DOUGLAS FIR PROFITABILITY

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ABSTRACT

Profitability of Douglas fir afforestation on a 55-year rotation, producing 186 m^3/ha from thinnings at age 35 and 932 m^3/ha from clearfelling for sawlogs, shows an internal rate of return (IRR) of 5.8% when social items are included, and 6.2% when social items are excluded. The biggest direct costs, at 6% interest, are for salaries and administration.

Timber realisations are based on analysis of sales of 120 000 m^3 from the largest producers, allowing 45% as export timber, with the price of thinnings being \$9.00 and of clearfellings \$18.21/m^3 on truck. The IRR rise to 6.4% and 6.75% if logs are exported (\$25.03/m^3 on truck), but are relatively insensitive to considerable changes in cost and return levels.

Results are similar to those calculated in 1967; radiata pine (**Pinus radiata** D. Don), because of its faster initial growth rate, is a far more profitable species.

INTRODUCTION

Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) has been planted on more than 38 000 ha of State Forests in New Zealand since 1901. It comprised 17.3% of state planting from 1966 to 1970, and 9.7, 6.8, and 6.4% in 1971, 1972, and 1973 respectively (details for earlier years are in Fenton, 1967a). It was stated earlier that:

'The superior versatility of radiata pine in utilization, and its formidable early increments, should continue to make this the premier species in New Zealand afforestation. Douglas fir is a valuable species, and extended future plantings are justified by considerations of biological diversification, its suitability for management in steep country, and its timber qualities.

It remains to assess the relative profitability of these two species'' (Fenton, 1967a).

Pathological developments have been considerable since this was written. The uncertainties raised by *Dothistroma pini* Hulbary needle-cast on radiata pine now seem answered by a spraying programme which costs from 2 to 5% of total growing cost at 10% interest for the range of regimes evaluated (Fenton and Tustin, 1972; Fenton and Dick, 1972a; 1972b; 1972c; Fenton, 1972a; 1972b). The planting of Corsican pine (*Pinus nigra* Arnold) is now less than 25 ha annually, due to the disease. More Douglas fir was planted annually between 1968 and 1970 than in any other years, and it is reasonable to ascribe much of this to anxiety about *Dothistroma* in radiata pine. But the discovery of *Phaeocryptopus gaeumannii* (Rohde) Petrak and/or an association of pathogens have now, in turn raised doubts about Douglas fir.

The necessity for production thinning, even in theory, has been removed by the development of 'short-rotation' and 'export-log' regimes for radiata pine (Fenton, 1972a;

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1972b; Fenton and Dick, 1972a). Hence the previous advantage of Douglas fir on steep country (that technically good timber for framing uses could be obtained by a silvicultural regime of dense stocking and delayed felling) has been greatly reduced. Technically good radiata pine timber can be produced more rapidly on steep country without production thinning. Douglas fir gives high quality framing timber, but it is less versatile than radiata pine. However, the profitability analyses were made (Fenton, 1967b) and showed for the area chosen—the Maraetai Blocks in the Bay of Plenty (Fenton and Grainger, 1965) — and for three regimes tested with rotations up to 50 years, that profitability was of a similar order to a production-thinned regime for radiata pine. Internal rates of return (IRR) were from 4.5 to 6%, depending partly on the price levels assumed. But later analyses of radiata pine (Fenton, 1972a; 1972b; Fenton and Dick, 1972a) showed enhanced returns of over 10% — even from 'normal' rates of afforestation — for short-rotation sawlog and export-log regimes. The 1967 Douglas fir analyses were not repeated as the species appeared to offer no commensurate advantage to offset its longer rotation. When profitability analyses were being prepared for the Forest Development Conference in 1969, for example, there was no mention that Douglas fir should be seriously considered either in comparison with agriculture, or as a profitable species. But, curiously, it was still regarded as a major afforestation species:

"87. For the most part, this future planting will be done in the two main species, radiata pine and Douglas fir. . . ." (National Development Conference, 1969).

