models fit the data set adequately.

As a result of the low values of the coefficients of determination, the arithmetic average of the prime overdraft rate for the period 1978 to 1997, was calculated as 16,7% and the rounded value of 17 percent will be used as the Nominal Cost of Capital in calculating the Real Cost of Capital.

Year	Average prime overdraft rate (%)
1978	12,1
1979	10,1
1980	9,5
1981	13,3
1982	18,8
1983	17,2
1984	23,0
1985	20,8
1986	13,9
1987	12,5
1988	15,2
1989	20,0
1990	19,6
1991	20,1
1992	18,3
1993	15,8
1994	16,3
1995	18,0
1996	19,8
1997	19,3
Average	16,7

Table 3.13: Prime overdraft rate used from 1978 to 1997 (Source: Standard Bank, 1998)

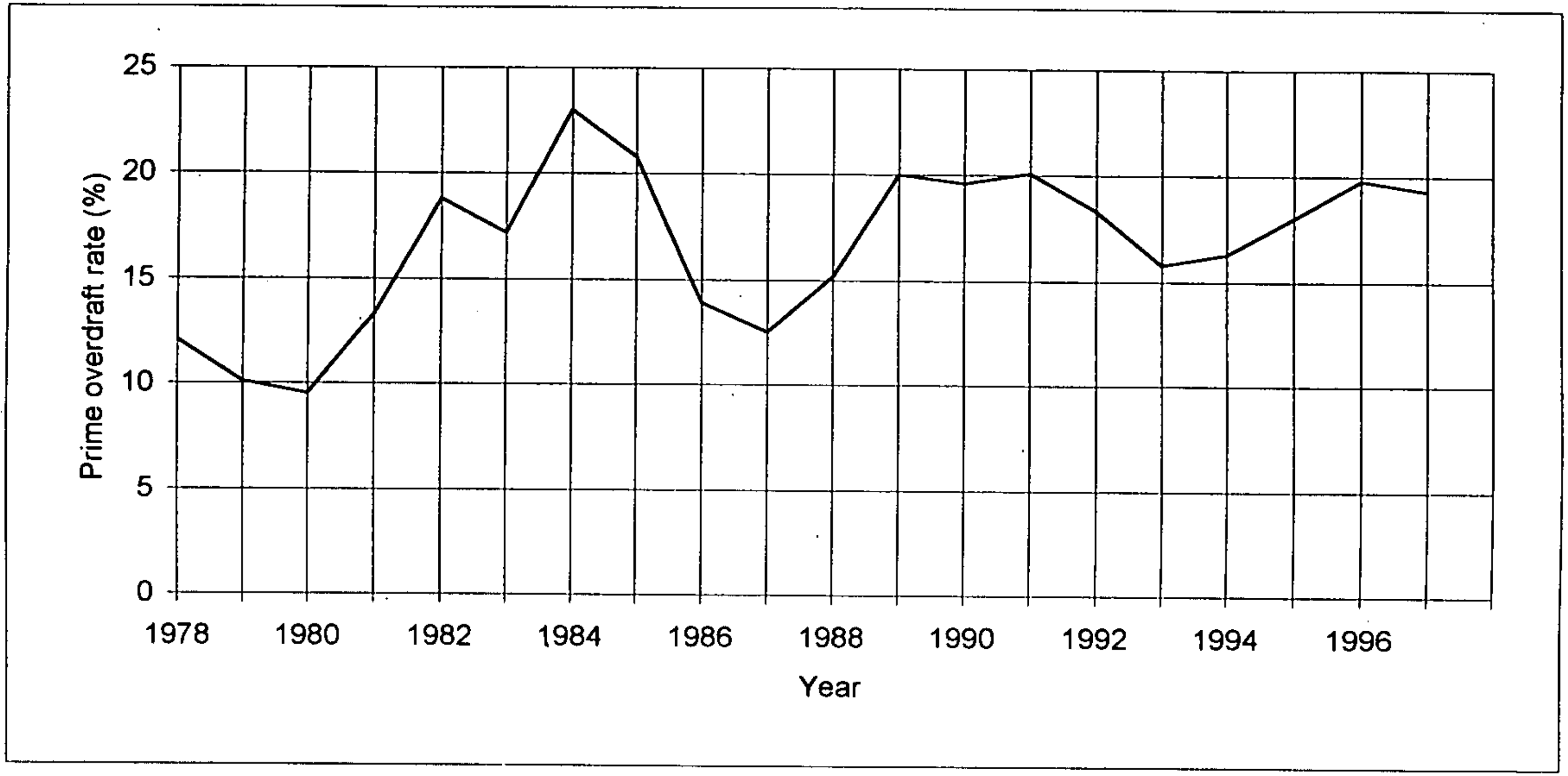

Figure 3.1: *The course of the prime overdraft rate from 1978 to 1997 (Source: Standard Bank, 1998)*

Description	Model	Intercept	Slope or rate of change	Coefficient of determination (r^2) in percentage
Linear	$Y = a + bX$	-640,54	0,3307	26,99
Exponential	$Y = e^{(a+bX)}$	-43,89	0,0235	31,55
Compound growth	$Y = a(1+b)^X$	+13,90	0,0188	25,43

Table 3.14: Regression analyses of the prime overdraft rate from 1978 to 1997

3.5.2 Inflation rate

The value of the inflation rate that will be used to determine the Real Cost of Capital is the predicted inflation rate in the forestry industry in South Africa. The trend of the Forestry Price Index (FPI) from the past will be used to predict the future inflation rate. The FPI for South Africa from 1975 to 1994, as well as the inflation rates that are calculated according to this index are shown in Table 3.15 (CSS, 1997). The behaviour of the inflation rate and the course of the FPI for this period are illustrated in Figures 3.2 and 3.3, respectively.

The future trend of the FPI can be obtained by trend extrapolation. The past trend can be determined by means of regression. Because the effect of inflation on a cash flow item is similar to the effect of compound interest, an exponential regression model that corresponds to the basic equation for compound interest is chosen:

$$Y = b_0(1 + b_1)^x \tag{3.4}$$

The value of the b_1-coefficient in this model represents the annual rate at which the FPI changes over the long term and can be regarded as the long-term inflation rate in the forestry industry. The above-mentioned model was fitted to the FPI over the 20-year period, 1975 to 1994 with the following fitting results:

Coefficients:	b_0	= 13,7044
	b_1	= 0,1328
Coefficient of determination (r^2)		= 0,9862

The regression line according to this model is shown in Figure 3.4.

Year	Forestry Price Index	Inflation Rate (%)
1975	13,2	-
1976	15,2	15,2
1977	16,1	5,9
1978	17,0	5,6
1979	19,6	15,3
1980	23,7	20,9
1981	27,3	15,2
1982	31,2	14,3
1983	34,8	11,5
1984	38,3	10,1
1985	43,8	14,4
1986	52,9	20,8
1987	61,3	15,9
1988	69,1	12,7
1989	86,4	25,0
1990	100,0	15,7
1991	107,4	7,4
1992	118,9	10,8
1993	122,3	2,9
1994	139,0	13,7

Table 3.15: The Forestry Price Index and inflation rate in South Africa from 1975 to 1994 (Source: CSS, 1997)

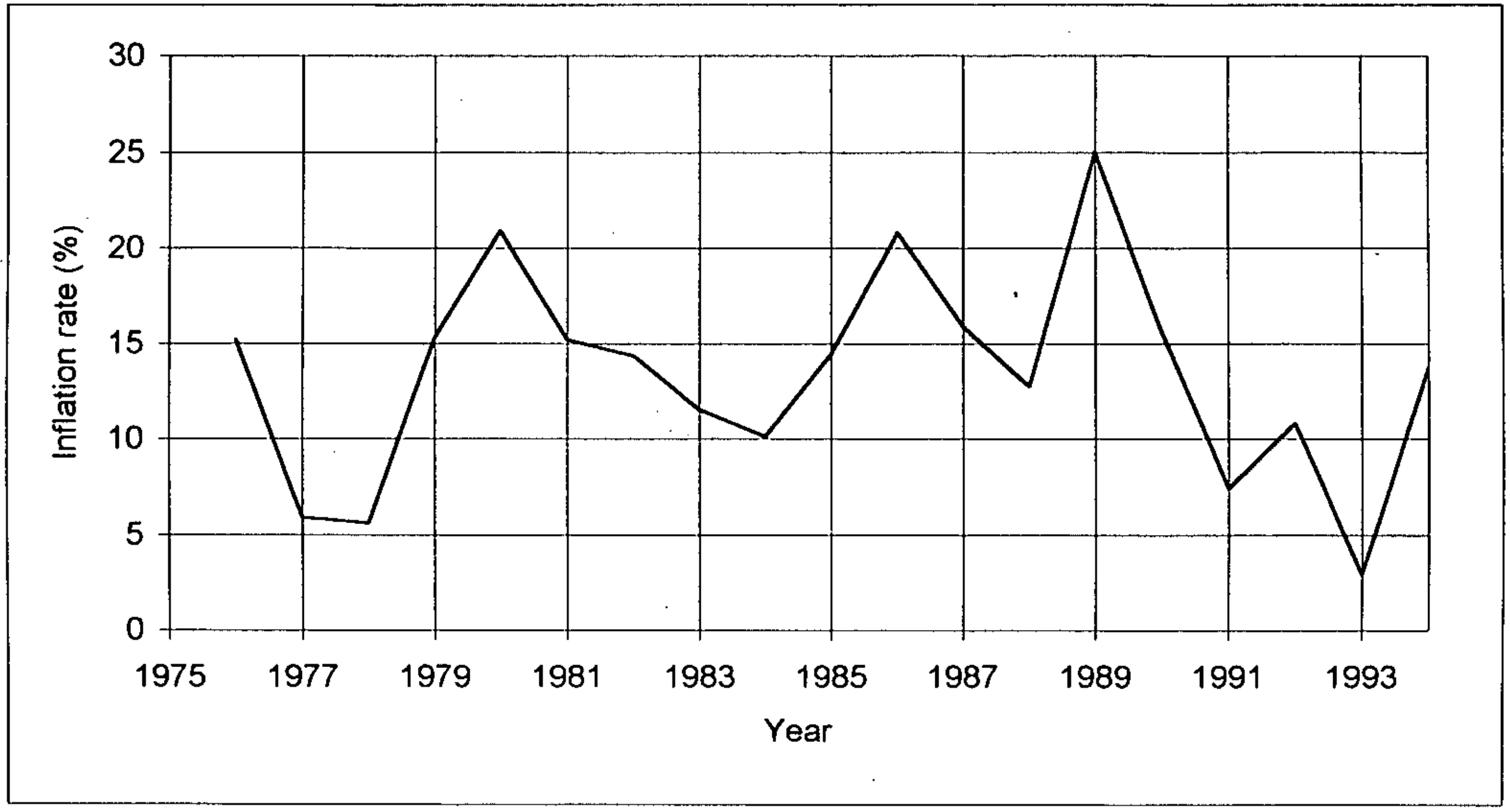

Figure 3.2: The behaviour of the inflation rate according to the FPI (Source: Table 3.15)

