ECONOMICS OF RADIATA PINE FOR SAWLOG PRODUCTION

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ABSTRACT

The economics of radiata pine (**Pinus radiata** D. Don) at a normal rate of afforestation, for sawlog production are evaluated for scrub-covered land, of relatively easy topography. Site index is 95. The rotation of 26 yr produces 8248 cu ft net per acre. Silviculture reduces final crop stocking to 80 s.p.a. by 35 ft and pruning two 18 ft lengths concentrates production on high quality logs. The forested areas are grazed from age 3½.

Values are based on 1967 levels and are charged from the mid-point of the year of origin. Interest rates from 3% to 14% are evaluated.

Net land expectation values (excluding grazing returns) at 7% are $99 when social costs are included and $117 when they are excluded. Corresponding internal rates of return are 10.5% and 11.5%.

Comprehensive sensitivity analyses are made on effects of altering costs and returns. At interest rates up to 10% sawing is the greatest single cost, then logging. Total costs of five pruning lifts and two thinnings to waste exceed logging costs at interest rates above 8½%. Pulpwood returns are minor.

Timing of tending steps is critical, otherwise risks are low.

The concept of concentrating production on high quality stems (64% of the sawn outturn is of high quality timber) and grazing stands may alter the class of land available for forestry.

The 10 yr reduction in sawlog rotations would help close the forest sector target gaps in national development. The regime evaluates where one of New Zealand's comparative advantages lies—the rapid production of high quality logs.

INTRODUCTION

The doctrine of maximisation of volume production has been explicit in forestry for over a century. "The non-forester probably expects a discussion of zero-interest doctrines to call up a collection of amiable eccentrics misquoting Marx, Gesell or St Thomas Aquinas. But not at all: the United States Forest Service itself adheres to a zero-interest doctrine, maximisation of mean annual yield, and many forestry texts and schools treat zero-interest doctrines with great respect . . . one finds strong undercurrents of support in popular literature, based on what it is probably fair to characterise as sheer mysticism, yet which still carry weight in determining public policy" (Gaffney, 1960). The maximisation of volume production through production thinning continues to dominate management concepts in New Zealand, although it is less influential in practice, and only a few thinning operations survive (as nominal prescriptions). A typical, theoretical sawlog regime with a single production thinning is evaluated in a companion paper (Fenton, 1972a). If, however, the cost of capital is accepted, analysis shows that forests are amongst the most highly capitalised of all production industries (Fenton, 1970; Fedkiw, 1960). Preliminary analyses of accelerated afforestation (Fenton *et al.,* 1968a, 1968b) showed the cost of delaying final crop increment by waiting for a production thinning reduced the internal rate of return (IRR) from 10% to $6\frac{1}{2}$%, but these comparisons were complicated by the different time scales and products involved.

This paper evaluates a silvicultural regime (Fenton and Sutton, 1968) designed to produce a specific size and quality of final crop tree of radiata pine (*Pinus radiata* D. Don). The regime has been amended to incorporate later research results (J. B. Crowe, R. N. James, R. L. Knowles, W. R. J. Sutton, pers. comm.).

It is a nominative study, the regime analysed has not been applied to local plantations. A "normal" rate of development is used to facilitate comparisons between different regimes.

The paper includes economic considerations beyond profitability, but is not a full cost/benefit analysis.

The base year for the Forestry Development conference was 1967 and prices and costs are generally for that year.

ASSUMED CHARACTERISTICS OF THE AREA

To maintain comparability with other studies (Fenton and Tustin, 1972; Fenton and Dick, 1972a, 1972b, 1972c, 1972d, 1972e), evaluation concerns an area with given characteristics. A gross area of 25 000 acres has:

	Acres net
Tractor plantable — frost flats — no release cutting	1 600
Tractor plantable — not frost flats — one release cutting	10 000
Not tractor plantable — not frost flats — one release cutting	7 000
Not tractor plantable — not frost flats — two release cutting	2 200
	20 800

The site index (Lewis, 1954) assumed in this model is 95, the port is 89 miles and the sawmill 25 miles from the mid-point of the forest. Initial cover is largely inflammable scrub.

TECHNICAL SPECIFICATIONS AND SILVICULTURE

The regime is required to maintain rapid diameter increment on the crop trees, and to promote good grazing conditions for sheep, cattle or deer. Grazing is, however, evaluated separately. The final tree size specified of 2 ft d.b.h. enables direct use of grade study results (Fenton, Sutton and Tustin, 1971; Fenton, 1972b) in calculating returns from trees of this size and age.

Silviculture is:

(1) Planting sites are cleared and burnt before establishment as for the log trade model (Fenton and Dick, 1972e).

(2) Initial spacing: trees 7 ft apart in rows 10 ft apart (620 s.p.a.).

(3) Blanking: 10% replacement assumed in the year following planting.

(4) Release cutting: one operation in the first year after planting. On steeper sites,

comprising 2200 acres net, a further operation is prescribed in the second year. This second operation has also been costed for the planting in year 2, as the sites would have been burnt only once.

(5) Pruning and thinning:
  (a) Prune 0/8 ft, 250-300 s.p.a.; 16 ft mean tree height. Thin all unpruned trees.
  (b) Prune 8/14 ft, 130-150 s.p.a.; 26 ft mean tree height.
  (c) Prune 14/20 ft, 80 s.p.a.; 36 ft mean tree height. Thin all trees not high-pruned.
  Profitability of second log pruning is also evaluated and would require:
  (d) Prune 20/26 ft, 80 s.p.a.; 45 ft mean tree height.
  (e) Prune 26/36 ft, 80 s.p.a.; 55 ft mean tree height.

(6) Protection: Needle blight (*Dothistroma pini* Hulbary) prevention measures are given later.

(7) Clearfelling at normality at age 26.

(8) The only variation from this regime is on frost flats where it has been assumed that *Pinus contorta* Dougl. planted at 20 × 7 ft spacing would form an initial shelterwood; this would be poisoned at about age 11 and radiata pine interplanted in the gaps between the rows. It has been assumed that further rotations could be re-established on old frost flats without undue trouble; as subsequent rotations begin at least 50 years after the year of origin of the forest, the financial effect of frost flat re-establishment will be slight.

(9) Second and subsequent rotations are assumed to be replanted on one-third of the area; direct seeded from the air on one-third; and naturally-regenerated on the remaining area. Subsequent treatment for sown and regenerated stands includes an extra spraying against *Dothistroma*; slasher-thinning cum release cutting at age 2; and no blanking. Treatment of stands of all origins is the same from about 5 ft in height onwards. The schedule of operations is given in Table 1.

YIELD PREDICTIONS

The growth projections calculated by R. N. James are given in Appendix 1. Further data from the Economics group at the New Zealand Forest Research Institute are available to improve the original stand growth projections (Fenton *et al.,* 1968a), and the within-tree volume distribution. The loss of increment due to heavy pruning has been quantified; stands are clearfelled before any mortality occurs. An extra year has been allowed on the projected rotation to reach a mean tree of 24.3 in. d.b.h. to ensure the full butt and second log volumes are attained.

Final crop trees have mean dimensions of:

d.b.h.o.b.	24.3 in.
Height	115 ft
Butt log, small end diameter (s.e.d.)	*ca.* 17-18 in.
volume (18 ft log)	39 cu ft
Second log, s.e.d.	*ca.* 15-16 in.
volume (18 ft log)	29 cu ft
Third log, s.e.d.	*ca.* 13 in.
volume (18 ft log)	20 cu ft
Top logs—pulpwood volume recovered	15.1 cu ft

Most of the volume lost in logging is in the small diameter logs of the upper crown.

TABLE 1—Management plan: area of each annual operation (acres)

Year	Planting Machine P. radiata	Planting Machine P. contorta	Planting Hand	Sowing	Blanking	Release Cutting 1	Release Cutting 2	Slasher Thinning	Pruning 1	Pruning 2	Pruning 3	Pruning 4	Pruning 5	Thinning to waste 1	Thinning to waste 2	Poison Overwood
1	800															
2	800				800	800										
3	800				800	800	800									
4	800				800	800										
5	800				800	800			800P					800P		
6	800				800	800										
7	800				800	800				800P						
8	800				800	800										
9	800				800	800					800P				800P	
10	800				800	800										
11	800				800	800						800P				
12	800	800	400		800	800										
13	400	800	800		800	800							800P			
14-23			800		800	800										
24			800		800	800	600*									800
25	800				800	800	800*									800
26	800				800	800	800*									
27			267P	267P	800	800										
28					267P	267P										
29								533P								

P = in perpetuity
* = Periodic, occurring every rotation (26 yr)

LABOUR REQUIREMENTS: DIRECT COSTS

Direct costs include: cost of labour and bonus; travel time; workers' compensation insurance and holiday pay; cost of vehicles and machinery.

The direct costs and unit labour requirements of forest operations are given in Table 2. The origin of the costs of land clearing and establishment (and all indirect costs) are detailed elsewhere (Fenton and Tustin, 1972). Costs of pruning and thinning to waste are based on work study data of the Silvicultural Economics group at the New Zealand Forest Research Institute. Only limited data are available for second log pruning costs, and these may be conservative. Clearfelling labour needs are based on a man-hour production of 100 cu ft.

Direct labour requirements are given in Table 3; staff and indirect labour in Table 4; and total labour in Table 5. The logging equipment required is listed in Table 6; direct logging costs have been taken as 3.0c per cu ft (excluding purchase of machinery, supervision costs and external overhead).