This contradiction — a species apparently unable to satisfy a given Treasury profitability criterion, yet still suggested for major planting — aroused no comment. The subject of species selection has not been dealt with in Departmental Annual Reports since 1963 (New Zealand Forest Service, 1963), apart from incidental remarks. There seems no obvious reason why Douglas fir should be allocated forest production or economic research resources.

But there has been a sustained undercurrent of support for the species by state foresters, articulate on committees if not in print. The updating of afforestation costs to 31/12/73 has recently been completed for radiata pine, so profitability assessments are facilitated. This paper formally presents profitability results for Douglas fir. In order to clarify the situation further, the full economic case will be considered in a subsequent paper. This includes marketability, timber quality, value added, risk spreading, supplementary siting, and recreational forestry.

EVALUATION OF PROFITABILITY

Assumed Characteristics of the Area; Site Index

The profitability analysis is based on "normal" afforestation of a particular area — the Maraetai block in the Bay of Plenty. Use of a "normal" rate of management enables strict comparisons to be made with other forest regimes. The site characteristics have been constant for all the profitability models tested (Fenton and Grainger, 1965).

Earlier comparisons of the top height growth of radiata pine and Douglas fir (Fenton, 1967b) give the following relationship:

P.M.H. Douglas fir $=$ 0.782 $\times$ P.M.H. radiata pine — 4.08.

(P.M.H. $=$ predominant mean height obtained from 41 pairs of adjacent stands of the same age on sites which had no obvious differences.)

Supplementary measurements on 10 more plots in 1971, and 8 in 1974 showed no significant differences in the relationship.

The P.M.H. is close to the 30 m at age 35 given as the mean for Douglas fir sample plots on North Island pumice sites (Spurr, 1963). Hence, results are applicable to considerable areas.

The management divisions, based on topography/machine classes are:

Preplanting	*First rotation*	*Areas* (net)
Giant-disced	Tractor plantable	4696 ha
Giant-disced	Not tractor plantable	2834 ha
Not giant-disced	Not tractor plantable, hill sites	890 ha
		8420 ha

The hill sites would not be thinned successfully by today's techniques, but to save work it has been assumed that all of the net area is treated on the same silvicultural schedule. As this thinning would not begin until year 85, the financial results are not much affected by this assumption.

The original studies treated 648 ha of frost flats separately; it has been assumed, perhaps optimistically, that Douglas fir could be directly established on such sites as they are all below 600 m in altitude. Experience recorded at Kaingaroa (Kirkland, 1969) indicates that good site preparation will often give high survival on frosty sites (rabbits were responsible for many early failures but there are negligible populations on the sites considered in this paper).

Dollars are New Zealand dollars, currently (August 1974) set at NZ$1.00 per US$1.48; devaluation on 24/9/74 reduced this to US$1.30, but parity with the Australian dollar was retained.

Technical Specifications, Silviculture and Management

The object of management is the production of sawlogs for conversion to framing (construction) timber but the dearth of quantified data on log conversion costs continues to hamper analysis. The current Rotorua Conservancy proposals were used as the management regime. The original profit analyses (Fenton, 1967b) used rotations of 35-50 years, but the management then envisaged 80 years or longer! Current proposals are for rotations of 55 years to produce a final crop tree of 50 cm mean d.b.h. This is more than twice the time that radiata pine would take on such sites. Clearly, only a formidable unit value difference could lead to similar profitability; the additional risks, loss of flexibility and postponement of spill-over benefits by locking up areas in such rotations would also have to be costed in a formal cost/benefit analysis.

Silviculture is:

(i) Land clearing: two alternative schedules and methods were evaluated.
In the "original" schedule, most of the standing scrub is cleared and burnt in year 1, and recurrent fires are prescribed to reduce the vigour of weed growth. All except the hill sites (890 ha) are giant-disced in the first rotation in the season of planting.

The "amended" clearing schedule replaces these overall operations with annual crushing and burning before planting, except for the 202 ha of native bush.

(ii) Initial spacing: trees 1.8 m apart in rows 2.4 m apart (2240 stems/ha). Trees are 2 or 3 years in the nursery.