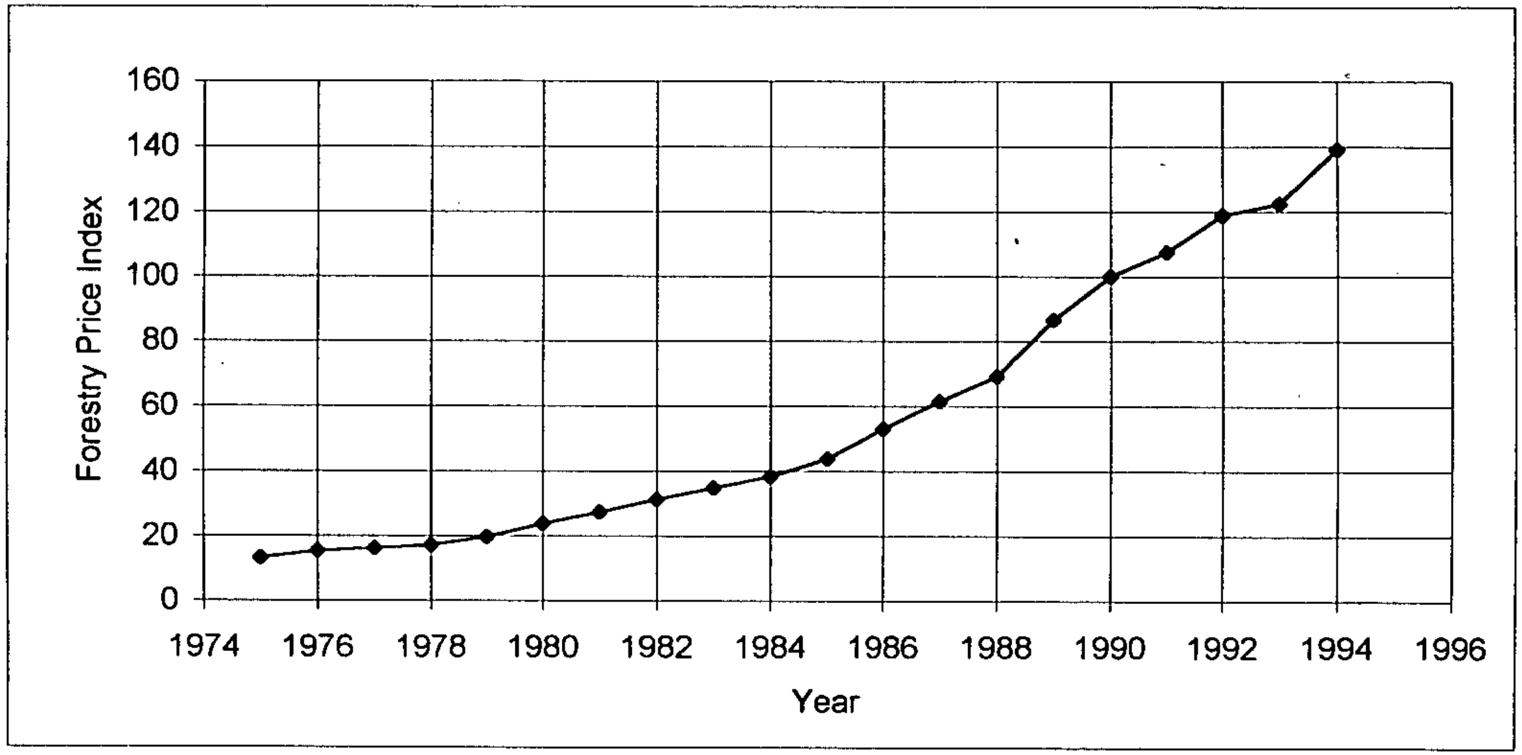

Figure 3.3: The course of the Forestry Price Index (Source: Table 3.15)

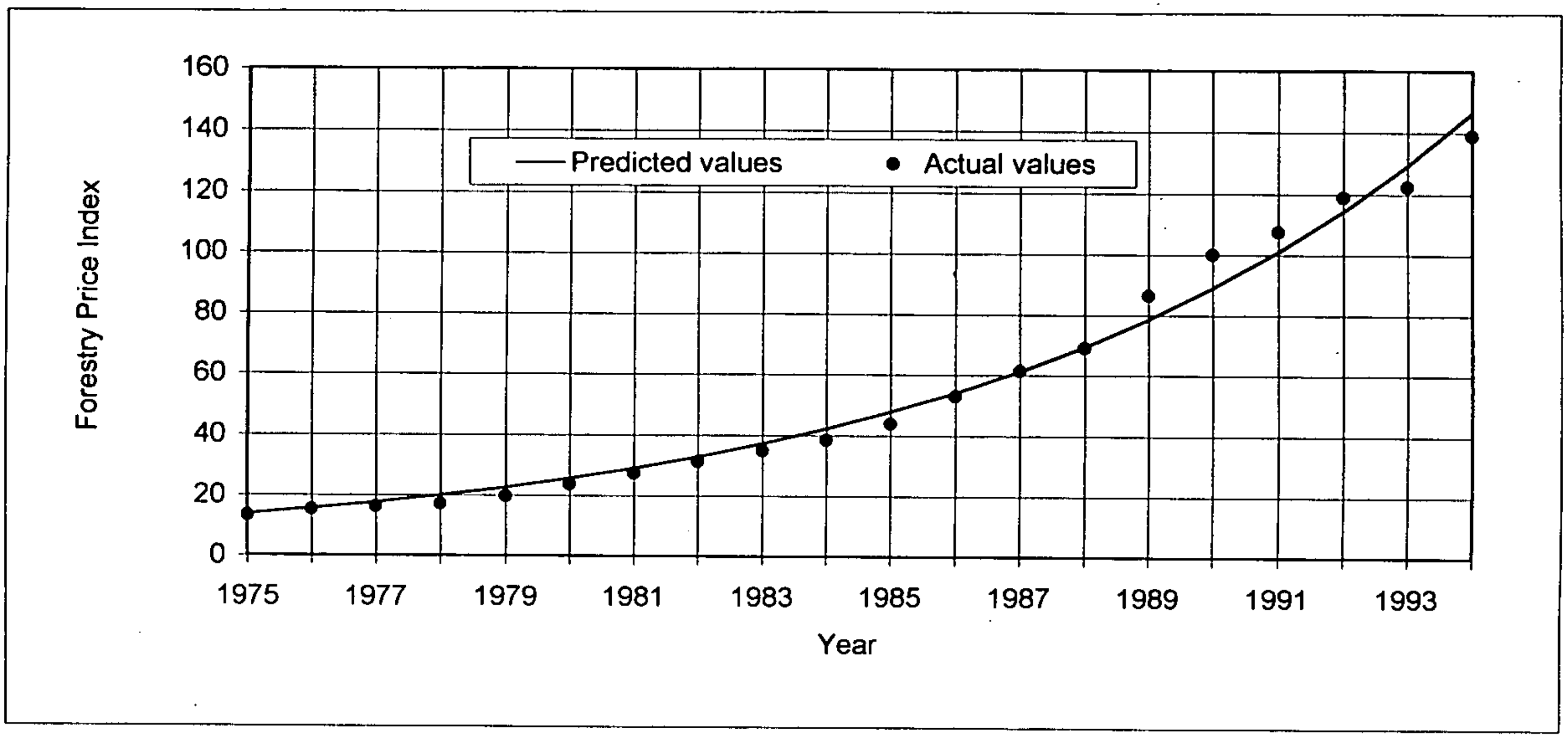

Figure 3.4: Long term secular trend of the FPI in South Africa

Inflation, according to the FPI, consequently followed a secular trend of 13,28% *per annum* over this 20-year period. This represents the underlying trend when short-term variations are ignored and the rounded value of 13% will be used in calculating the Real Cost of Capital.

3.5.3 Determination of the Real Cost of Capital

The Real Cost of Capital is determined according to Equation (2.8). This equation can be re-written in the following form:

$$i = \left[\frac{(1+k)}{(1+f)} - 1 \right] 100 \qquad (3.5)$$

where the symbols have the same meaning as in Equation (2.8).

Based on the inflation rate of 13,0% and the Nominal Cost of Capital of 17%, a Real Cost of Capital of 3,5% was calculated.

This study is not intended to be applicable to a specific forestry company in the escarpment area of Mpumalanga and the Real Cost of Capital can differ substantially between companies. Consequently a scenario approach will be followed in the discounted cash flow analysis in Chapter 4. In the base case scenario 3,5% will be used as the Real Cost of Capital. In the other two scenarios a low Real Cost of Capital of 2,0% and a high Real Cost of Capital of 5% will be used (1,5% lower than 3,5% and 1,5% higher than 3,5%).

4. EXPERIMENTATION

4.1 Computer program

The computer program FINROT was chosen for all calculations because the program is adapted to South African forestry conditions and it uses the more convenient convention where it is assumed that projects start at the zero point in time.

The FINROT program's first, second, third and fourth screens are indicated in Tables 4.1; 4.2; 4.3 and 4.4 respectively. The general information related to the forestry project is entered in on screen 1 (see Table 4.1). On screens two and three (Tables 4.2 and 4.3), the cash flow information such as activities in different years, the direct cost and gross revenue is entered. The General Annual Cost, the total cost and the Net Cash Flow will appear automatically on this screen. All cost and revenues are entered in R/ha. Table 4.4 displays the fourth output screen showing the values of eight financial criteria.

4.2 Financial analysis

The financial analysis is based on the Net Present Value (NPV) and Real Internal Rate of Return (RIRR), as calculated by the FINROT program. Calculation of the NPV's and RIRR's for Mean Annual Increment at 20 years of age, from 5 to 25 m^3/ha/*annum* is done using Equations (2.1) and (2.2). The calculations are done for three different scenarios; i.e., for each cash flow three different values for the Real Cost of Capital are used (2,0%; 3,5% and 5,0%). This necessitated 63 computer runs.

The Mean Annual Increment at 20 years of age which will yield an NPV of greater than zero and a Real Internal Rate of Return of greater than the Cost of Capital is the minimum required yield for profitable production of sawtimber from *Pinus patula* in the escarpment area of Mpumalanga.