Fire and *Dothistroma* protection costs are in Table 7 and 8 respectively. Social costs include: roading — Table 9; accommodation — Table 10; and services — Table 11. It has been assumed that 10 men can be recruited locally, and they have not been housed on the forest. The costs of running the camp have been taken as $122 per man per year. Houses cost $8,400 each, huts $700. Maintenance of buildings costs 1¼% of capital annually.

TABLE 2—Summarised direct costs and labour requirements

Operation	Direct Cost $ per acre	Man-days per acre
Land clearing		
Burning	0.50	Contractor
Light scrub-crushing	4.00	Contractor
Heavy scrub-crushing	6.00	Contractor
Heavy scrub-cutting	17.00	Contractor
Bush felling	32.00	Contractor
Bush slash raking	16.00	Contractor
Planting		
Hand	15.34	0.62
Machine	10.00	0.155
Sowing	10.00	Negligible
Blanking	3.00	0.3
Release Cutting	5.30	0.67
Pruning		
0-8 ft	9.9	1.0
8-14 ft	13.7	1.4
14-20 ft	13.7	1.4
20-28 ft	19.6	2.0
28-36 ft	19.6	2.0
Thinning to Waste		
From 600 to 300 at 16 ft	5.00	0.33
From 300 to 80 at 35 ft	10.35	0.7
Slasher Thinning regeneration	6.50	0.67
Poison overwood	7.50	0.67

TABLE 3—Direct labour requirements, forest growing and tending (man-days)

Year	Planting		Blanking	Release Cutting		Slasher Thinning	Pruning					Thinning to waste		Poison Overwood	Total	Years
	Machine	Hand		1	2		1	2	3	4	5	1	2			
1	124														124	1
2	124		240	533											897	4
3	124		240	533	533										1,430	6
4	124		240	533											897	4
5	124		240	533			800P					267P			1,964	8
6	124		240	533											1,964	8
7	124		240	533				1,120P							3,084	13
8	124		240	533											3,084	13
9	124		240	533					1,120P				560P		4,764	20
10	124		240	533											4,764	20
11	124		240	533						1,600P					6,364	27
12	124		240	533											6,364	27
13	186	248	240	533							1,600P				8,274	35
14	124	496	240	533											8,460	35
15-17		496	240	533											8,336	35
18-23		496	240	533											8,336	35
24		496	240	533	400*									533	9,269	39
25	124		240	533	533*									533	9,030	38
26	124		240	533	533*										8,497	36
27		166P	240	533											8,006	34
28			80P	178P											7,491	32
29						356P									7,847P	33P

P = in perpetuity
* = Periodic, occurring every rotation (26 yr) excluded from totals

TABLE 4—Staff and indirect labour schedule

Year	1	2	3-6	7-8	9-25	26	27	28+
STAFF								
Forest								
Officer in charge	1							1
Forester		1						1
Ranger/Foreman		1			1		1	3
Clerk	1							1
Clerk/Stores							1	1
Logging								
Officer in charge						1		1
Forest Ranger / Forest Foreman							2	2
Clerk							1	1
Roading								
Officer in charge	1							1
OTHER LABOUR								
Men	2					1		3
Fleet								
Mechanics	1						3	4
Drivers	1						2	3
Other								
Tractor driver	1							1
Fire lookout			1					1
Fire storekeeper			1					1
Camp attendant							1	1
Carpenter/Painter	1						1	2
HQ gang				1			2	3
Tool maintenance	1							1
Total	10	12	14	15	16	18	32	

TABLE 5—Total manpower required (man-years)

Year	Forest*	Staff and Indirect†	Logging	Total
1	1	10		11
2	4	12		16
3	6	14		20
4	4	14		18
5-6	8	14		22
7-8	13	15		28
9-10	20	16		36
11-12	27	16		43
13-23	35	16		51
24	39	16		55
25	38	16		54
26	36	18		54
27	34	32P	40P	106
28	32			104
29	33P			105P

P = in perpetuity
* = From Table 3
† = From Table 4

TABLE 6—Schedule of logging equipment

Year	No.	Item	Unit Cost $
26	1	Trekka truck	1,770
	1	D7 tractor	53,000
	2	Tip trucks	4,500
27	1	D7 tractor	53,000
	8	D6 tractors	35,000
	8	Arches	5,000
	4	Loaders	35,000
	3	Gang trucks	5,000
	32	Power saws	150
	2	Field service units	5,000
		Miscellaneous equipment	4,600
		Stores (purchase)	5,000

TABLE 7—Fire protection costs

Item	Year	Cost $
Firebreak Preparation	1-26	150 p.a.
Fencing	1-5	500 p.a.
Telephone	3	1,225
Equipment		
Radio	3	1,200
Fire engine	3	10,200
Fire tanker	5	3,600
Fire pumps (2)	4	1,200
Miscellaneous	3	3,400
Buildings		
Lookout		
Capital	3	5,500
Depreciation		65 yr life
Garage and store		
Capital	5	4,400
Depreciation		65 yr life

Annual charges: are roughly proportional to the area planted:
$0.81 per acre up to 7,500 acres
$0.53 per acre from 7,500 to 13,000 acres
$0.46 per acre above 13,000 acres

TABLE 8—Anti-**Dothistroma** costs

Operation	Unit Cost $ per acre
Aerial Survey	0.01
Ground Survey	0.10
Spraying Cost:	
Chemicals	1.90
Aircraft	0.85-1.00*
Ground staff and transport	0.10-0.34*
Total spraying	3.00 approx.*

* = The range of costs is for large-scale operations over 1,500 ac areas; the mean is very close to $3.

TABLE 9—Social costs: Roading

			Year
Road formation	$4,060 p.a.		1-26
Road metalling	$3,692 p.a.		26-52
Road maintenance	$0.30 per acre of established forest		
Equipment	Tip truck (½)	$2,250	1*
	Grader	$20,000	13
	10-cwt truck	$2,000	13
	Tip truck (½)	$2,250	26*

* The other half is charged to forest administration

TABLE 10—Accommodation required

Year	No. to be Accommodated	Houses New	Houses Total	Camp	
1	1	1	1		
2	6	5	6		
3	9	3	9		
4	7	–	9		
5	11	2	11		
6	11	–	11		
7	17	6	17		
8	17	–	17		
9	25	8	25		
10	25	–	25		
11	32	7	32		
12	32	–	32		
13	40	8	40		
14-23	40	–	40		
24	44	4	44P		
25	43				
26	43				
27	95			51 huts	
				Cookhouse	$27,700
				Caterer's house	$6,700
				Ablution block	$8,900
28	93				
29	94P				

P = in perpetuity

TABLE 11—Social costs: Services

Year	Water Supply* $	Site Preparation $	Share of "Services"† Acreage	Share of "Services"† $ per acre	Services N.E.I. $
1	2,500	1,000	800	0.22	604
2	2,500		1,600	0.20	604
3	1,100	1,200	2,400	0.19	604
4			3,200	0.18	604
5			4,000	0.165	604
6			4,800	0.155	604
7			5,600	0.14	604
8			6,400	0.13	604
9			7,200	0.12	604
10			8,000	0.11	604
11			8,800	0.105	604
12			9,600	0.10	604
13			10,400	0.09	604
14			11,200	0.085	604
15			12,000	0.08	604
16			12,800	0.07	604
17			13,600	0.07	604
18			14,400	0.07	604
19			15,200	0.065	604
20			16,000	0.06	604
21			16,800	0.06	604
22			17,600	0.06	604
23			18,400	0.06	604
24			19,200	0.06	604
25			20,000	0.06	604
26			20,800	0.06P	604

P = in perpetuity

N.E.I. = not elsewhere indicated

* = These amounts are half the total costs; equal sums are allotted to "Capital Works" (Table 13)

† = These amounts are half of the "Services" component of the repairs and maintenance charge (Table 15)

INDIRECT COSTS

Staff salaries are given in Table 12; external overheads have been taken as 60% of these amounts. A forest building programme is given in Table 13 and vehicles and stores are listed in Table 14.

Net charges for "services and general" costs, with those of general administration are on a per acre basis, and are given in Table 15.

Depreciation is charged by allowing the cost of the asset concerned at the end of its service life. The service lives of all replaceable assets are given in Table 16.