(iii) Blanking: done if establishment is below 85%. None has been costed until year 51 as site preparation should allow better establishment on disced sites. Blanking after year 50 assumes that 10% of the trees are replaced.

(iv) Releasing: once on disced areas, twice on hillsides, and throughout in subsequent rotations.

(v) Thinning: At age 20, thinning-to-waste (to 740 stems/ha) and production thinning at age 35 (66-74 cm d.b.h.) to 370 stems/ha, yielding 186 m^3/ha recoverable volume.

(vi) Protection: no measures have been formulated against *Phaeocryptopus* yet; this analysis deals only with the earlier, relatively disease-free situation. The effect of loss of increment within the given rotation is tested in the sensitivity analyses. Standard fire protection measures would apply.

The increase of noxious animal and weed populations at Kaingaroa has necessitated control operations. These have been costed at $0.70/ha of established forest, but it is reiterated that the area concerned, in its original state, was free of such problems.

(vii) Clearfelling: at normality at 43 m top height at age 55. Yield predictions by R. B. Tennent are detailed in Appendix 1; clearfelling yields are 932.3 m^3/ha recoverable volume on truck. Areas of each operation are given in Table 1.

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

Year	Planting		Blanking	Releasing		Thinning to waste	Production thinning	Clear-felling
	Machine	Hand		First	Second			
1 - 20	153			153P				
21 - 30	153					153P		
31	106	47						
32 - 35		153P						
36 - 50							153P	
51			120					
52			153P		120			
53 - 55					153P			
56								153P

P = in perpetuity.

Labour Requirements; Direct Costs

The labour content and costs of operations are given in Table 2. Details on which these direct, and all other, costs are based are given by Fraser and Walker (1974). Direct costs comprise wages and production bonus, compensation and holiday pay, direct stores charges, transport, and machinery hire. Supervision and indirect costs are charged separately. Table 3 shows the land preparation needed in the first rotation for the original clearing schedule.

TABLE 2—Summarised direct costs ($/ha) and labour requirements (man days/ha).

Operation		Cost	Labour
Land Clearing —	Burning	2.10	
	Discing	23.00	
	Light Scrub	14.83	done by contractor
	Heavy Scrub	67 + 22*	
	Bush	143 + 59 + 4*	
Planting —	Hand	86.90	2.20
	Machine	50.90	0.33
	Blanking	22.06	1.11
	Release Cutting	33.10	2.12
	Thinning to Waste	70.00	3.7

* See Table 3.

TABLE 3—Land preparation — first rotation. Original schedule

Year	Operation	Area (ha)	Rate ($/ha)
1	Cut heavy scrub	607	67.72
	Crush heavy scrub	607	22.24
	Crush light scrub	2428	14.83
	Overall burn	9712	0.25
4	Overall burn	6880	2.10
10 - 25	Annual burns	306 p.a.	2.10
25	Felling bush	202	143.32
26	Burning felled bush	202	4.15
28	Bulldozing bush slash	202	59.30
1 - 49	Discing	153 p.a.	23.00
50	Discing	33	23.00

p.a. = per annum.

Total supervisory staff and indirect labour are scheduled in Table 4, and total manpower is summarised in Table 5.

TABLE 4—Staff and indirect labour schedule (in perpetuity from the years given).

Staff	Year					Total
	1	3 – 34	35	36 – 55	56	
Forest						
Officer in charge	1					1
Forester		1				1
Ranger/Foreman					1	1
Clerk	1					1
Clerk/Stores				1		1
Logging						
Officer in charge			1			1
Ranger/Foreman				1	2	3
Clerk					1	1
Roading						
Officer in charge	1					1
Other Labour						
Roading men	2			1		3
Fleet						
Mechanics	1			2	1	4
Drivers	1				2	3
Other						
Tractor driver	1					1
Fire storekeeper		1				1
Camp attendant				1		1
Carpenter/Painter	1			1		2
H.Q. gang		1		1		2
Tool maintenance	1					1

TABLE 5—Total manpower

Year	Forest labour	Staff and indirect	Total
1 – 2	1	10	11
3 – 20	2	13	15
21 – 31	4	13	17
32 – 34	5	13	18
35	18	14	32
36 – 50	18	22	40
51 – 55	20	22	42
56	36	29	65

The logging equipment needed, and its costs, are listed in Table 6. Thinning costs of \$2.221/m^3 and clearfelling costs of \$1.373 were allowed (loaded on truck at forest).