FINROT

No	to edit [0]		
1	Cash flow no	1	
2	Species	P. patula	
3	Product	Sawtimber	
4	By-product	Pulpwood	
5	Region	Mpumalanga	
6	M.A.I	15	(cubic m/ha at 20 years)
7	Real rate of change of roundwood prices	0	(%/Yr)
8	Real rate of change of direct cost	0	(%/Yr)
9	Real rate of change of general annual cost	0	(%/Yr)
10	Real rate of change of land value	0	(%/Yr)
11	Expected log-term inflation rate	13	(%/Yr)
12	Nominal cost of capital	17	(%/Yr)
13	Inflation-free cost of capital	3.539825	(%/Yr)
14	Value of land and infrastructure	2202	(R/ha)
15	General annual cost	625	(R/ha/Yr)
16	Clearfelling options from 28 to 28		(Years)

Table 4.1: First computer screen of the FINROT program

CASH FLOW WITH constant PRICES (ALL values in R/ha)

No to edit [0]

No	Age	Direct cost		G.A.C	Total cost	Gross revenue	Net cash flow
1	0	E	1 658		1 658		-1 658
2	1	W	296	625	921		-921
3	2	W	296	625	921		-921
4	3	PW	470	625	1095		-1095
5	4		0	625	625		-625
6	5	P	179	625	804		-804
7	6		0	625	625		-625
8	7	P	169	625	794		-794
9	8	T	727	625	1352	2105	753
10	9	P	173	625	625		-798
11	10		0	625	625		-625
12	11		0	625	625		-625
13	12		0	625	625		-625
14	13	T	1013	625	1638	2975	1337
15	14		0	625	625		-625
16	15		0	625	625		-625
17	16		0	625	625		-625
18	17		0	625	625		-625
19	18		0	625	625		-625
20	19		0	625	625		-625

Table 4.2: Second computer screen of the FINROT program

CASH FLOW WITH constant PRICES (ALL values in R/ha)

No to edit [0]

No	Age	Direct cost	G.A.C	Total cost	Gross revenue	Net cash flow
21	20	0	625	625	0	-625
22	21	0	625	625	0	-625
23	22	0	625	625	0	-625
24	23	0	625	625	0	-625
25	24	0	625	625	0	-625
26	25	0	625	625	0	-625
27	26	0	625	625	0	-625
28	27	0	625	625	0	-625
29	28	CF 7505	625	8130	36813	28683

Table 4.3: Third computer screen of the FINROT program

VALUES OF THE CRITERIA

Next Screen [0]

R	NPV (R/ha)	EAI (R/ha/Yr)	RIRR (%)	PI	BCR	LEV R/ha)	NPVI (R/ha)	RIRRI (%)
28	-2056.07	-116.93	2.69	0.47	0.899	-1101.25	-3303.25	0.00

Table 4.4: Fourth computer screen of the FINROT program

5. RESULTS

The values of NPV and RIRR obtained after running the FINROT computer program for the 63 cash flows in Appendix B are indicated in Table 5.1.

MAI_{20}	Cost of Capital = 2,0%		Cost of Capital = 3,5%		Cost of Capital = 5,0%	
	NPV (R/ha)	RIRR (%)	NPV (R/ha)	RIRR (%)	NPV (R/ha)	RIRR (%)
5	(12 609,49)	(6,39)	(12 078,02)	(6,39)	(11 509,33)	(6,39)
6	(11 426,48)	(4,83)	(11 268,76)	(4,83)	(10 937,05)	(4,83)
7	(10 010,47)	(3,45)	(10 281,01)	(3,45)	(10 223,62)	(3,45)
8	(8 893,39)	(2,45)	(9 540,19)	(2,45)	(9 717,53)	(2,45)
9	(7 432,15)	(1,43)	(8 546,89)	(1,43)	(9 020,69)	(1,43)
10	(5 942,53)	(0,54)	(7 550,85)	(0,54)	(8 336,17)	(0,54)
11	(4 399,39)	0,24	(6 493,67)	0,24	(7 587,32)	0,24
12	(2 913,62)	1,18	(5 490,00)	1,18	(6 887,98)	1,18
13	(1 200,43)	1,57	(4 314,69)	1,57	(6 053,74)	1,57
14	372,49	2,13	(3 264,76)	2,13	(5 331,43)	2,13
15	2 158,97	2,69	(2 056,07)	2,69	(4 487,73)	2,69
16	3 866,49	3,19	(898,78)	3,19	(3 679,42)	3,19
17	5 789,12	3,69	410,06	3,69	(2 758,19)	3,69
18	7 761,07	4,18	1 759,38	4,18	(1 803,31)	4,18
19	9 602,49	4,59	3 001,93	4,59	(939,64)	4,59
20	11 263,97	5,14	4 455,24	5,14	307,32	5,14
21	13 076,58	5,52	5 707,05	5,52	1 199,33	5,52
22	14 989,85	5,91	7 036,84	5,91	2 154,97	5,91
23	16 953,81	6,28	8 387,95	6,28	3 113,91	6,28
24	18 893,56	6,63	9 732,49	6,63	4 076,36	6,63
25	20 823,46	6,96	11 067,85	6,96	5 028,29	6,96

Table 5.1: *NPV and RIRR for different MAI_{20} classes* in the escarpment area of Mpumalanga

It is evident from Table 5.1 that the NPV increases with increasing MAI_{20} and decreases with increasing Real Cost of Capital from 2,0% to 5,0%. The RIRR also increases with increasing MAI_{20} but does not change when the real Cost of Capital changes, because it is a return internal to the project and calculated independently of a discount rate.

The behaviour of NPV and RIRR as a function of MAI_{20} when the real Cost of Capital is 2,0% is illustrated in Figure 5.1 and 5.2 respectively. The minimum required MAI_{20} for profitability is 14 m^3/ha/*annum*, because the NPV is greater than zero and the RIRR is greater than the real Cost of Capital at this yield level (refer to Figures 5.1 and 5.2, as well as to Table 5.1).

Figures 5.3 and 5.4 displays respectively the behaviour of NPV and RIRR as a function of MAI_{20} when the real Cost of Capital is 3,5%. The minimum required MAI_{20} for profitable production is 17 m^3/ha/*annum*, because the NPV is greater than zero (refer to Figure 5.3 and Table 5.1) and the RIRR is greater than the real Cost of Capital at this level of MAI_{20} (refer to Figure 5.4, as well as to Table 5.1).

Figures 5.5 and 5.6 show the behaviour of NPV and RIRR as a function of MAI_{20} when the real Cost of Capital is 5%. The minimum required yield potential in this case is 20 m^3/ha/*annum*.

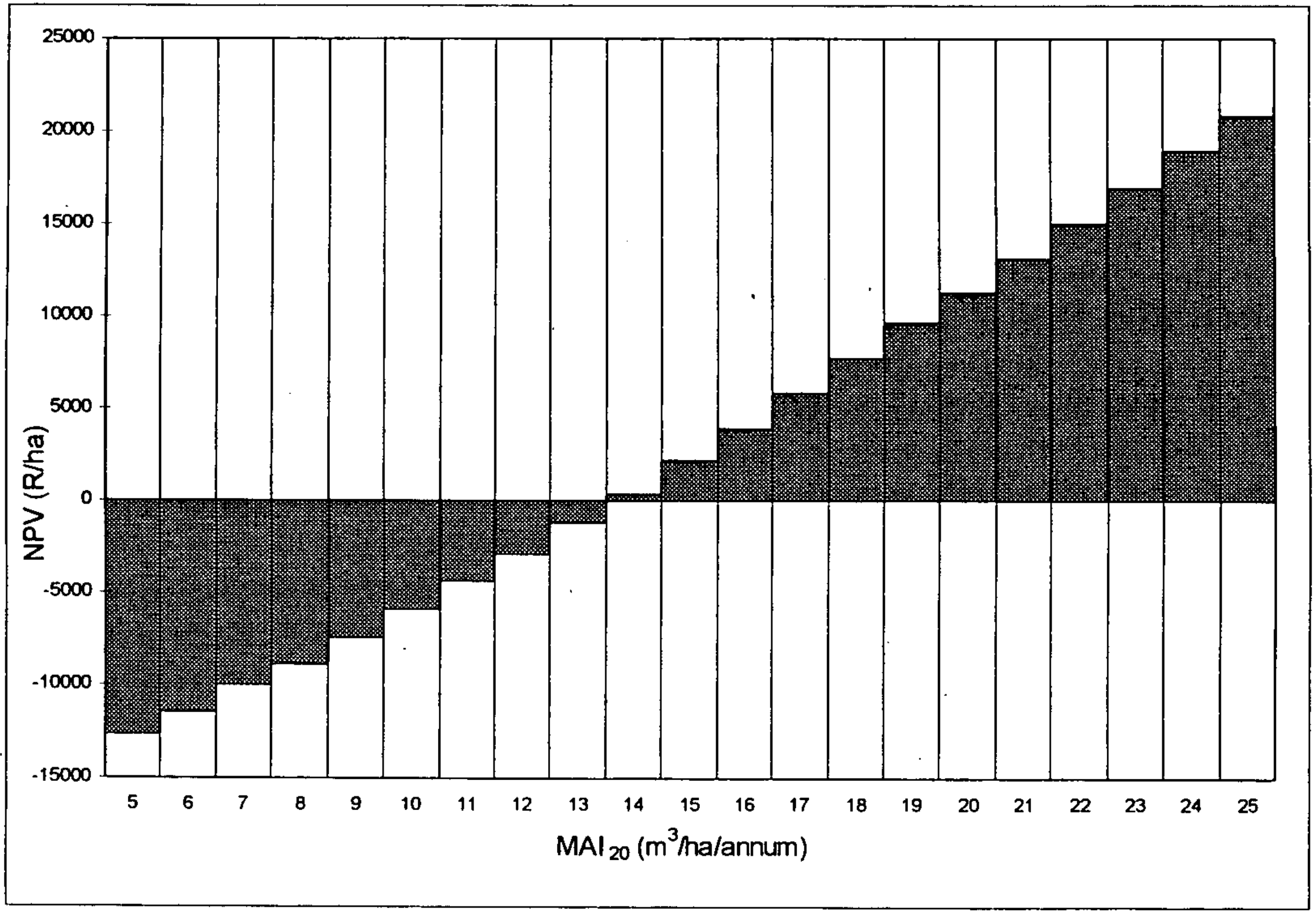

Figure 5.1: NPV as a function of different MAI_{20} classes at a RCOC of 2% (Source: Table 5.1)