TABLE 12—Salaries ($ per year)

Category Year	1	2	3-6	7-8	9-12	13-25	26	27 + (P)
A. Forest Staff								
Officer in charge	3,410	3,410	3,550	3,750	3,750	3,900	3,900	3,900
Forester		2,570	2,570	2,810	2,810	3,170	3,170	3,170
Foreman		2,250	2,250	2,360	2,360	2,360	2,360	4,610
Ranger					2,570	2,570	2,570	2,690
Roading ranger	2,250	2,250	2,250	2,570	2,570	2,570	2,690	2,690
Clerk	2,230	2,230	2,450	2,450	2,450	2,450	2,450	2,690
Stores clerk								2,450
Total A	7,890	12,710	13,180	13,940	16,510	17,020	17,140	22,200
B. Logging Staff								
Officer in charge							3,410	3,410
Foreman								2,360
Ranger								2,690
Clerk								2,230
Total B							3,410	10,690
Total A + B	7,890	12,710	13,180	13,940	16,510	17,020	20,550	32,890

TABLE 13—Capital works required

Year	Item	Cost $
1	Office and store	7,750
	Petrol and oil store	3,300
	Telephone	1,225*
	Water supply	2,500†
2	Garage/workshop	16,000
	Water supply	2,500†
3	Water supply	1,100†
27	Office extension	7,750
	Garage extension	16,000

* An equal amount is charged to Protection

† An equal amount is charged to Social Costs

TABLE 14—Miscellaneous vehicles

Year	No.	Item	Cost $	Charged to
1	1	10-cwt truck*	2,000	Forest
	1	Gang truck	5,000	Forest
	1	Tip-truck	4,500	Forest — half Roading — half
	1	HD6 tractor	13,250	Forest
		Consumable stores	500 p.a. for 20 yrs	Forest
		Class "A" stores	680 p.a. for 20 yrs	Forest
3	1	Office car*	2,500	Forest
7	1	10-cwt truck*	2,000	Forest
	1	Gank truck	5,000	Forest
13	1	10-cwt truck*	2,000	Roading
	1	Grader	20,000	Roading
26	1	Tip-truck	4,500	Forest — half Roading — half
	1	"Trekka" truck*	1,770	Logging
	2	Tip truck	4,500 each	Logging
		Miscellaneous plant and equipment	9,200	Logging — half Forest — half
	3	10-cwt trucks*	2,000	Forest

* Annual charges, excluding depreciation, on these vehicles are $755

TABLE 15—Services and general: Repairs and maintenance, and administration costs

Year	Acreage	Total "S & G" Charge ($ per acre)	General Admin. ($ per acre)
1	800	1.09	1.152
2	1,600	1.01	1.152
3	2,400	0.95	1.152
4	3,200	0.89	1.152
5	4,000	0.83	1.152
6	4,800	0.75	0.576
7	5,600	0.71	0.576
8	6,400	0.66	0.576
9	7,200	0.61	0.576
10	8,000	0.56	0.576
11	8,800	0.52	0.576
12	9,600	0.49	0.576
13	10,400	0.46	0.408
14	11,200	0.42	0.408
15	12,000	0.39	0.408
16	12,800	0.36	0.408
17	13,600	0.35	0.408
18	14,400	0.34	0.408
19	15,200	0.32	0.348
20	16,000	0.31	0.348
21	16,800	0.31	0.348
22	17,600	0.30	0.348
23	18,400	0.30	0.348
24	19,200	0.30	0.348
25	20,000	0.30	0.348
26	20,800	0.30C	0.348C

C = charge per established acre thereafter

TABLE 16—Service lives

Item	Charged to	Life yr	Remarks
Houses	Social — accommodation	65	
Huts	Social — accommodation	20	Single men's camp
Caterer's quarters	Social — accommodation	65	Single men's camp
Ablution block	Social — accommodation	40	Single men's camp
Cookhouse	Social — accommodation	40	Single men's camp
Water supply	Social — accommodation — half; Capital works — half	—	Depreciation covered in Services and General Charge
Office; store	Capital works	40	
Garage	Capital works	40	
Oil store	Capital works	40	
Telephone	Capital works — half; Protection — half	—	Depreciation covered in Services and General Charge
Fire look-out; store	Protection	65	
Fire engine; tanker	Protection	10	
Pumps; radio	Protection	10	
10-cwt trucks; car Trekka trucks	Forest vehicles & equipment	10	Trekka to logging; one 10-cwt truck to roading
Gang trucks		10	2 to forest; 4 to logging
Tip trucks	Forest vehicles & equipment	10	1 to forest; 2 to logging; 1 to roading
HD6 tractor	Forest vehicles & equipment	6	
Miscellaneous equipment	Forest vehicles & equipment—half; logging—half	10	
D6 tractors	Logging	6	
D7 tractors	Logging	6	
Loaders	Logging	10	
Logging arches	Logging	10	
Field service units	Logging	10	
Miscellaneous equipment	Logging	3	
Chain saws	Logging	2	
Grader	Social — roading	10	

PROFIT CALCULATION; RESULTS

Sawing costs are considered in Appendix 2. These are the greatest of all plantation costs but unfortunately the least accurately known. The credit for sawmill slabs utilised for pulping is calculated in Appendix 3. The price for clearwood, based on a price for finger-jointed clears in Melbourne, is given in Appendix 4, with detailed realisations for butt, second and third logs.

Net sawlog realisations, with different sawing costs are given in Table 17.

TABLE 17—Net sawlog realisations

Log Height class (18 ft logs)	Volume (cu ft)	Sawing Cost ($/100 bd ft)	Value, c per cu ft Profit on Mill Social Costs Included	Excluded
Butt	39	1.50	49.2229	49.8259
		1.99	45.9400	46.5430
Second	29	1.50	39.7143	40.2992
		1.99	36.5293	37.1143
Third	20	1.99	17.6760	18.2161

Originally, a stumpage of 3.75c per cu ft was allowed for pulpwood, but current stumpages of 3c have been used in this model, as there have been no signs of increased stumpages since pulpwood utilisation began in New Zealand. This excludes the costs of logging, and the direct logging costs of 3c have been added to the pulpwood stumpage in calculating results to a loaded-on-truck basis. Allocation of appropriate social costs becomes artificial (both houses and huts are required) therefore all such costs, and the indirect logging costs, have been retained against the forest.

Rents have been allowed as social returns; houses yield $150 (50 weeks at $3) and huts $4.50 per year.

Costs and returns have been discounted to the year of origin of the forest and are charged from the mid-point of the year in which they occur. Details of the programme used are in an earlier paper (Fenton and Tustin, 1972).

The land expectation value (LEV) equivalents, or the present net worth per acre, for cost elements are given in Appendix 5 for interest rates of 3% to 14%. These are grouped by major classes (establishment, tending, protection, indirect, logging, and social) in Table 18. Returns and the net LEVs, the prices which could be paid in $ per acre of land to break-even at the various interest rates with social items included are given in Table 19, and without social items in Table 20. In both tables sawing costs of $1.50 are allowed for butt and second logs. In Table 21, sawing costs are $1.99 for all logs. Net LEVs are graphed in Fig 1. The relative importance of the major cost classes are shown in Fig. 2.

The IRR, or the rates of interest generated by the project as a whole, are found from Fig. 1. They are:

(a) including social costs — about $10\frac{1}{2}\%$

(b) excluding social costs — nearly $11\frac{1}{2}\%$

The break-even growing costs are given in Table 22; these are the forest costs of production per unit of wood (viz. the volume which is finally extracted and loaded) at the interest rate of 3% to 14%.

TABLE 18—Land expectation values

	LEV at Interest Rate %											
	3	4	5	6	7	8	9	10	11	12	13	14
	$ per acre											
COSTS												
Direct												
Land clearing	3.64	3.53	3.46	3.36	3.29	3.21	3.14	3.08	3.03	2.98	2.93	2.88
Establishment	16.39	13.18	11.09	9.56	8.37	7.43	6.67	6.05	5.52	5.05	4.65	4.34
Tending (3 pruning lifts)	48.16	33.58	25.04	19.48	15.62	12.80	10.68	9.02	7.71	6.65	5.78	5.06
(5 pruning lifts)	77.94	53.57	39.36	30.19	23.86	19.28	15.87	13.22	11.15	9.51	8.16	7.06
Total Direct (3 pruning lifts)	68.19	50.29	39.59	32.40	27.28	23.44	20.49	18.15	16.26	14.68	13.36	12.28
(5 pruning lifts)	97.97	70.28	53.91	43.11	35.52	29.92	25.68	22.35	19.70	17.54	15.74	14.28
Protection												
Dothistroma	9.11	6.52	5.00	3.98	3.28	2.76	2.34	2.02	1.78	1.56	1.39	1.25
Fire	12.86	9.20	7.08	5.71	4.74	4.06	3.54	3.11	2.81	2.52	2.30	2.12
Total Protection	21.97	15.72	12.08	9.69	8.02	6.82	5.88	5.13	4.59	4.08	3.69	3.37
Administration												
Salaries and overheads	53.65	38.46	29.60	23.88	19.91	17.02	14.81	13.10	11.72	10.61	9.67	8.88
Buildings, stores	3.89	3.20	2.77	2.49	2.27	2.13	2.00	1.89	1.81	1.73	1.66	1.61
Vehicles	10.60	7.55	5.82	4.72	3.96	3.39	2.99	2.65	2.40	2.19	2.04	1.88
Total Administration	68.14	49.21	38.19	31.09	26.14	22.54	19.80	17.64	15.93	14.53	13.37	12.37
Total Growing Costs (3 pruning lifts)	158.30	115.22	89.86	73.18	61.44	52.80	46.17	40.92	36.78	33.29	30.42	28.02
(5 pruning lifts)	188.04	135.21	104.18	83.89	69.68	59.28	51.36	45.12	40.22	36.15	32.80	30.02
Logging												
Salaries and overheads	10.53	6.13	3.82	2.48	1.66	1.14	0.80	0.56	0.40	0.29	0.21	0.16
Machinery	61.43	37.07	23.90	16.06	11.13	7.90	5.68	4.16	3.09	2.30	1.72	1.34
Extraction	115.98	66.49	40.77	26.08	17.22	11.65	8.00	5.59	3.95	2.83	2.02	1.50
Total Logging Costs	187.94	109.69	68.49	44.62	30.01	20.69	14.48	10.31	7.44	5.42	3.95	3.00
Total Growing and Logging Costs	375.98	244.90	172.67	128.51	99.69	79.97	65.84	55.43	47.66	41.57	36.75	33.02
Social												
Roading	13.27	9.58	7.38	5.87	4.83	4.06	3.45	2.98	2.62	2.31	2.06	1.86
Accommodation	26.49	20.11	16.39	13.95	12.26	10.96	9.94	9.11	8.41	7.84	7.32	6.81
Total Social Costs	39.76	29.69	23.77	19.82	17.09	15.02	13.39	12.09	11.03	10.15	9.38	8.67
Total Costs	415.74	274.59	196.44	148.33	116.78	94.99	79.23	67.52	58.69	51.72	46.13	41.69
RETURNS												
Rents (social)	7.05	4.91	3.67	2.87	2.32	1.91	1.61	1.38	1.20	1.04	0.92	0.82

TABLE 19—Discounted returns and net LEV—including social items

Interest Rate %	Returns, in $ per acre Log Height Class Butt	Second	Third	Top	Total	Net LEV
3	748.37	448.97	137.81	35.32	1,370.47	961.78
4	434.45	260.65	80.01	20.50	795.61	525.92
5	269.68	161.80	49.66	12.73	493.87	301.10
6	174.80	104.87	32.19	8.25	320.11	174.65
7	116.80	70.07	21.51	5.51	213.89	99.43
8	79.86	47.91	14.71	3.77	146.25	53.17
9	55.59	33.35	10.24	2.62	101.80	24.18
10	39.27	23.56	7.33	1.85	71.91	5.77
11	28.08	16.85	5.17	1.33	51.43	–6.06
12	20.29	12.17	3.74	0.96	37.16	–13.52
13	14.80	8.88	2.72	0.70	27.10	–18.11
14	10.88	6.52	2.00	0.51	19.91	–20.96

TABLE 20—Discounted returns and net LEV—excluding social items

Interest Rate %	Returns, in $ per acre Log Height Class Butt	Second	Third	Top	Total	Net LEV
3	758.19	455.57	142.01	35.32	1,391.09	1,015.11
4	440.15	264.48	82.45	20.50	807.58	562.68
5	273.22	164.18	51.17	12.73	501.30	328.63
6	177.09	106.41	33.17	8.25	324.92	196.41
7	118.33	71.10	22.17	5.51	217.11	117.42
8	80.91	48.61	15.16	3.77	148.45	68.48
9	56.32	33.84	10.55	2.62	103.33	37.49
10	39.79	23.91	7.45	1.85	73.00	17.57
11	28.45	17.10	5.33	1.33	52.21	4.55
12	20.56	12.35	3.85	0.96	37.72	–3.85
13	14.99	9.01	2.80	0.70	27.50	–9.25
14	11.02	6.62	2.06	0.51	20.21	–12.81

Sawing costs of $1.50 allowed for butt and second logs; $1.99 for third logs

TABLE 21—Discounted returns and net LEV—sawing costs of $1.99

Interest Rate %	Including Social Items Returns, in $ per acre Log Heights Class Butt	Second	Third	Top	Total	Net LEV	Excluding Social Items Net
3	698.46	412.96	137.81	35.32	1,284.55	875.86	929.19
4	405.47	239.75	80.01	20.50	745.73	476.05	512.80
5	251.69	148.82	49.66	12.73	462.90	270.13	297.66
6	163.14	96.46	32.19	8.25	300.04	154.58	176.34
7	109.01	64.45	21.51	5.51	200.48	86.02	104.01
8	74.53	44.07	14.71	3.77	137.08	44.00	59.31
9	51.88	30.68	10.24	2.62	95.42	17.80	31.11
10	36.65	21.67	7.23	1.85	67.40	1.26	13.06
11	26.21	15.50	5.17	1.33	48.21	–9.28	1.33
12	18.94	11.19	3.74	0.96	34.83	–15.85	–6.18
13	13.81	8.17	2.72	0.70	25.40	–19.81	–10.95
14	10.15	6.00	2.00	0.51	18.66	–22.21	–14.06

TABLE 22—Break-even growing costs

Interest Rate %	LEV Equivalent of 1c per cu ft ($ per acre)	Break-even Growing Costs Excluding Social Costs (c per cu ft) 3*	5*	Break-even Growing Costs Including Social Costs (c per cu ft) 3*	5*
3	40.192	3.938	4.678	4.928	5.668
4	23.333	4.938	5.794	6.210	7.067
5	14.483	6.204	7.193	7.845	8.834
6	9.387	7.795	8.936	9.907	11.048
7	6.273	9.794	11.107	12.518	13.832
8	4.289	12.310	13.821	15.812	17.323
9	2.985	15.467	17.206	19.953	21.691
10	2.109	19.402	21.394	25.135	27.126
11	1.508	24.390	26.671	31.704	33.985
12	1.089	30.569	33.195	39.889	42.516
13	0.794	38.312	41.309	50.125	53.123
14	0.584	47.979	51.404	62.825	66.250