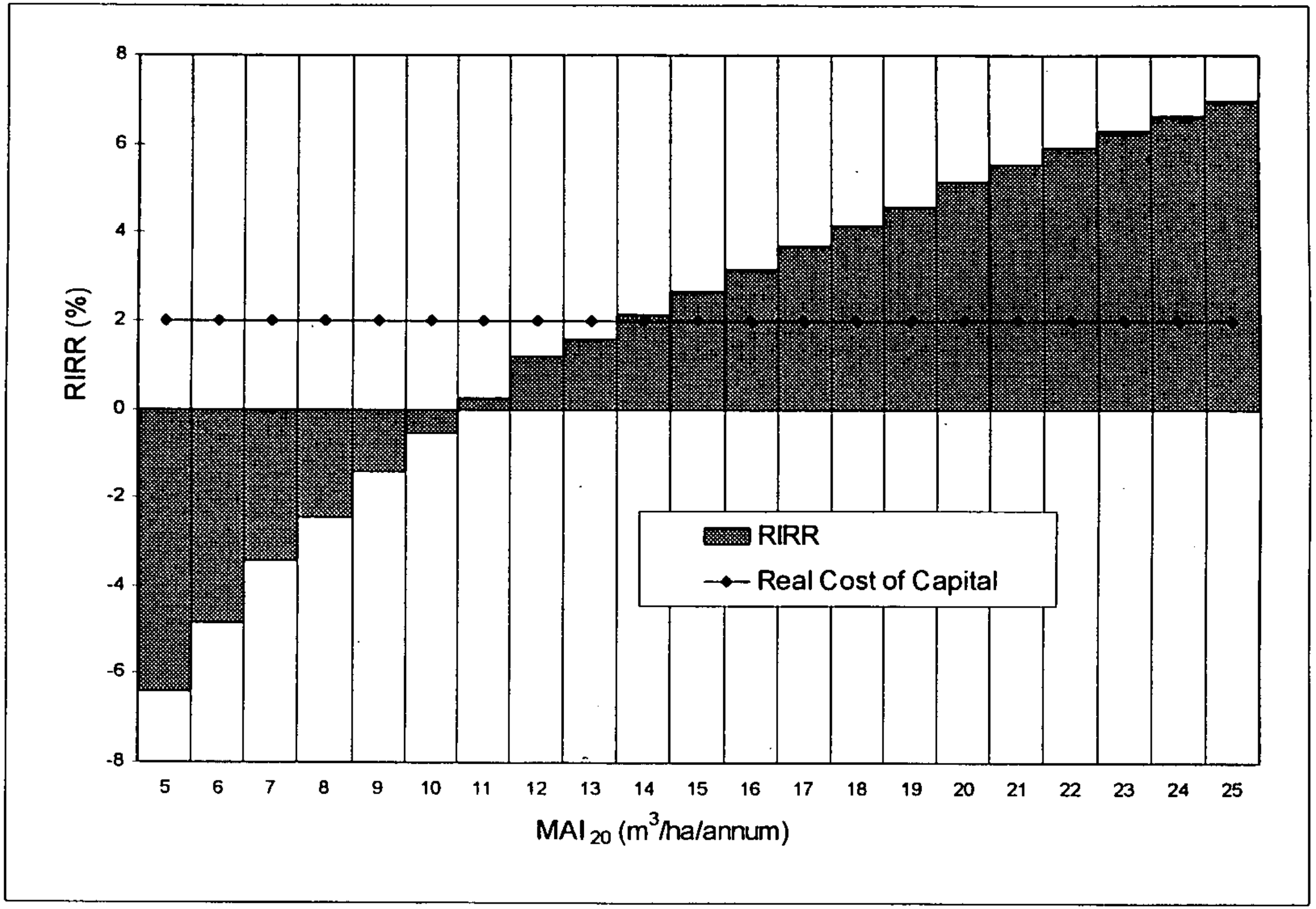

Figure 5.2: RIRR as a function of different MAI_{20} classes compared to a RCOC of 2% (Source: Table 5.1)

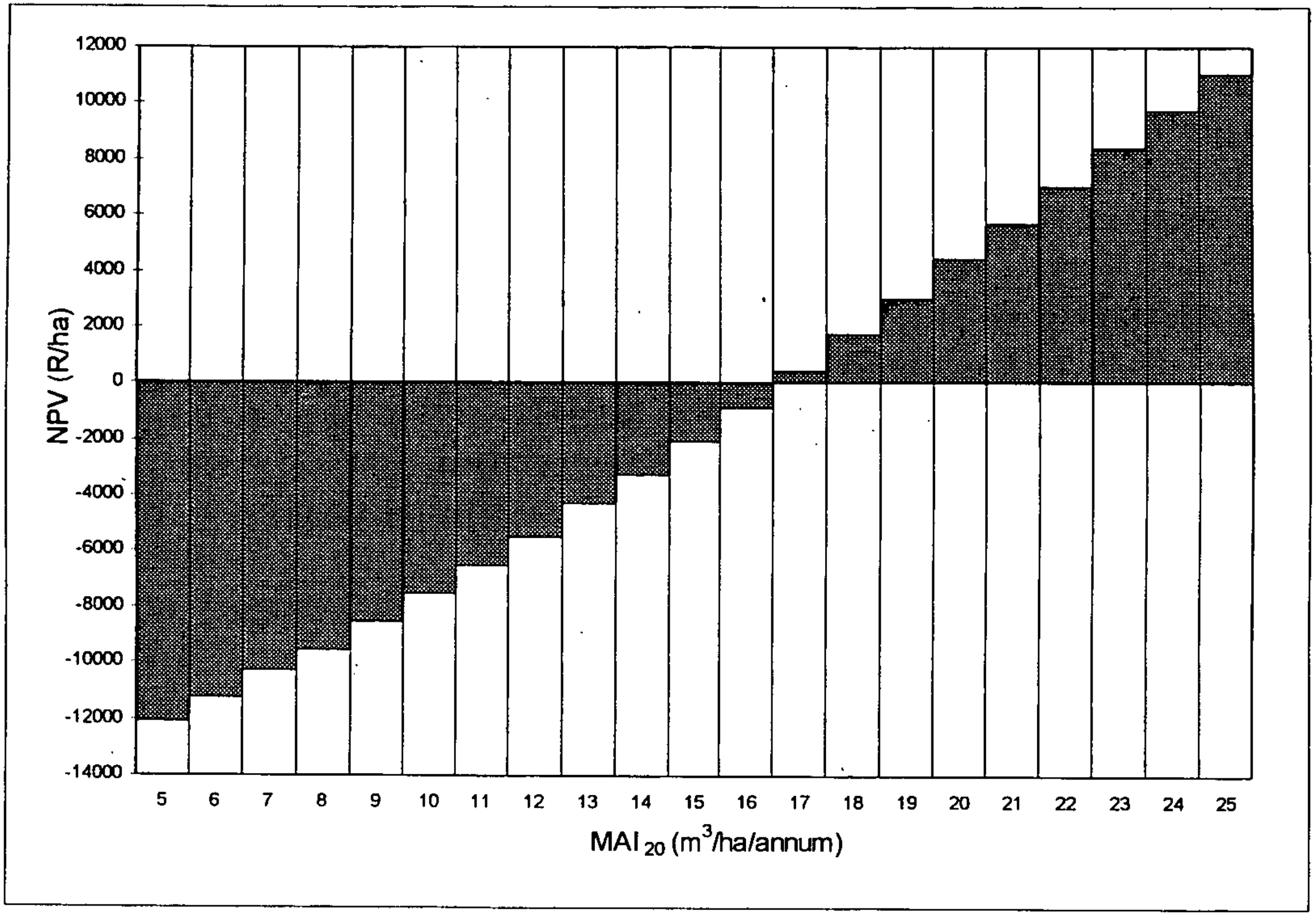

Figure 5.3: NPV as a function of different MAI_{20} classes at a RCOC of 3.5% (Source: Table 5.1)

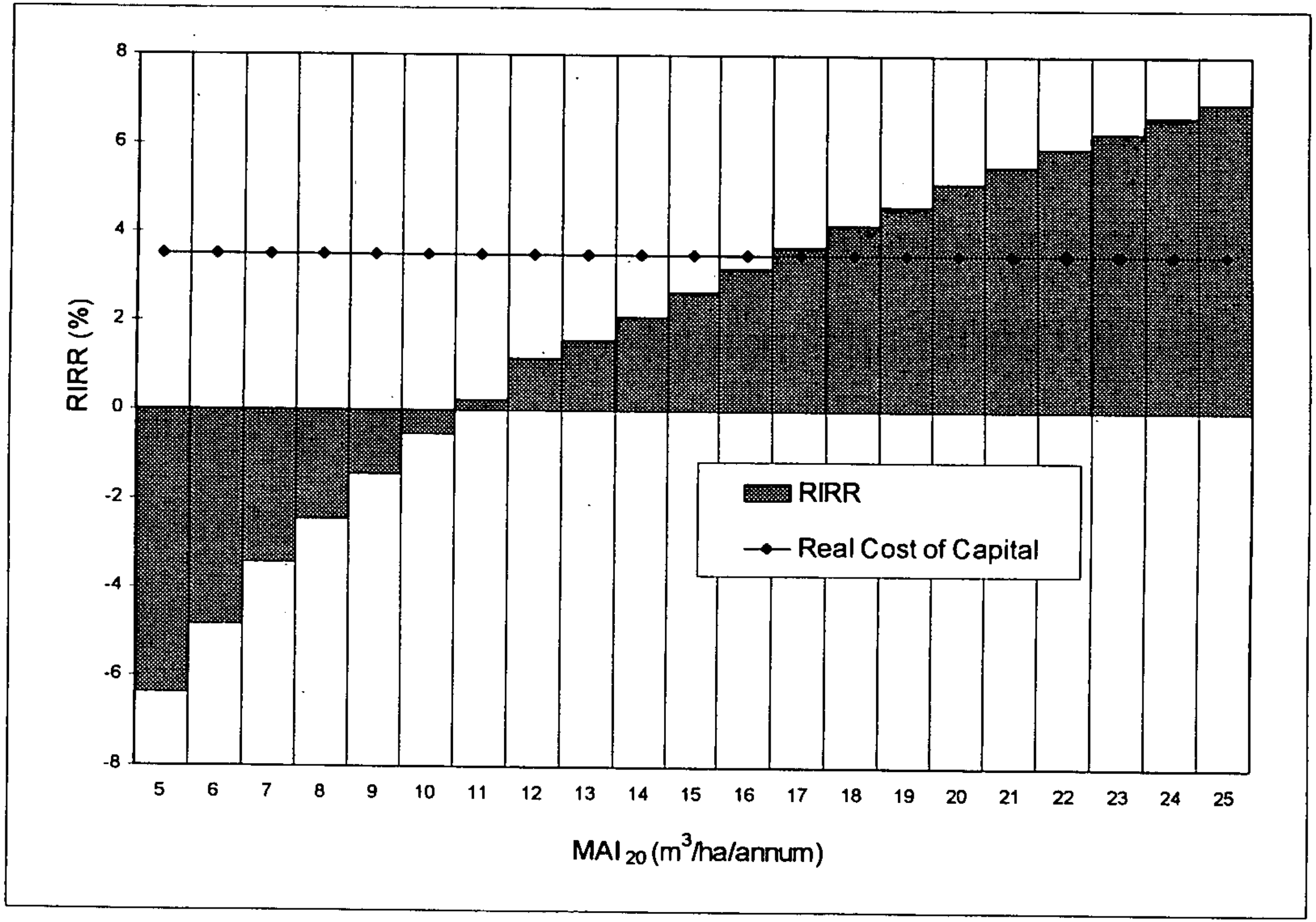

Figure 5.4: RIRR as a function of different MAI_{20} classes compared to a RCOC of 3.5% (Source: Table 5.1)