* = number of pruning lifts

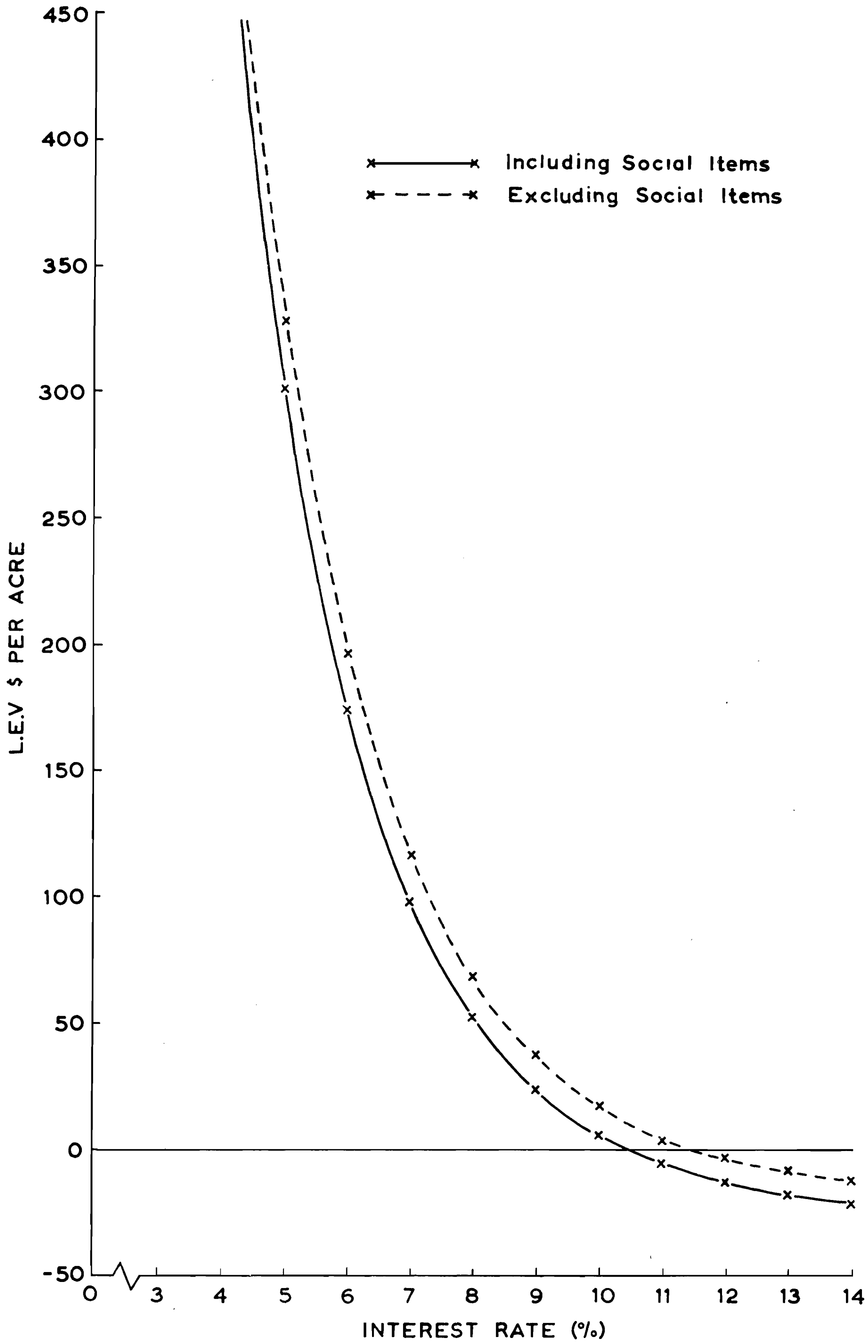

FIG. 1—Net land expectation values

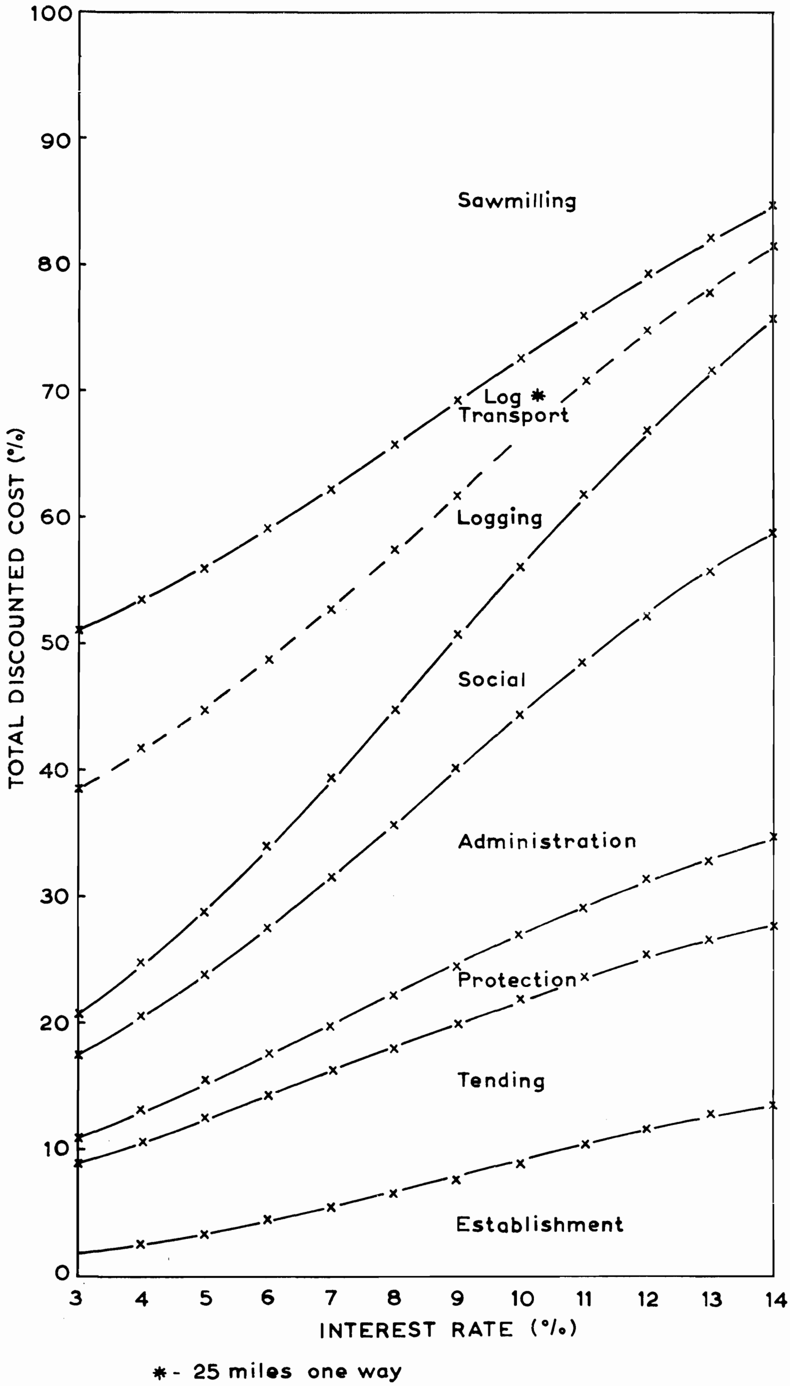

FIG. 2—Relative importance of forest and utilisation costs

FOREST COSTS

All costs are finally expressed in discounted terms as LEV in this discussion. As interest rates rise, those cost items incurred earliest in the rotation became increasingly significant. Establishment costs, for example, increase from less than 2% to over 14% of total costs over the range of interest rates of 3% to 14%. Correspondingly, protection costs are from 2% to 6% of total costs; fire protection being about 60% of these, and *Dothistroma* 40% for most interest rates. The slasher thinning of regeneration, five pruning lifts and two thinnings to waste which together make up "tending" comprise 7% of total costs at 3% interest, and 14% at 14% interest.

The biggest items of indirect costs are salaries and the associated external overheads. The indirect costs are probably less sensitive to site factors than to the scale of the project (Sutton, 1969). Three cost items: general administration, annual fire charges, and repairs and maintenance of "services and general assets", have been costed as decreasing unit charges with increasing area.

The "e" values of all indirect costs of administration and protection, with and without social costs, are given in Table 23 for this model. They represent the annuity to be capitalised in the traditional Faustmann formula, which can be used for quick comparisons of forest management regimes. (These "e" values apply to afforestation of unplanted land, not to existing forests). The spread of values is narrow from $3.90 at 3% to $3.42 at 14% including social costs; this is presumably due to the compensatory effects of different cost items through time. Results are close to those found for export log regimes and similarly decrease with rising interest rates if afforestation follows a "normal" tempo.

Total forest growing, protection and social costs approximately equal the combined logging, log haul and sawing costs at 9% interest, whereafter combined forest costs exceed combined utilisation costs on this rotation.

TABLE 23—Value of "e" in the Faustmann formula

Interest Rate %	Social Costs Excluded $	Social Costs Included $
3	2.70	3.90
4	2.60	3.78
5	2.51	3.70
6	2.45	3.64
7	2.39	3.59
8	2.35	3.55
9	2.31	3.52
10	2.28	3.49
11	2.26	3.47
12	2.23	3.45
13	2.22	3.44
14	2.20	3.42

UTILISATION COSTS

Generally, the clearfelling of tended stands is likely to be appreciably cheaper than is indicated here. At a man-hour production of 100 cu ft, a gang equipped with over $130,000 of equipment (plus spares) would not fell a tree per man-hour. It is thought the ease of working stands pruned to 36 ft, of 80 uniform trees per acre has been underestimated. Work study analysis (Fenton *et al.*, 1968b — Appendix 10) has shown that production rates three times those used are feasible.

Similarly, the sawmilling costs are considered likely to be lower in practice. Sawmilling is the dominant cost (Fig. 2) in forest regimes designed for sawlog production at interest rates up to about 10%. Costs are based on an outmoded basis of allowing a mill 15% profit on capital. As only 23% of the log volume to be sawn is of unpruned third logs, which average *ca.* 13 in. s.e.d. and the remainder are of pruned logs of 15 to 18 in. s.e.d.; as all logs can be assumed to be straighter than from current untended stands; and as all logs would be of consistent quality they should represent a better class of material to process (leaving aside sawn timber quality and realisations) than the industry has had to date. There has been difficulty in getting this point recognised. The effects of an increase of about 25% in sawing cost for the butt and second logs (77% of the total volume) on overall profitability are given in Table 21 compared with Tables 19 and 20. LEV decrease by $4.51 at 10% interest though the project still has an IRR of over 10%. The decrease in LEV at 7% is $13.41 or about 13½%. These figures can be used for any change in the realisation statements which alter butt and second log returns by about $0.50 per 100 bd ft. As utilisation costs are so important the use of unduly high costs is regrettable, but because of the lack of research in these fields, is currently unavoidable.

RETURNS

Results are sensitive to changes in return. The details in the realisation statements for each log height class given in Appendix 4 and the equivalent LEV in Tables 19, 20 and 21 can be used to find the effect of any changes in volume and/or value. Once detailed break-downs of all cost and return elements are presented, the range of sensitivity analyses becomes almost infinite. Only two variations in returns are presented; both are minor.

If pulplogs — a low volume constituent (14%) in this model—have a doubled stumpage of 6c instead of 3c per cu ft the LEV for this category rise 50% (as the direct logging costs of 3c have been allowed in calculating these returns). Although the net effect is small, for example the IRR is scarcely affected, the net LEV at 10% interest rises $0.92 or 16%. At these high interest rates many costs or return elements can be marginal. Pulpwood makes a relatively small contribution to returns. For forestry, pulpwood represents a low value component physically attached to the profit-making component, the sawlog.

Changes can be made in physical parameters, and an approximately equal change in LEV would result if the butt logs were of 40 and not 39 cu ft. The calculation in full at 10% interest is:

Extra gross return: $39.27 \times \frac{40}{39} - 39.27 = \$1.01$ LEV

The net return requires allowance for the extra log haul required (3.63c per cu ft) and an extra logging cost. It can be sensibly argued that only a marginal cost is involved in logging—the log is about $2\frac{1}{2}\%$ larger and requires no further trimming. If the full direct logging cost is allowed this is 3c per cu ft and the total LEV to be subtracted for logging and hauling is equivalent to 6.63c per cu ft. This effect can be calculated from several sources; the most direct is the LEV for butt logs:

LEV \$39.27 is from 39 cu ft per log worth 45.94c per cu ft so LEV required is

$$\frac{39.27 \times 6.63}{45.94 \times 39} = \$0.13$$

The net gain in LEV is therefore \$1.01 — 0.13 = \$0.88.

It is an interesting conjecture as to which is the more likely possibility — a doubling of pulpwood stumpages (14% of the volume) or a change in tree form to yield a further 1 cu ft on butt logs (less than 1% of the volume).

These examples quantify the much greater importance of the butt logs against the top logs.

EFFECT OF THE INTEREST RATE

This is shown throughout for costs and returns of the project in Tables 18 onwards and in Fig. 1 and Fig. 2.

If 10% is taken seriously in resource allocation in New Zealand, more directed management should achieve better financial results than those shown here. This is particularly true of all indirect expenditure in the first 5 to 10 yr of any project. Many capital works could be postponed, and many operations requiring machinery purchase would be better done on contract. This is only true nationally to the extent to which the resources are under-utilised. Indeed, one beneficial effect of a high rate of interest, apart from direct management efficiency, could be to mobilise machinery between jobs. Providing silviculture does not suffer, other expenditure should be pared. The net effect would be greater financial efficiency at the possible cost of greater management difficulty. The latter may be imaginary in part as there would be fewer assets to worry about, and more time available for the trees. Indirect costs are formidable even at 3% interest, and are over one-third of total costs at 10% interest. Unfortunately, the effects of reductions in government expenditure are too frequently on direct expenditure, and not on administrative charges. If 10%, or another measure of economic efficiency is taken seriously then much administration would need restructuring to ensure economically efficient decisions are made.

LOCATION EFFECTS

In contrast to the simpler export log models (Fenton and Dick, 1972d, 1972e), location effects here are complex and cannot be directly evaluated. The known components are:

(a) Log haul forest to sawmill—25 miles one way allowed
(b) Chip haul sawmill to pulpmill—5 miles one way allowed
(c) Export timber sawmill to port—74 miles one way allowed
(d) Domestic timber sawmill to rail point—differential in freight allowed.

The direct extra cost of sawmill location at the port can be found for log haul, with the compensatory saving of export timber transport. Sawmill and pulpmill integration could reduce chip transport. But to complete the analysis it would not only be necessary to calculate the interaction of these four freight differentials, but to include the freight saved on the eventual transport of the pulp and paper products. Further, the effects on sawmill and pulpmill capital and running costs would have to be considered. A comprehensive cost/benefit analysis could resolve these difficulties.

BREAK-EVEN GROWING COSTS PER CU FT

While it is possible to calculate the cost of growing per cu ft (of the volume finally logged) there are limitations when different classes of produce are involved. It becomes progressively more unreal to differentiate between log height classes in production costs, although final values differ markedly. If these distinctions are ignored, and costs assigned to the whole volume, the costs of growing (Table 22) are higher than for corresponding export log production regimes (Fenton and Dick, 1972e). There are three reasons: more silvicultural operations are needed; net MAI is lower; and rotations are 3 yr longer. Actual costs at 7% (including social costs) are 7.99c for export logs and 11.11c for the sawlog regime (9.79c if only one log is pruned); The export logs cost 18% to 28% less to grow. At 10% interest the corresponding figures are 14.80c for export logs, 19.40 and 21.39c for the sawlog regime. The break-even growing costs can be used to determine minimum stumpage values if necessary. Clearly, the effect of requiring a forest to make 15%, as allowed to sawmills under the timber sales procedure, would have startling consequences. It seems anomalous to allow a given rate of profit to one industry and not to that of the far more highly capitalised forest-growing enterprise. This leads to questions on whether vertically integrated concerns know where their capital investments lie, a fertile field for research.

RISKS

Losses due to biological risks are speculative on present knowledge. *Sirex* woodwasps have been absent in treated young stands despite hot, dry, summers that favour the *Sirex*. *Dothistroma* infection should be checked by the treatments specified as the upward spread of the fungus through the lower crowns would be retarded by the pruning, and the more open stands may alter the microclimate.

Physical losses through wind are not likely to be serious in stands felled at 113 ft. The stands are not subject to the sudden opening up at *ca.* 90 ft which is attendant on a production thinning.

Fire risk should be reduced as all crop trees will be 0/18 ft pruned by about age 9 and later 0/36 ft pruned. The chances of a ground fire "crowning" would be negligible. Furthermore, grazing can be expected to reduce chances even of a ground fire to insignificant proportions. The only stands at risk would be up to about 15 ft in height. A logical consequence would be a reduction in fire precautions and hence lower costs.

Managerial risks, although less than for regimes which prescribe production thinning, would still be high. Pruning malpractices (Fenton, 1968) could not be tolerated. The regime is a precise instrument, hence tending operations must be accurately applied and the pruning contracts have to be advertised and executed in the right year. Management *control* of the silviculture would be easier at each pruning step, as fewer stems are involved than in much current practice, and nearly all stems are pruned after stands are 25 ft high.

Marketing risks are considered to be low. The data in Table 24 show what is produced per acre—it is of higher grade and versatility than any other softwood plantation forestry in the world can hope to produce. Data for the sawlogs are based on grade study results. The butt and third logs are from trees of similar age and size (Fenton *et al.,* 1971). The more limited sample of second logs are of comparable size (Fenton, 1972b). The pruning prescribed in this model would be better directed than that received by the trees sawn in these grade studies, and it is possible the grade outturns given in Appendix 4 will be bettered for the pruned logs.

The pruned logs could be used for veneering, with increases in forest value. As demonstrated elsewhere (Fenton, 1971) the stands can, if necessary, produce large volumes of framing timber. The pulp logs are of such low value at current stumpages that they have a minor effect on the enterprise; if necessary they can be burnt after felling. It is difficult to see why a profitable pulp and paper industry cannot pay more for the cost of growing its raw material. A 3% cost, or less, per ton of newsprint or Kraft paper is low compared with Scandinavian, but not Canadian, stumpages.

TABLE 24—Yields per acre by end products

A.	Sawn timber bd ft		
	100% clear	11,352	
	Superior Factory	10,912	
	Ordinary Factory	1,152	
	Superior Dressing	5,160	
	Ordinary Dressing	672	
	Sub-total	29,248	64% of sawn out-turn
	Merchantable	7,312	
	Box	8,344	
	No. 1 and No. 2 Framing	672	
	Total	45,576	36% of sawn out-turn
B.	Pulpwood (heartwood free throughout) cu ft		
	100% clear sawmill slabs	1,160	
	Knotty sawmill slabs	424	
	Top logs (roundwood)	1,208	
	Total	2,792	

GRAZING

Grazing has been excluded from the net results here.

Technical data on grazing are based on the works of R. L. Knowles. There are three sets of possible returns from grazing:—

(a) Category 1—the sward available under planted stands from age $3\frac{1}{2}$, to 6 months before felling, viz. 24 yr grazing per rotation. (The 6 months' interval between grazing cessation and clearfelling is to allow salvage of fencing.) This area would be 5% greater than the planted area, with extra grazing available on fire breaks and stand edges.

(b) Category 2—grazing on the area cleared but not yet planted in the first rotation.

(c) Category 3—area permanently unplanted.

LEV when leasing values are $0.50 per acre per year are given in Table 25. Category 1 returns (those from the planted area) are considered the most likely to be obtained; the other categories would depend on local circumstances. At $0.50 per acre Category 1 returns are 66% those of pulpwood from the top logs, at 10% interest. If this grazing return increased to $6 per acre, the IRR of the whole project would rise to 11% if social items are included. If all categories of grazing were available, at $0.50 per acre, the IRR would rise to about 10.8%. These examples are, of course, at the margin. At 7% interest net LEV would increase by about 2.3% for every $0.50 obtained from Category 1 grazing.

TABLE 25—Grazing returns

Interest Rate %	LEV in $ per acre Grazing Category Planted Area plus 5%	Temporarily Unplanted	Permanently Unplanted
3	8.39	4.08	2.07
4	5.60	3.82	1.60
5	4.01	3.59	1.24
6	3.00	3.38	1.03
7	2.32	3.20	0.87
8	1.84	3.03	0.80
9	1.49	2.87	0.67
10	1.23	2.73	0.60
11	1.02	2.60	0.55
12	0.86	2.48	0.50
13	0.73	2.38	0.46
14	0.63	2.28	0.42

* = At $0.50 per acre per year

Grazing will provide indirect benefits. A fully pruned tree crop and a grazed sward for ground cover should reduce the fire protection needed. If these costs were initially halved, grazing benefits would increase by about $1 LEV at 10% interest (equal to pulplog stumpage). Direct tending costs would be reduced by improved access to the stands. The greatest indirect benefits are, however, macro-economic; with new ideas in forestry (or the revival of an old idea), the contest with agriculture over land use (Fenton, 1965) could often end in a nationally desirable and efficient compromise so "retrieving the phrase multiple-use from a polite fiction to an actuality" (Fenton and Sutton, 1969).

Again, while ". . . it takes about 25 to 30 years from planting before significant income can be derived from a new forest . . . this would provide no satisfactory solution to the pressing shorter-run problems facing the farmers and the nation" (New Zealand Economic Council, 1970), grazing a growing forest could give a partial answer to this dilemma. It would provide interim returns, particularly in the early years of plantation growth. The decreased opposition to forestry expansion, coupled with diversification of national production into both animals and trees, would change forestry's (and perhaps agriculture's) role in New Zealand. Another result would be an enhancement of the landscape.

It is the author's opinion that deer, rather than sheep and cattle, will ultimately be both easier to manage (lower stocking density) and more profitable (tourist shooting licences). Equally, changes would be feasible in forestry. If better soils are available as a result of a shift to grazing/high quality log regime, there are arguments in favour of growing hardwoods. Radiata pine represents probably the only softwood which can be profitably grown on a large scale in New Zealand, and further economic diversification would be desirable. Poplars (*Populus* spp.) and eucalypts (*Eucalyptus* spp.) are the most likely trees to plant, as some species combine high quality wood and fast growth potential.

SOCIAL COSTS

Roads and accommodation comprise social costs in forestry. The extent to which these costs should be allocated to production depends on circumstances. In Britain, it was argued that inclusion of forestry's housing costs depended on whether they represented net claims on national resources, because if the workers were not housed on the forest, they would be housed elsewhere" . . . by town corporations and we should . . . only charge the extra cost (if any) of providing forestry houses" (Walker, 1960). Walker concluded ". . . on economic ground the inclusion of such costs is not correct". Forests established to utilise existing labour resource, may have a local cost advantage in using existing rural housing, when compared with forest extension in areas lacking housing. Generally, the minimum number of people should be housed on the forest, as towns have better social facilities (Fenton, 1968; Fenton and Terlesk, 1971). Future forest workers may well be commuters.

The New Zealand Treasury opinion in 1968 was to incorporate social costs. In any case, the isolation of each cost constituent, including roading, houses, huts, allows the effect of each to be noted.