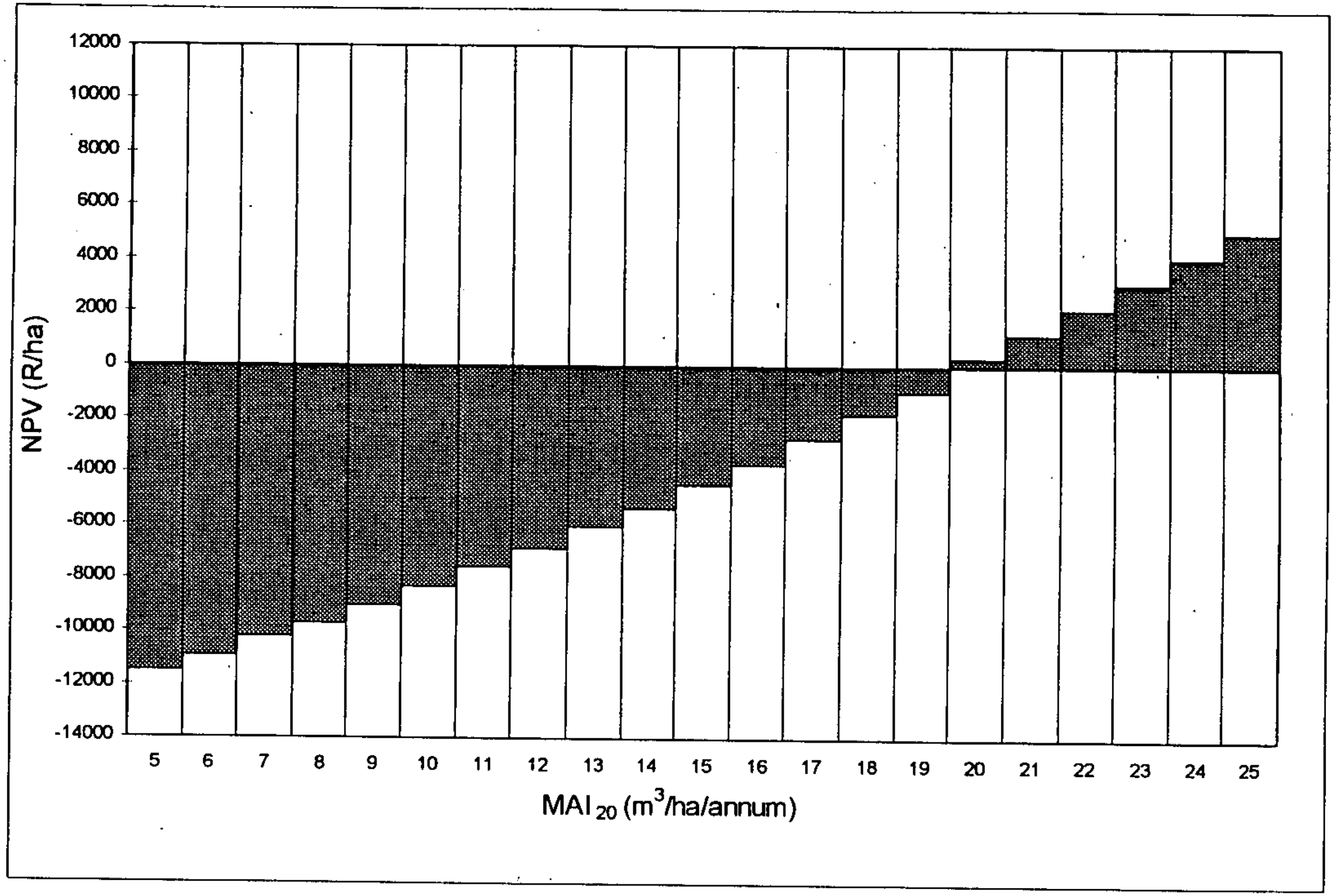

Figure 5.5: NPV as a function of different MAI_{20} classes at a RCOC of 5% (Source: Table 5.1)

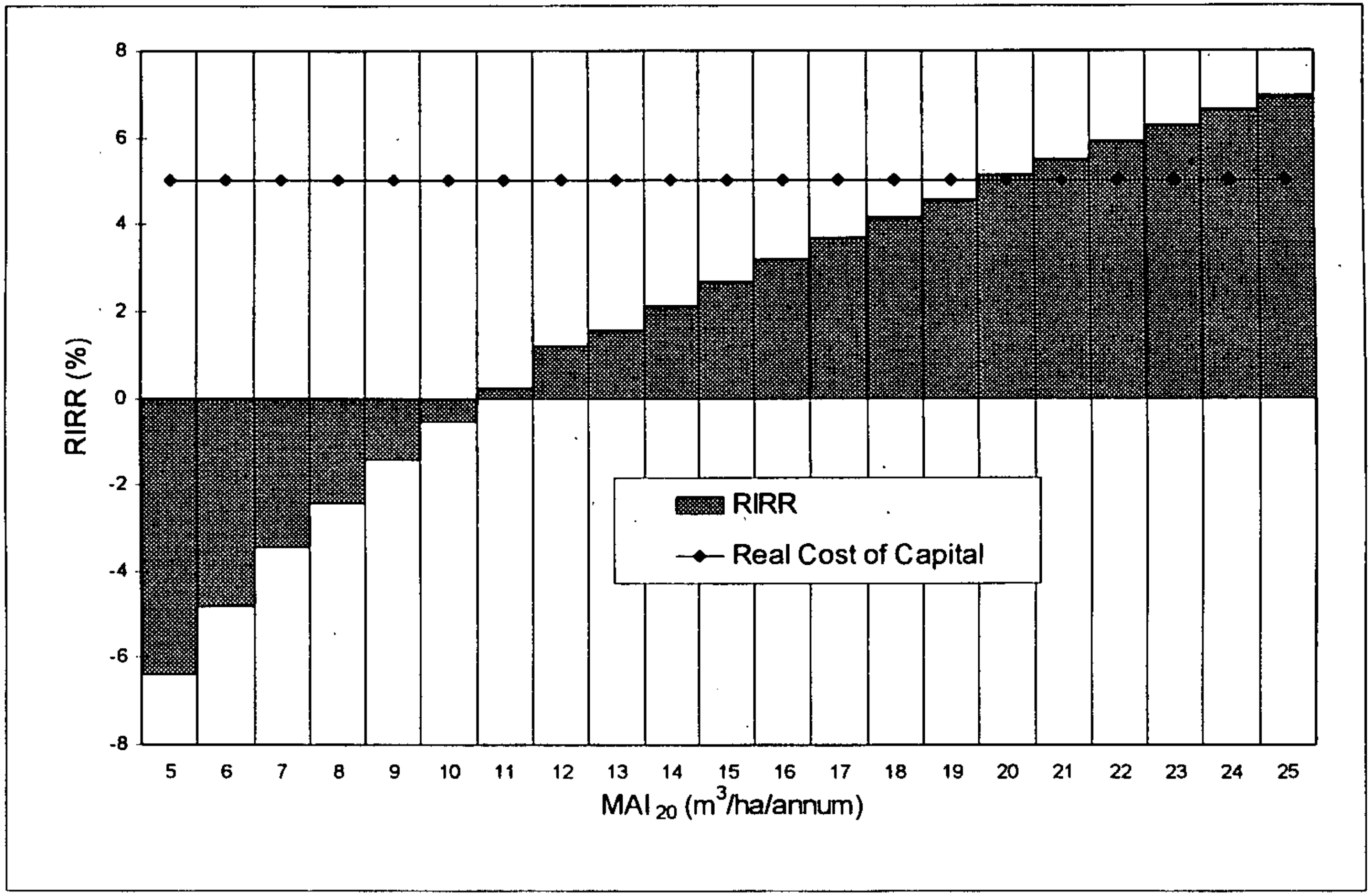

Figure 5.6: RIRR as a function of different MAI_{20} classes compared to a RCOC of 5% (Source: Table 5.1)

The minimum required yield (m^3/ha/*annum*) for profitable forestry in South Africa, established by other authors is shown in Table 5.2.

Required MAI (m^3/ha/*annum*)	Region	Species	Product	RDR (%)	Author
17,0	Natal	*Pinus patula*	Sawtimber	2,7	Olivier (1993)
16,0	W-Cape	*Pinus radiata*	Sawtimber	0,9	Du Toit (1992)
20,0	SA	*Eucalyptus*	Sawtimber		Schönau, Stubbings and Norris (1993)
15,0	SA	-	-	-	Stratten (1985)
9,8	E-Tvl	Pines	Sawtimber and pulpwood	-	FES (1997)
15,0	SA	*Eucalyptus*	-	-	Schönau and Stubbings (1987)

Table 5.2: Minimum required MAI's established by different authors in South Africa

The minimum required MAI_{20} of 14, 17 and 20 m^3/ha/*annum* (using a Real Cost of Capital of 2,0%; 3,5% and 5,0%) found in this study, differs from the values found by the other authors (refer to Table 5.2). The reasons for the differences are:

a) the different discount rates used in the studies;

b) difference in cost structures between the studies;

c) differences with regard to products, species and prices; and

d) different approaches to the calculation of profitability of forestry projects.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The minimum Mean Annual Increment at 20 years of age in the escarpment area of Mpumalanga, for profitable production of *Pinus patula* sawtimber, is: 14 m^3/ha/*annum*, 17 m^3/ha/*annum* and 20 m^3/ha/*annum* at discount rates 2,0%; 3,5% and 5,0% respectively.

According to the Directorate of Forestry (1981) the average MAI_{20} for sawtimber stands in the escarpment area of Mpumalanga is only 12 m^3/ha/*annum* for sawlogs over 18 cm in diameter and only 4 m^3/ha/*annum* for sawlogs under 18 cm in diameter. FES (1997) reported an average MAI_{20} for pines (sawtimber and pulpwood) in the same area of 15 m^3/ha/annum. Although *Pinus patula* is not the only softwood species in this area, it is the most important one with 43,7% of the area (refer to Figure 2.4) and the conclusion can be made that considerable areas of *Pinus patula* stands in the study area produce a yield of less than the marginal MAI_{20} found in this study. In other words some *Pinus patula* stands managed for the production of sawtimber in this area do not yield a profit.

6.2 Recommendations

Compartments with MAI_{20} below the minimum required yield must be accurately identified in the field and scrutenised. Some of them should not be used for commercial afforestation programmes and should be converted to other uses like conservation, recreation, farming or tourism.

It is recommended that forestry managers concentrate on compartments with a high yield potential and not so much on sub-marginal growth sites because they have a higher silvicultural cost *per* unit of production.

The marginal MAI_{20} as found in this study must not be thought of as something fixed or immutable. It can be reduced by the following:

a) Annual increases in the nominal price of sawtimber which keep pace with inflation. According to Uys (1997) the real price of softwood sawtimber indicated a decreasing trend of 2,2% *per annum* for the period 1964 to 1989;

b) Exploitation of export markets in order to sell the products at higher prices;

c) Soil analysis of growing sites and appropriate fertilizer applications;

d) Application of optimal financial rotations;

e) Effective matching of species to sites; and

f) Effective and efficient execution of activities such as soil preparation, planting, weeding, pruning, thinning and clearfelling in order to get the optimum yield on invested funds.