The author's opinions are that roading costs should be charged to forestry, and, where other public use (actual or potential) of roads arises, then appropriate returns or benefits should be allowed. Accommodation costs can be allotted depending on local circumstances. Houses must be provided and, if appropriate, some wider benefit such as improvement of rural Maori housing, be allowed. If rents are recovered, it seems debatable that these should be treated only as transfer items and not a return to the project. Hut rents are trivial, however, so they can scarcely repay the administrative costs of collection.

Accommodation costs are important throughout, largely as the houses have been built first and the camp at the time utilisation begins. To some extent, this extra cost was incurred to ensure labour was available while the forest was being established.

LABOUR REQUIREMENTS

The export log profitability studies (Fenton and Tustin, 1972; Fenton and Dick, 1972a, 1972b, 1972e) and this paper, specify labour needs by skills over time. If necessary, schedules of labour needs parallel to those of capital requirements can be built up from budgets. Table 26 shows the relative labour needs and productivity of the two types of forest production at normality. Executive and professional skills (rangers and foresters) are approximately the same, as are the requirements for tradesmen. The only marked difference is the shift of labour between forest growing and logging. As logging is a dangerous industry (Fenton and Terlesk, 1971) this

TABLE 26—Comparative labour requirements at normality on Site Index 95

	Labour Category				
	Direct Forest Operations	Indirect Forest Operations	Logging	Total	Volume per man per year (thousand cu ft)
Export log production*	9	32	56	97	76.75
Sawlog production	33	32	40	105	62.84

* Fenton and Dick, 1972e

could favour sawlog production. Total production per man at normality is 22% greater for export logs, and less labour is needed before utilisation begins. The high quality final product in the sawlog regime incurs more labour before utilisation begins, and a lower productivity in terms of log volume.

Full evaluation of labour, as with location and social aspects, would justify a comprehensive cost/benefit analysis for any specific large scale forestry project.

NATIONAL PLANNING TARGETS

The regime reduces rotations on site index 95 from 36 to 26 years, when compared with a regime prescribing one production thinning. If it was applied widely, one effect would be to bring forward current national forest production targets by a decade. This would be particularly desirable as the rate of expansion in general forest production slows over 1980-95 (Forestry Committee, 1969). The material produced is of higher quality than that likely from any other softwood plantations in the world, most of which will only produce pulpwood or smaller diameter sawlogs. The smallest log sawn in this model is bigger than almost any available in Scandinavia. Nowhere else could such large, high-quality logs be produced in the same time. On the best site index of 120, rotations would be of 20-21 yr. The overwhelming influence of butt log values on profitability demonstrates that the comparative advantage of local forestry lies in relinquishing production thinning in favour of concentrated growth on final crop stems.

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REFERENCES

FEDKIW, J. 1960: Capital budgeting for acquisition and development of timberlands. Paper in Financial Management of Large Forest Ownerships. **Yale School of Forestry Bulletin 66.**

FENTON, R. 1965: Exotic forestry and land use in New Zealand. **Proceedings Fourth New Zealand Geography Conference, Dunedin:** 37-45.

——— 1968: "Silviculture and profitability of plantation forestry in New Zealand". Australian National University, Canberra (unpublished thesis).

——— 1970: Criteria for production forestry. **New Zealand Journal of Forestry 15 (2):** 150-7.

——— 1971: Silviculture and management of **Pinus radiata** for framing timber production. **New Zealand Journal of Forestry Science 1 (1):** 60-73.

——— 1972a: Economics of sawlog silviculture which includes production thinning. **New Zealand Journal of Forestry Science 2 (3) (this issue):** 348-68.

——— 1972b: Profitability of second log pruning. **New Zealand Journal of Forestry Science** (in press).

FENTON, R., and DICK, M. MERLE 1972a: Profitability of radiata pine afforestation for the export log trade—on site index 80. **New Zealand Journal of Forestry Science 2 (1):** 69-99.

——— 1972b: Profitability of radiata pine afforestation for the export log trade—on site index 110. **New Zealand Journal of Forestry Science 2 (1):** 100-27.

——— 1972c: Import costs and overseas earnings of afforestation models for the export log trade. **New Zealand Journal of Forestry Science 2 (1):** 128-43.

——— 1972d: Significance of the profit studies of afforestation for the export log trade. **New Zealand Journal of Forestry Science 2 (1):** 144-64.

——— 1972e: Profitability of "normal" afforestation for the overseas log trade on site indexes 95 and 100. **New Zealand Journal of Forestry Science (this issue):** 289-312.

FENTON, R.; GRAINGER, M. B.; SUTTON, W. R. J., and TUSTIN, J. R. 1968a: Profitability of **Pinus radiata** afforestation—short rotation sawlogs. **New Zealand Forest Service, Forest Research Institute, Silvicultural Branch Report 112** (unpublished).

——— 1968b: Profitability of **Pinus radiata** afforestation—updating of 1962 results. **New Zealand Forest Service, Forest Research Institute, Silviculture Branch Report 111** (unpublished).

FENTON, R., and SUTTON, W. R. J. 1968: Silvicultural proposals for radiata pine on high quality sites. **New Zealand Journal of Forestry 13 (2):** 220-8.

——— 1969: Economics. **New Zealand Forest Service** report 9/10/1969 (unpublished).

FENTON, R.; SUTTON, W. R. J., and TUSTIN, J. R. 1971: Clearwood yields from tended 26-year-old second crop radiata pine. **New Zealand Journal of Forestry Science 1 (2):** 140-59.

FENTON, R., and TERLESK, C. J. 1971: Aspects of labour in New Zealand Forestry. **New Zealand Journal of Forestry 16 (1):** 208-222.

FENTON, R., and TUSTIN, J. R. 1972: Profitability of radiata pine afforestation for the export log trade—on site index 95. **New Zealand Journal of Forestry Science 2 (1):** 7-68.

FORESTRY COMMITTEE, 1969: Report to second plenary session, National Development Conference, N.D.C.5, Wellington, New Zealand.

GAFFNEY, M. M. 1960: Concepts of financial maturity of timber. Department of Agricultural Economics, North Carolina State College. Agricultural Information Series 62.

LEWIS, E. R. 1954: Yield of unthinned **Pinus radiata** in New Zealand. **New Zealand Forest Service, Forest Research Institute, Forest Research Note 1 (10).**

NEW ZEALAND ECONOMIC COUNCIL, 1970: New Zealand and an enlarged EEC. **New Zealand Economics Council Report 19.**

SUTTON, W. R. J. 1969: Overhead costs in relation to forest size. **New Zealand Journal of Forestry (14) 1:** 87-9.

WALKER, K. R. 1960: The Forestry Commission and the use of hill land. **Scottish Journal of Political Economy 7 (1):** 14-35.

APPENDIX 1 — GROWTH PROJECTIONS

by R. N. James

While standard growth projections (Beekhuis, 1966) were largely used, modifications were necessary as the basal area of the proposed silviculture is initially below the range where standard projections apply. Further, allowances for the loss of height and diameter increment caused by the heavy pruning schedule are needed. This loss of increment has been quantified for a number of regimes which involve selective pruning (Sutton and Crowe, 1970).

1. Basal Area at 35 ft

The basal area of 600 unpruned and unthinned s.p.a. was found from Forest Research Institute plots in the Tasman Pulp and Paper Company spacing trial in the Tarawera Valley. The equivalent basal area for a crop element of 150 s.p.a. was derived from Table 4 of Beekhuis. This corresponds to the element that by 35 feet would have been pruned to 14 feet and from which the 80 final crop stems per acre would be selected. The pruning regime proposed here is intermediate between two assessed by Sutton and Crowe. Loss of diameter (d.b.h.) increment was interpolated, and averages 1.08 in. per tree at 35 ft. Both the increase in size expected as a result of the early thinning-to-waste and the allocation of basal area to the crop 80 s.p.a. were calculated using ratios derived from stands that had received similar treatment (R. L. Knowles pers. comm.). These last two calculations are pragmatic as no better method is available. These steps are summarised in Table 27 below. The calculated result of a basal area of 20.32 sq ft per acre on 80 s.p.a. at height 35 feet appears reasonable when compared with stands which have received similar treatment.

2. Projections from 35 to 45 ft

The few stands known to have received such a treatment exhibit a check in both height and diameter growth immediately after high pruning and thinning to 80 s.p.a. For the first ten feet—to 45 ft—a basal increment of only 17 sq ft/per acre has been allowed as this is the increment found in practice. It is approximately half that which would be conventionally predicted (Beekhuis, 1966).

3. Projections after 45 ft

After 45 ft the standard projection (Beekhuis, 1966) appears to slightly underestimate basal area increment and has therefore been used without modification.

In the absence of data, further pruning above 20 feet has been assumed to have no effect on increment.

Age for a given height can be determined from yield tables (Lewis, 1954). The effect of pruning 80 s.p.a. at 35 ft is predicted to result in a reduction in height equivalent to about one year's growth (at Site Index 95). A similar reduction in height increment also follows the thinning. The total age is therefore 2 years more than shown in the yield tables. The full projection is given in Table 27.

APPENDIX 2 — COST OF SAWING

Sawing is the biggest single cost in the growth and production of plantation sawtimber (Fenton **et al.,** 1968b; FRI Annual Report 1962). There are still no better data on which to amend the earlier estimates of cost, and these are summarised below.

1. Log specification

The mill would cut wholly radiata pine, with pruned logs largely of 15-20 in. s.e.d., and unpruned logs of 12-14 in. Nearly all logs would be 18 ft long. Cutting patterns would

TABLE 27—Growth predictions

A. Derivation of Initial Basal Area:

Predom. mean ht	Stems per acre	Basal area (sq. ft/acre)	Source of data
35	600	113.8	From Tarawera spacing trial
35	150	38.68	From Table 4 (Beekhuis, 1966)
35	150	27.42	Allowance for loss due to low and medium pruning
35	150	35.65	Allowance for gain due to early thinning
35	80	20.32	Reduced to 80 s.p.a. at 35 ft

B. Growth from Initial Basal Area:

Predom. mean ht ft	Stems per acre	Mortality (s.p.a.)	Net basal area increment (sq ft/acre)	Basal area (sq ft/acre)	Mean d.b.h. (o.b.) (in.)
35	80			20.3	6.8
		0	17.0		
45	80			37.3	9.2
		0	16.2		
50	80			53.5	11.1
		0	32.3		
60	80			85.8	14.0
		0	32.4		
70	80			118.2	16.5
		0	32.3		
80	80			150.5	18.6
		0	32.4		
90	80			182.9	20.5
		0	32.3		
100	80			215.2	22.2
		0	32.4		
110	80			247.6	23.8
		1	30.0		
120	79			277.6	25.4
		1	29.5		
130	78			307.1	26.9
		1	29.1		
140	77			336.2	28.3

be straightforward, with a maximum recovery of clears and wide boards. About 36.5 million bd ft would be sawn from 5.6 million cu ft of logs annually.

2. Costs

These are based on a 9-hour day of the Waipa State Mill bandmill.

	$ per 100 bd ft
Log handling	0.13
Band sawing	0.60
Sorting and resawing	0.51
Grading and branding	0.27
Yard handling	0.41
Waste disposal	0.03
1967 cost of green rough sawn timber	1.95
Add 2% for 1967 devaluation	0.04
Cost as at April 1968	1.99

3. Sawmill capital

	$
Mill buildings	146,000
Plant: imported	117,000
local	229,000
Accommodation	209,000
	701,000

4. Profit allowance

15% on sawmill buildings and equipment	($510,000)	76,500
5% on sawmill accommodation	($209,000)	10,450
Annual profit to be allowed		86,950
Based on 240 working days: profit per day		362
Based on 50,000 bd ft per day: profit per 100 bd ft		0.724
		(say 0.72)
excluding mill social capital		0.69

Note: Sawing costs are better based on log volume, not sawn outturn. Two levels of sawing cost are tested for butt and second logs in the sensitivity analyses.

APPENDIX 3 — SAWMILL — slab credits

1. Quantity

While relative chip recovery increases as log diameter and conversion factor falls, total recovery of sawntimber plus chips remains constant at 75-78% of log volume. Recovery per log height class is then:

Log height class	Conversion factor base 12	%	chip recovery % (total 76.5%)
Butt	6.7	56	20.5
Second	6.5	54	22.5
Third	6	50	26.5

2. Chip value

Sale of chips is by the "unit" of 200 cu ft of uncompacted chips, which is equivalent to 73 cu ft of solid wood. Based on Waipa State sawmill chipping operations in 1967, the economics of chipping slab waste can be assessed as:

Delivered value $15.20 per "unit"		
= 20.82c per cu ft solid wood		
Less cost of production: cents per cu ft		
Manufacture	**5.30**	
Cartage	1.57	
Profit	1.86	8.73
Margin		12.09c per cu ft solid wood

3. Slabwood value

Butt	2.48c per cu ft
Second	2.72c per cu ft
Third	3.20c per cu ft

APPENDIX 4 — REALISATIONS

1. Clearwood price

This is derived from a price for finger-jointed, hence kiln-dried, clears in Melbourne, Victoria.

Item				$ per 100 bd ft
1	Price delivered Melbourne yard			21.00
2	Less cartage from wharf			0.36
3	**Value on wharf** (Melbourne)			20.64 (kiln dry)
4	Less commission %			0.98
5	**Landed value**			19.66 (kiln dry)
6	Less sea freight			3.05
7	**Value f.o.b. Mt Maunganui**			16.61 (kiln dry)
8	Less port charges:	Wharfage	0.10	
		Marshalling	0.12	
		Inspection	0.03	0.25
9	**Value at port (Mt Maunganui)**			16.36
10	Less road transport			0.50
11	**Value on truck at mill**			15.86 (kiln dry)
12	Less cost of kiln drying			2.05
13	**Realisation**			13.81 (green)
14	Less sales expenses			0.70
15	Value ex sawmill			13.11 (green)

f.o.b. = free on board

2. Realisations — price basis

(1) Clearwood prices at mill are taken from the figures above, less items 8, 10 and 14, giving a net price on truck at mill of $14.56 per 100 bd ft. (The items omitted are then charged proportionally in the realisation statements.)

(2) Other export prices are taken from the NZ Sawmillers' Federation Export Price List as at 17.4.1968. This list was based on an f.o.b. basis.
(3) Domestic prices are taken from the Waipa wholesale price list as at 12.12.1966 which applied in May 1968.
(4) All Factory, Dressing and Clear timber is assumed to be exported, the remainder sold on the domestic market.
(5) Chip credits per cu ft of sawlog are calculated in Appendix 3.

3. Transport costs (contract — viz includes profits)

Saw and pulp logs 25 mile haul forest-mill 3.63c per cu ft.
Chips. No data were available for a short haul; on long hauls costs are 7½% higher for chips than for logs; the net cost (assumed) is:

5 mile haul to pulp mill 1.57c per cu ft solid
Sawntimber, by road — kiln dry — 50c per 100 bd ft
Port dues:

Wharfage	10c per 100 bd ft
Marshalling	12c per 100 bd ft
Inspection	3c per 100 bd ft
	25c per 100 bd ft

4. Realisations — butt logs

(1) $ per 100 bd ft

Export sales

Grade	Size	%	Price	Value
Clears	All	37	14.56	
Factory	10 × 1	32	10.80	
Dressing	6 × 1	1	8.10	
	10 × 1	10	10.25	
		80		9.95
Less 80% of				
Mill handling		0.70		
Transport		0.50		
Wharfage		0.25		
		1.45		—1.16
				8.79

Domestic sales

Grade	Size	%	Price	Value
Merch.	8 × 1	8	6.35	
Box	to 6 × 1	2	4.15	
	8 × 1 and over	10	4.45	
				1.036
Less 7½%; 2½ discounts				0.934
Plus D.I.F. at 0.06/100 bd ft				0.014
				0.948

	(a)	(b)
Price at mill	9.74	
Less cost of milling	1.50	
	8.24	
Less mill profit allowance		
(a) incl. mill social costs / (b) excl. mill social costs	—0.72	—0.63
	7.52	7.61
(2) cents per cu ft*		
	50.37	50.98
Plus chip credit	2.48	2.48
Less log cartage forest to mill	3.63	3.63
Net loaded at forest	49.22	49.83
If sawing cost $1.99 per 100	—3.28	—3.28
	45.94	46.54

* Conversion factor 6.7 bd ft per cu ft of log

5. Realisations — second logs — pruned

(1) $ per 100 bd ft

Export sales					Domestic sales				
Grade	Size	%	Price	Value	Grade	Size	%	Price	Value
Clears	All	24	14.56		Merch.	8 × 1	8	6.35	
Factory	6 × 1	8	8.10			6 × 1	2	6.00	
	10 × 1	20	10.80		Box	8 × 1	15	4.45	
Dressing	6 × 1	4	8.10			4 × 1	4	4.15	
	10 × 1	15	10.25						
		71		8.16			29		1.46
Less 71% of					Less 7½; 2½% discounts				1.32
Mill handling		0.70			Plus D.I.F. at 0.06/100 bd ft				0.02
Transport		0.50							
Wharfage		0.25							
		1.45		—1.03					
				7.13					1.34
Price at mill				8.47					
Less cost of milling				1.50					
				6.97					
Less mill profit allowance									
(a) incl. mill social costs				—0.72	(b) excl. mill social costs				—0.69
				6.25					6.34

(2) cents per cu ft*

	40.62	41.21
Plus chip credit	2.72	2.72
Less log cartage forest to mill	3.63	3.63
Net loaded at forest	39.71	40.30
If sawing cost $1.99	36.53	37.11

* Conversion factor 6.5 bd ft per cu ft of log

Grade yields from Fenton (1963, 1972b).

6. Realisations — third logs

(1) $ per 100 bd ft

Export Sales					Domestic Sales				
Grade	Size	%	Price	Value	Grade	Size	%	Price	Value
Factory	6 × 1	4	8.10		Merch.	4 × 1	7	5.12	
	10 × 1	8	10.80			8 × 1	36	6.35	
Dressing	6 × 1	2	8.10		Box	4 × 1	3	4.15	
	10 × 1	5	10.25			8 × 1	28	4.45	
					1 Framing	4 × 2	6	7.62	
					2 Framing	4 × 2	1	6.52	
		19		1.86			81		4.54
Less 19% of					Less 7½; 2½% discounts				4.09
Mill handling		0.70			Plus D.I.F. at 0.06				0.05
Transport		0.50							
Wharfage		0.25							
		1.45		—0.28					
				1.59					4.14
Price at mill				5.73					
Less cost of milling				1.99					
				3.74					
Less mill profit allowance									
(a) incl. mill social costs				—0.72	(b) excl. mill social costs				—0.63
				3.02					3.11
(2) cents per cu ft*									
				18.11					18.65
Plus chip credit				3.20					3.20
Less log haul				3.63					3.63
Net loaded at forest				17.68					18.22

* Conversion factor 6 bd ft per cu ft of log