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APPENDIX A:

Volume yield tables for *Pinus patula* generated by the COMPAS system

Age	SPH	$MAI_{20} = 5$							$MAI_{20} = 6$						
		H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
2	1 221	1.0	0	0	0	0	0	0	1.1	0	0	0	0	0	0
3	1 221	2.3	0	0	0	0	0	0	2.4	0	0	0	0	0	0
4	1 221	3.5*	0	0	0	0	0	0	3.7*	1	1	0	0	0	0
5	1 221	4.5	3	3	0	0	0	0	4.9	4	4	0	0	0	0
6	1 221	5.5*	7	7	0	0	0	0	5.8*	10	9	0	0	0	0
7	1 221	6.4	12	12	0	0	0	0	6.8	16	15	1	0	0	0
8	1 221	7.2	18	17	1	0	0	0	7.7	24	21	3	0	0	0
T	571	7.2	7	7	0	0	0	0	7.7	9	8	1	0	0	0
9	650	7.9	17	14	3	0	0	0	8.5*	21	15	6	0	0	0
10	650	8.6*	22	16	6	0	0	0	9.2	28	17	10	0	0	0
11	650	9.3	28	17	11	0	0	0	9.9	35	19	16	0	0	0
12	650	9.8	35	18	16	0	0	0	10.5	42	19	22	1	0	0
13	650	10.4	41	19	21	1	0	0	11.1	50	19	28	3	0	0
T	250	10.4	13	7	5	0	0	0	11.1	15	7	8	0	0	0
14	400	10.9	33	12	19	3	0	0	11.7	40	12	23	5	0	0
15	400	11.4	38	12	22	5	0	0	12.2	46	12	26	9	0	0
16	400	11.9	44	12	25	7	0	0	12.8	53	12	28	13	0	0
17	400	12.4	49	12	26	11	0	0	13.3	59	11	29	19	0	0
18	400	12.8	55	11	28	15	0	0	13.7	66	11	31	24	0	0
19	400	13.1	60	11	29	20	0	0	14.1	73	11	31	30	0	0
20	400	13.5	66	11	30	24	0	0	14.4	79	11	32	36	1	0
21	400	13.8	71	11	30	30	0	0	14.7	86	11	32	42	1	0
22	400	14.0	77	11	31	34	1	0	15.0	93	11	32	48	2	0
23	400	14.3	82	11	31	39	1	0	15.3	99	11	32	54	3	0
24	400	14.5	88	11	31	44	2	0	15.6	101	10	31	59	5	0
25	400	14.8	93	11	31	48	3	0	15.8	112	10	31	64	6	0
26	400	15.0	98	10	31	53	4	0	16.1	118	10	31	68	9	0
27	400	15.2	103	10	31	56	5	0	16.3	124	10	31	72	11	0
CF 28	400	15.4	108	10	31	60	7	0	16.5	130	10	31	76	13	0

* Height at which trees are pruned

Age	SPH	MAI₂₀ = 7							MAI₂₀ = 8						
		H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
2	1 221	1.2	0	0	0	0	0	0	1.2	0	0	0	0	0	0
3	1 221	2.6	0	0	0	0	0	0	2.7	0	0	0	0	0	0
4	1 221	3.9*	1	1	0	0	0	0	4.1*	1	1	0	0	0	0
5	1 221	5.2	5	5	0	0	0	0	5.4	6	6	0	0	0	0
6	1 221	6.2*	12	12	0	0	0	0	6.5*	15	14	1	0	0	0
7	1 221	7.2	20	18	2	0	0	0	7.6	24	21	3	0	0	0
8	1 221	8.1*	29	24	5	0	0	0	8.6*	34	27	7	0	0	0
T	571	8.1	11	10	2	0	0	0	8.6	13	11	2	0	0	0
9	650	9.0	25	17	8	0	0	0	9.4	29	18	12	0	0	0
10	650	9.8	33	18	14	0	0	0	10.3	38	19	19	1	0	0
11	650	10.5	41	19	21	1	0	0	11.1	48	19	26	2	0	0
12	650	11.2	50	19	28	3	0	0	11.8	58	19	33	5	0	0
13	650	11.8	59	19	34	6	0	0	12.4	68	19	39	10	0	0
T	250	11.8	18	8	10	1	0	0	12.4	21	8	12	2	0	0
14	400	12.4	47	12	26	9	0	0	13.0	54	12	29	14	0	0
15	400	13.0	55	12	29	14	0	0	13.7	63	11	31	21	0	0
16	400	13.6	62	11	30	20	0	0	14.3	71	11	32	28	0	0
17	400	14.1	70	11	31	27	0	0	14.8	80	11	32	36	0	0
18	400	14.5	77	11	32	34	0	0	15.3	89	11	32	44	1	0
19	400	14.9	85	11	32	41	1	0	15.7	98	11	33	53	2	0
20	400	15.3	93	11	32	49	2	0	16.1	107	11	32	60	3	0
21	400	15.6	101	11	32	55	3	0	16.4	116	10	32	68	5	0
22	400	16.0	109	11	32	62	4	0	16.8	124	10	32	74	8	0
23	400	16.2	116	10	32	68	6	0	17.1	133	10	32	81	11	0
24	400	16.5	124	10	31	73	9	0	17.4	142	10	31	86	14	0
25	400	16.8	131	10	31	78	11	0	17.7	150	10	31	91	18	0
26	400	17.1	138	10	31	82	15	0	17.9	158	10	31	95	23	0
27	400	17.3	145	10	31	86	18	0	18.2	166	10	30	99	27	0
CF 28	400	17.5	152	10	30	90	22	0	18.4	174	10	30	101	32	0

* Height at which trees are pruned

Age	SPH	MAI$_{20}$ = 9 H$_T$ (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	MAI$_{20}$ = 10 H$_T$ (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0
2	1 221	1.3	0	0	0	0	0	0	1.3	0	0	0	0	0	0
3	1 221	2.8	0	0	0	0	0	0	3.0*	0	0	0	0	0	0
4	1 221	4.3*	2	2	0	0	0	0	4.5	2	2	0	0	0	0
5	1 221	5.7*	8	8	0	0	0	0	5.9*	9	9	0	0	0	0
6	1 221	6.8	17	16	1	0	0	0	7.1	20	18	2	0	0	0
7	1 221	8.0	28	23	5	0	0	0	8.3	32	25	6	0	0	0
8	1 221	9.0*	39	29	1	0	0	0	9.3*	44	30	14	0	0	0
T	571	9.0	15	12	3	0	0	0	9.3	17	13	4	0	0	0
9	650	9.9	33	18	5	0	0	0	10.3	38	19	18	1	0	0
10	650	10.7	44	19	3	1	0	0	11.2	49	19	27	2	0	0
11	650	11.6*	54	20	1	4	0	0	12.1*	61	20	35	6	0	0
12	650	12.3	66	19	7	9	0	0	12.8	73	19	41	13	0	0
13	650	13.0	77	19	3	15	0	0	13.5	86	19	46	21	0	0
T	250	13.0	24	8	4	3	0	0	13.5	27	8	15	4	0	0
14	400	13.6	62	11	30	20	0	0	14.2	69	11	32	26	0	0
15	400	14.3	71	11	32	28	0	0	14.9	79	11	33	35	0	0
16	400	14.9	80	11	33	36	0	0	15.5	90	11	33	45	1	0
17	400	15.5	90	11	33	46	1	0	16.1	101	11	33	55	2	0
18	400	16.0	100	11	33	55	2	0	16.6	112	11	33	65	3	0
19	400	16.4	110	11	33	64	3	0	17.1	123	11	32	74	5	0
20	400	16.8	120	10	32	72	5	0	17.5	134	10	32	83	9	0
21	400	17.2	130	10	32	79	9	0	17.9	145	10	32	91	13	0
22	400	17.6	140	10	32	87	12	0	18.3	156	10	31	97	18	0
23	400	17.8	150	10	31	92	17	0	18.6	167	10	31	103	23	0
24	400	18.2	160	10	31	97	21	0	18.9	178	10	31	107	30	0
25	400	18.5	169	10	31	102	26	0	19.2	188	10	30	111	37	0
26	400	18.8	178	10	30	106	32	0	19.5	199	10	30	115	43	1
27	400	19.0	188	10	30	109	38	1	19.8	209	10	30	118	50	2
CF 28	400	19.3	197	10	30	111	44	1	20.0	219	10	29	120	57	3

* Height at which trees are pruned

Age	SPH	MAI_{20} = 11 H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	MAI_{20} = 12 H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0
2	1 221	1.4	0	0	0	0	0	0	1.4	0	0	0	0	0	0
3	1 221	3.1*	0	0	0	0	0	0	3.2*	0	0	0	0	0	0
4	1 221	4.7	3	2	0	0	0	0	4.8	3	3	0	0	0	0
5	1 221	6.1*	10	10	0	0	0	0	6.3*	12	12	0	0	0	0
6	1 221	7.4	22	19	3	0	0	0	7.6	25	21	4	0	0	0
7	1 221	8.6*	36	27	8	0	0	0	8.9*	39	28	11	0	0	0
8	1 221	9.7	50	32	18	0	0	0	10.0	55	33	22	0	0	0
T	571	9.7	20	14	6	0	0	0	10.0	22	14	7	0	0	0
9	650	10.7	42	19	21	1	0	0	11.0	46	19	25	2	0	0
10	650	11.6	54	20	31	4	0	0	12.0*	59	20	34	6	0	0
11	650	12.5*	67	19	38	9	0	0	12.9	74	19	42	13	0	0
12	650	13.3	81	19	44	17	0	0	13.7	89	19	47	23	0	0
13	650	14.0	95	19	48	28	0	0	14.5	104	19	51	35	0	0
T	250	14.0	30	8	17	5	0	0	14.5	33	8	18	7	0	0
14	400	14.7	76	11	32	32	0	0	15.2	83	11	33	39	0	0
15	400	15.4	87	11	33	43	0	0	15.9	95	11	33	50	1	0
16	400	16.1	99	11	33	54	1	0	16.6	108	11	33	62	2	0
17	400	16.7	111	11	33	64	3	0	17.3	121	11	33	73	4	0
18	400	17.3	123	11	33	75	5	0	17.8	135	10	32	84	8	0
19	400	17.7	135	10	32	84	9	0	18.3	148	10	32	94	12	0
20	400	18.2	148	10	32	93	13	0	18.8	161	10	32	102	18	0
21	400	18.6	160	10	31	100	19	0	19.2	175	10	31	109	25	0
22	400	18.9	172	10	31	107	24	0	19.6	188	10	31	114	33	0
23	400	19.2	184	10	31	111	32	0	19.9	201	10	30	119	41	1
24	400	19.6	196	10	30	116	40	1	20.3	214	10	30	124	49	1
25	400	19.9	207	10	30	120	47	1	20.6	226	10	30	126	59	2
26	400	20.2	219	10	30	122	55	2	20.9	239	10	29	128	68	3
27	400	20.6	230	10	29	124	64	3	21.2	251	10	29	130	77	5
CF 28	400	20.8	241	10	29	126	72	4	21.5	263	9	29	132	85	7

* Height at which trees are pruned

Age	SPH	MAI$_{20}$ = 13 HT (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	MAI$_{20}$ = 14 HT (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0
2	1 221	1.5	0	0	0	0	0	0	1.5	0	0	0	0	0	0
3	1 221	3.3*	0	0	0	0	0	0	3.4*	0	0	0	0	0	0
4	1 221	5.0	4	4	0	0	0	0	5.1	4	4	0	0	0	0
5	1 221	6.5*	13	13	0	0	0	0	6.7*	15	14	1	0	0	0
6	1 221	7.8	27	23	5	0	0	0	8.1	30	24	6	0	0	0
7	1 221	9.2*	43	30	14	0	0	0	9.4*	47	31	16	0	0	0
8	1 221	10.3	60	34	26	1	0	0	10.6	65	34	30	1	0	0
T	571	10.3	24	15	9	0	0	0	10.6	26	15	10	0	0	0
9	650	11.4	50	19	28	3	0	0	11.7	54	19	31	4	0	0
10	650	12.3*	65	19	37	8	0	0	12.7*	70	19	40	11	0	0
11	650	13.3	80	19	44	17	0	0	13.7	87	19	47	21	0	0
12	650	14.1	97	19	49	29	0	0	14.5	104	19	51	35	0	0
13	650	15.0	113	19	52	43	0	0	15.4	122	19	53	51	0	0
T	250	15.0	35	8	19	9	0	0	15.4	38	7	19	11	0	0
14	400	15.7	90	11	33	45	1	0	16.1	97	11	33	52	1	0
15	400	16.4	103	11	33	58	2	0	16.9	112	11	33	65	3	0
16	400	17.2	117	11	33	70	4	0	17.7	127	11	33	78	5	0
17	400	17.8	132	11	33	82	6	0	18.3	142	10	32	90	9	0
18	400	18.4	146	10	32	93	11	0	18.9	157	10	32	101	15	0
19	400	18.9	160	10	32	102	17	0	19.4	173	10	31	110	22	0
20	400	19.4	175	10	31	110	24	0	19.9	189	10	31	117	31	0
21	400	19.8	189	10	31	116	32	0	20.3	204	10	30	123	41	0
22	400	20.2	204	10	30	121	42	1	20.8	220	10	30	129	50	1
23	400	20.5	218	10	30	126	51	1	21.1	235	10	30	131	62	2
24	400	20.9	232	10	30	129	61	2	21.5	250	10	29	134	74	3
25	400	21.2	245	10	29	131	72	3	21.9	265	10	29	137	84	6
26	400	21.6	259	10	29	134	81	6	22.2	279	9	29	138	95	8
27	400	21.9	272	9	29	136	91	8	22.5	293	9	28	139	106	11
CF 28	400	22.1	285	9	28	136	101	10	22.8	307	9	28	139	115	15

* Height at which trees are pruned

Age	SPH	$MAI_{20} = 15$ HT (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	$MAI_{20} = 16$ HT (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0
2	1 221	1.6	0	0	0	0	0	0	1.6	0	0	0	0	0	0
3	1 221	3.5*	0	0	0	0	0	0	3.5*	0	0	0	0	0	0
4	1 221	5.3	5	5	0	0	0	0	5.4	6	6	0	0	0	0
5	1 221	6.9*	16	16	1	0	0	0	7.1*	18	17	1	0	0	0
6	1 221	8.3	33	25	7	0	0	0	8.5*	35	26	9	0	0	0
7	1 221	9.7*	51	32	19	0	0	0	9.9	55	32	22	0	0	0
8	1 221	10.9	70	35	34	2	0	0	11.1	76	35	38	2	0	0
T	571	10.9	28	16	12	0	0	0	11.1	30	16	13	0	0	0
9	650	12.0*	59	19	34	6	0	0	12.3*	63	19	36	8	0	0
10	650	13.0	75	19	42	14	0	0	13.4	81	19	44	17	0	0
11	650	14.1	93	19	48	26	0	0	14.4	100	19	50	31	0	0
12	650	14.9	112	19	52	42	0	0	15.3	120	19	53	49	0	0
13	650	15.8	131	18	54	59	0	0	16.2	140	18	54	67	0	0
T	250	15.8	41	7	20	13	0	0	16.2	44	7	21	16	0	0
14	400	16.6	104	11	33	59	2	0	17.0	112	11	33	65	2	0
15	400	17.3	120	11	33	72	4	0	17.8	128	11	33	80	5	0
16	400	18.1	136	10	33	85	7	0	18.6	145	10	32	93	10	0
17	400	18.8	152	10	32	98	12	0	19.3	163	10	32	104	16	0
18	400	19.4	169	10	32	108	19	0	19.9	180	10	31	115	24	0
19	400	19.9	186	10	31	117	27	0	20.4	198	10	31	122	35	0
20	400	20.4	202	10	31	123	38	0	21.0	216	10	30	129	46	1
21	400	20.9	219	10	30	129	49	1	21.4	234	10	30	134	59	2
22	400	21.3	236	10	30	133	61	2	21.8	251	10	29	137	72	3
23	400	21.7	252	10	29	136	74	3	22.2	269	10	29	140	85	5
24	400	22.1	268	10	29	139	85	6	22.6	286	9	29	142	98	8
25	400	22.4	284	9	29	140	97	8	23.0	303	9	28	143	111	11
26	400	22.8	299	9	28	141	109	11	23.3	319	9	28	144	122	16
27	400	23.1	314	9	28	142	119	16	23.7	335	9	28	145	133	21
CF 28	400	23.4	329	9	28	142	129	21	24.0	351	9	27	144	144	26

* Height at which trees are pruned

Age	MAI$_{20}$ = 19: SPH	MAI$_{20}$ = 19: H_T (m)	MAI$_{20}$ = 19: U Vol/ha (m^3/ha)	MAI$_{20}$ = 19: S (m^3/ha)	MAI$_{20}$ = 19: A (m^3/ha)	MAI$_{20}$ = 19: B (m^3/ha)	MAI$_{20}$ = 19: C (m^3/ha)	MAI$_{20}$ = 19: D (m^3/ha)	MAI$_{20}$ = 20: SPH	MAI$_{20}$ = 20: H_T (m)	MAI$_{20}$ = 20: U Vol/ha (m^3/ha)	MAI$_{20}$ = 20: S (m^3/ha)	MAI$_{20}$ = 20: A (m^3/ha)	MAI$_{20}$ = 20: B (m^3/ha)	MAI$_{20}$ = 20: C (m^3/ha)	MAI$_{20}$ = 20: D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	1 221	0.2	0	0	0	0	0	0
2	1 221	1.7	0	0	0	0	0	0	1 221	1.7	0	0	0	0	0	0
3	1 221	3.8*	0	0	0	0	0	0	1 221	3.8*	0	0	0	0	0	0
4	1 221	5.8*	8	8	0	0	0	0	1 221	5.9*	8	8	0	0	0	0
5	1 221	7.6	23	20	2	0	0	0	1 221	7.7	24	21	3	0	0	0
6	1 221	9.1*	43	29	14	0	0	0	1 221	9.2*	46	30	16	0	0	0
7	1 221	10.6	67	34	31	1	0	0	1 221	10.8	71	34	34	2	0	0
8	1 221	11.9*	91	36	49	6	0	0	1 221	12.1*	96	36	53	7	0	0
T	571	11.9	36	17	18	1	0	0	571	12.1	38	17	20	2	0	0
9	650	13.1	75	19	42	14	0	0	650	13.4	80	19	43	17	0	0
10	650	14.3	97	19	49	29	0	0	650	14.5	102	19	50	33	0	0
11	650	15.4	119	19	53	48	0	0	650	15.7	126	19	53	54	0	0
12	650	16.3	143	18	54	70	1	0	650	16.7	151	18	54	77	1	0
13	650	17.3	167	18	55	93	2	0	650	17.6	176	18	55	101	3	0
T	250	17.3	52	7	22	24	0	0	250	17.6	55	7	22	26	0	0
14	400	18.1	133	11	33	84	6	0	400	18.5	140	10	33	89	8	0
15	400	19.0	152	10	32	98	11	0	400	19.3	161	10	32	104	14	0
16	400	19.8	173	10	32	111	20	0	400	20.2	182	10	32	117	23	0
17	400	20.6	193	10	31	123	30	0	400	21.0	204	10	31	127	36	0
18	400	21.2	214	10	31	131	43	0	400	21.7	226	10	30	136	49	1
T									150	21.7	69	4	12	47	6	0
19	400	21.8	236	10	30	137	57	1	250	22.2	173	6	18	90	57	3
20	400	22.4	257	10	30	142	73	3	250	22.8	191	6	18	91	71	6
21	400	22.8	278	10	29	146	89	5	250	23.3	209	6	17	91	85	10
22	400	23.3	299	9	29	147	105	9	250	23.8	228	6	17	91	98	16
23	400	23.7	320	9	28	148	121	14	250	24.2	247	6	17	89	110	25
24	400	24.2	340	9	28	149	134	19	250	24.6	267	6	16	88	122	35
25	400	24.5	360	9	28	149	149	25	250	25.0	286	6	16	87	130	47
26	400	24.9	380	9	27	148	161	34	250	25.4	306	5	16	86	139	60
27	400	25.3	399	9	27	148	171	43	250	25.8	325	5	16	84	145	75
CF 28	400	25.6	418	9	27	147	182	53	250	26.1	344	5	16	83	150	91

* Height at which trees are pruned

Age	SPH	$MAI_{20} = 21$							$MAI_{20} = 22$						
		H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0
2	1 221	1.8	0	0	0	0	0	0	1.8	0	0	0	0	0	0
3	1 221	3.9*	1	1	0	0	0	0	4.0*	1	1	0	0	0	0
4	1 221	6.0*	9	9	0	0	0	0	6.1*	10	10	0	0	0	0
5	1 221	7.8	26	22	3	0	0	0	8.0	27	23	4	0	0	0
6	1 221	9.4*	49	30	18	0	0	0	9.6*	51	31	20	0	0	0
7	1 221	11.0	75	35	37	3	0	0	11.2	79	35	40	3	0	0
8	1 221	12.4*	102	36	56	9	0	0	12.6*	107	37	60	11	0	0
T	571	12.4	40	17	21	2	0	0	12.6	42	17	23	3	0	0
9	650	13.6	84	19	45	20	0	0	13.9	88	19	47	22	0	0
10	650	14.8	107	19	51	37	0	0	15.1	112	19	52	42	0	0
11	650	16.0	132	18	54	60	0	0	16.3	139	18	54	66	0	0
12	650	17.0	159	18	55	84	1	0	17.3	166	18	55	92	2	0
13	650	17.9	185	18	55	109	4	0	18.3	194	18	55	117	5	0
T	250	17.9	58	7	22	29	0	0	18.3	61	7	22	32	0	0
14	400	18.8	147	10	33	95	10	0	19.2	154	10	32	100	12	0
15	400	19.7	169	10	32	109	18	0	20.1	177	10	32	114	21	0
16	400	20.6	191	10	31	122	27	0	21.0	200	10	31	126	33	0
17	400	21.4	214	10	31	132	42	0	21.8	224	10	30	136	47	1
18	400	22.1	237	10	30	140	57	1	22.5	249	10	30	143	65	2
T	150	22.1	73	4	12	49	8	0	22.5	76	4	12	51	9	0
19	250	22.6	182	6	18	91	63	4	23.1	191	6	18	92	70	5
20	250	23.2	200	6	18	92	77	8	23.7	210	6	17	93	84	10
21	250	23.7	220	6	17	92	92	13	24.2	230	6	17	92	99	16
22	250	24.2	239	6	17	91	105	21	24.7	251	6	17	91	112	25
23	250	24.6	259	6	17	90	118	30	25.0	272	6	16	90	124	36
24	250	25.1	280	6	16	88	128	42	25.5	293	6	16	89	134	49
25	250	25.5	301	5	16	87	137	55	25.9	315	5	16	87	143	64
26	250	25.9	321	5	16	85	144	71	26.3	337	5	16	85	149	81
27	250	26.3	342	5	16	84	150	87	26.7	358	5	16	84	155	98
CF 28	250	26.6	361	5	15	83	155	103	27.0	379	5	15	82	159	117

* Height at which trees are pruned

Age	SPH	MAI_{20} = 23 H_r (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)	MAI_{20} = 24 H_r (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0	0.2	0	0	0	0	0	0
2	1 221	1.8	0	0	0	0	0	0	1.9	0	0	0	0	0	0
3	1 221	4.1*	1	1	0	0	0	0	4.1*	1	0	0	0	0	0
4	1 221	6.2*	10	10	0	0	0	0	6.3*	11	11	0	0	0	0
5	1 221	8.1	29	24	5	0	0	0	8.3	30	25	6	0	0	0
6	1 221	9.7*	54	31	22	0	0	0	9.9*	57	32	24	1	0	0
7	1 221	11.4	82	36	43	4	0	0	11.6*	86	36	46	5	0	0
8	1 221	12.8*	112	37	63	13	0	0	13.0	117	37	65	15	0	0
T	571	12.8	45	17	24	3	0	0	13.0	47	17	26	4	0	0
9	650	14.1	92	19	47	26	0	0	14.3	96	19	48	29	0	0
10	650	15.3	118	19	52	47	0	0	15.6	123	19	53	52	0	0
11	650	16.5	145	18	54	72	1	0	16.8	152	18	54	78	1	0
12	650	17.6	174	18	55	99	3	0	17.8	182	18	55	106	3	0
13	650	18.6	203	17	54	125	6	0	18.9	212	17	54	133	8	0
T	250	18.6	64	7	22	35	0	0	18.9	67	7	22	37	0	0
14	400	19.5	162	10	32	105	14	0	19.8	169	10	32	109	17	0
15	400	20.4	185	10	32	119	24	0	20.7	193	10	31	124	28	0
16	400	21.3	210	10	31	130	38	0	21.7	219	10	31	134	43	0
17	400	22.1	235	10	30	140	54	1	22.5	245	10	30	143	61	1
18	400	22.8	260	10	30	146	73	3	23.2	272	10	29	149	80	3
T	150	22.8	80	4	12	53	11	0	23.2	83	4	12	55	13	0
19	250	23.4	200	6	18	93	76	7	23.8	208	6	17	94	82	9
20	250	24.1	220	6	17	93	91	12	24.4	229	6	17	94	98	15
21	250	24.6	241	6	17	93	105	20	25.0	251	6	17	93	112	24
22	250	25.1	262	6	17	91	119	30	25.5	274	6	17	91	125	35
23	250	25.5	284	6	16	90	130	43	25.9	297	6	16	90	136	50
24	250	26.0	307	6	16	88	140	57	26.4	320	5	16	88	145	65
25	250	26.4	329	5	16	86	148	74	26.8	344	5	16	86	152	84
26	250	26.8	352	5	16	85	154	92	27.2	368	5	16	85	159	103
27	250	27.2	374	5	15	83	159	111	27.6	391	5	15	83	162	125
CF 28	250	27.5	396	5	15	82	162	132	28.0	413	5	15	81	166	146

* Height at which trees are pruned

Age	SPH	MAI$_{20}$ = 25							
		H_T (m)	U Vol/ha (m^3/ha)	S (m^3/ha)	A (m^3/ha)	B (m^3/ha)	C (m^3/ha)	D (m^3/ha)
1	1 221	0.2	0	0	0	0	0	0
2	1 221	1.9	0	0	0	0	0	0
3	1 221	4.2*	1	1	0	0	0	0
4	1 221	6.4*	12	12	0	0	0	0
5	1 221	8.4*	32	25	6	0	0	0
6	1 221	10.1	59	32	26	1	0	0
7	1 221	11.7*	90	36	49	6	0	0
8	1 221	13.2	123	37	68	18	0	0
T	571	13.2	49	17	27	5	0	0
9	650	14.6	101	19	49	32	0	0
10	650	15.8	128	18	53	56	0	0
11	650	17.1	158	18	55	84	1	0
12	650	18.1	190	18	55	113	4	0
13	650	19.2	221	17	54	141	9	0
T	250	19.2	70	7	22	40	1	0
14	400	20.1	176	10	32	114	20	0
15	400	21.1	201	10	31	127	33	0
16	400	22.0	228	10	30	138	49	1
17	400	22.8	255	10	30	146	68	2
18	400	23.6	283	10	29	152	88	5
T	150	23.6	87	4	12	56	15	0
19	250	24.2	217	6	17	94	88	11
20	250	24.8	239	6	17	94	104	18
21	250	25.4	262	6	17	93	118	28
22	250	25.9	285	6	16	91	130	41
23	250	26.3	309	6	16	89	141	56
24	250	26.8	334	5	16	88	149	75
25	250	27.2	358	5	16	86	157	95
26	250	27.7	383	5	15	84	162	116
27	250	28.1	407	5	15	83	166	138
CF 28	250	28.4	431	5	15	81	169	160

* Height at which trees are pruned

APPENDIX B:

Cash flow tables for different classes of MAI_{20} in the escarpment area of Mpumalanga

The General Annual Cost for each year during the rotation is R625/ha/annum and the value of land and infrastructure is R2 202/ha. These two cost items are not shown in the following cash flows.

MAI_{20} = 5 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	267	
2	Weed control	267	
3	Weed control	267	
4	Pruning to 1,5m	174	
6	Pruning to 3,0m	179	
8	Thinning	259	605
10	Pruning to 5,0m	169	
13	Thinning	373	906
28	Clearfelling	2 454	9 083

MAI_{20} = 6 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	267	
2	Weed control	267	
3	Weed control	267	
4	Pruning to 1,5m	174	
6	Pruning to 3,0m	179	
8	Thinning	304	751
9	Pruning to 5,0m	169	
13	Thinning	442	1 086
28	Clearfelling	2 957	11 351

MAI$_{20}$ = 7 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	267	
2	Weed control	267	
3	Weed control	267	
4	Pruning to 1,5m	174	
6	Pruning to 3,0m	179	
8	Pruning to 5,0m	169	
8	Thinning	369	984
13	Thinning	532	1 383
28	Clearfelling	3 460	13 796

MAI$_{20}$ = 8 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	267	
2	Weed control	267	
3	Weed control	267	
4	Pruning to 1,5m	174	
6	Pruning to 3,0m	179	
8	Pruning to 5,0m	169	
8	Thinning	391	1 071
12	Pruning to 7,0m	173	
13	Thinning	601	1 593
28	Clearfelling	3 939	16 171

MAI_{20} = 9 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	267	
2	Weed control	267	
3	Weed control	267	
4	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
8	Pruning to 5,0m	169	
8	Thinning	435	1 217
11	Pruning to 7,0m	173	
13	Thinning	670	1 803
28	Clearfelling	4 465	18 910

MAI_{20} = 10 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	282	
2	Weed control	282	
3	Weed control	282	
3	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
8	Pruning to 5,0m	169	
8	Thinning	479	1 364
11	Pruning to 7,0m	173	
13	Thinning	715	1 953
28	Clearfelling	4 990	21 815

MAI_{20} = 11 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	282	
2	Weed control	282	
3	Weed control	282	
3	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
7	Pruning to 5,0m	169	
8	Thinning	547	1 571
11	Pruning to 7,0m	173	
13	Thinning	783	2 163
28	Clearfelling	5 493	24 612

MAI_{20} = 12 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	282	
2	Weed control	282	
3	Weed control	282	
3	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
7	Pruning to 5,0m	169	
8	Thinning	569	2 403
10	Pruning to 7,0m	173	
13	Thinning	852	2 703
28	Clearfelling	5 974	27 398

MAI_{20} = 13 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	282	
2	Weed control	282	
3	Weed control	282	
3	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
7	Pruning to 5,0m	169	
8	Thinning	637	1 838
10	Pruning to 7,0m	173	
13	Thinning	920	2 642
28	Clearfelling	6 477	30 447

MAI_{20} = 14 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	282	
2	Weed control	282	
3	Weed control	282	
3	Pruning to 1,5m	174	
5	Pruning to 3,0m	179	
7	Pruning to 5,0m	169	
8	Thinning	660	1 898
10	Pruning to 7,0m	173	
13	Thinning	945	2 735
28	Clearfelling	6 980	33 542

MAI_{20} = 15 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	296	
2	Weed control	296	
3	Pruning to 1,5m	174	
3	Weed control	296	
5	Pruning to 3,0m	179	
7	Pruning to 5,0m	169	
8	Thinning	727	2 105
9	Pruning to 7,0m	173	
13	Thinning	1 013	2 975
28	Clearfelling	7 505	36 813

MAI_{20} = 16 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	296	
2	Weed control	296	
3	Pruning to 1,5m	174	
3	Weed control	296	
5	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Thinning	750	2 165
9	Pruning to 7,0m	173	
13	Thinning	1 105	3 304
28	Clearfelling	7 985	39 897

MAI_{20} = 17 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	296	
2	Weed control	296	
3	Pruning to 1,5m	174	
3	Weed control	296	
5	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Thinning	818	2 375
9	Pruning to 7,0m	173	
13	Thinning	1 150	3 483
28	Clearfelling	8 511	43 379

MAI_{20} = 18 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	296	
2	Weed control	296	
3	Pruning to 1,5m	174	
3	Weed control	296	
5	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Thinning	885	2 582
9	Pruning to 7,0m	173	
13	Thinning	1 219	3 752
28	Clearfelling	9 036	46 860

MAI_{20} = 19 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	296	
2	Weed control	296	
3	Pruning to 1,5m	174	
3	Weed control	296	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Pruning to 7,0m	173	
8	Thinning	908	2 642
13	Thinning	1 310	4 082
28	Clearfelling	9 539	50 203

MAI_{20} = 20 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	311	
2	Weed control	311	
3	Pruning to 1,5m	174	
3	Weed control	311	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Pruning to 7,0m	173	
8	Thinning	977	2 852
13	Thinning	1 356	4 261
18	Thinning	1 680	6 116
28	Clearfelling	7 876	45 712

MAI_{20} = 21 m^3/ha/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	311	
2	Weed control	311	
3	Pruning to 1,5m	174	
3	Weed control	311	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Pruning to 7,0m	173	
8	Thinning	1 000	2 913
13	Thinning	1 425	4 530
18	Thinning	1 771	6 573
28	Clearfelling	8 242	48 462

MAI_{20} = 22 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	311	
2	Weed control	311	
3	Pruning to 1,5m	174	
3	Weed control	311	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Pruning to 7,0m	173	
8	Thinning	1 068	3 123
13	Thinning	1 493	4 799
18	Thinning	1 840	6 891
28	Clearfelling	8 630	51 396

MAI_{20} = 23 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	311	
2	Weed control	311	
3	Pruning to 1,5m	174	
3	Weed control	311	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
8	Pruning to 7,0m	173	
8	Thinning	1 091	3 183
13	Thinning	1 562	5 068
18	Thinning	1 931	7 348
28	Clearfelling	9 042	54 457

MAI_{20} = 24 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	311	
2	Weed control	311	
3	Pruning to 1,5m	174	
3	Weed control	311	
4	Pruning to 3,0m	179	
6	Pruning to 5,0m	169	
7	Pruning to 7,0m	173	
8	Thinning	1 159	3 393
13	Thinning	1 607	5 247
18	Thinning	2 023	7 805
28	Clearfelling	9 430	57 391

MAI_{20} = 25 m^3/ha/*annum*			
Age	Activity	Cost (R/ha)	Revenue (R/ha)
0	Establishment cost	1 658	
1	Weed control	326	
2	Weed control	326	
3	Pruning to 1,5m	174	
3	Weed control	326	
4	Pruning to 3,0m	179	
5	Pruning to 5,0m	169	
7	Pruning to 7,0m	173	
8	Thinning	1 205	3 543
13	Thinning	1 699	5 655
18	Thinning	2 091	8 173
28	Clearfelling	9 819	60 275