Fire protection costs are summarised in Table 7. Annual fire control costs include stand-by and routine patrols, break maintenance, building maintenance, and operation and maintenance of equipment; these are roughly proportional to the area planted.

TABLE 6—Logging equipment (including production thinning)

Year	Number	Item	Unit cost (\$)
35	1	½ tonne truck	2 700
36	3	C4 Skidders	25 000
	1	Loader	58 000
	12	Power saws	320
	1	Large gang truck	7 550
55	1	D7 tractor	68 000
	2	Tip trucks	8 500
56	2	C7 Skidders	30 000
	2	Loaders	58 000
	2	Gang trucks	7 550
	10	Power saws	320
	1	Field service unit	6 000
		Miscellaneous equipment	6 900
		Stores (purchase)	10 000

TABLE 7—Fire protection costs

Item	Year	Cost (\$)
Firebreaks — preparation	1 - 55	130 p.a.
Fencing	1 - 55	680 p.a.
Equipment		
Radio	3	2 000
Fire engine	3	18 000
Fire tanker	5	6 300
Fire pumps (2)	4	2 120
Miscellaneous	3	6 000
Buildings		
Fire store — capital	5	6 900
Annual Charges (\$/ha)		
up to 3035 ha; 1.48		
from 3035 ha to 5260 ha; 1.11		
above 5260 ha; 0.74		

p.a = per annum

Social Costs

These comprise roading, accommodation, and minor items. Roading items are listed in Table 8 (with minor items). Housing and accommodation are given in Table 9; it has been assumed that 10 men are recruited locally and are not housed. The final number of houses has been taken as 24 to maintain comparability with other studies. Camp costs have been taken as $100/man/year. Houses cost $17 000 each, have a 65-year life and a $1\frac{1}{4}$% annual repair and maintenance charge. Huts cost $1400 each. The Services components (and miscellaneous items) of social costs are listed in Table 10.

TABLE 8—Social costs: roading

Item	Year	Cost ($)
Road formation	1 – 55	3 496 p.a.
Road metalling	55 – 110	2 185 p.a.
Road maintenance $1.48/ha of established forest		
Equipment		
Tip truck ($\frac{1}{2}$)	1*	8 500
Grader	27	28 000
$\frac{1}{2}$-tonne truck	27	2 700
Tip truck ($\frac{1}{2}$)	55*	8 500

* The other half is charged to forest administration.
p.a. = per annum.

TABLE 9—Accommodation requirements

Year	Houses		Camp huts	
	New	Total	New	Total
1 – 2	1	1		
3 – 20	4	5		
21 – 31	2	7		
32 – 34	1	8		
35	4	12	10	10*
			Small ablution block	
36 – 50	8	20		
51 – 55	2	22		
56	2	24	21	31
			Cookhouse	$43 210
			Caterer's house	$15 000
			Ablution block	$13 880

* Larger self-contained huts at $1400; smaller huts are $1100.

TABLE 10—Social costs and services ($)

Year	Water supply*	Site preparation	Services N.E.I.
1	4200	1820	480 p.a. to year 55
2	4200	—	
3	1850	2180	55 ,,

* An equal amount is charged to the forest account.
NB: R and M of services is equivalent to a fifth of those in administration costs (Table 14).

Indirect Costs

Staff salaries are given in Table 11, and external overheads have been taken as 60% of these. Costs of forest buildings are given in Table 12, and of vehicles and stores in Table 13. Net "services and general", and "general administration" costs are charged on a per hectare basis, and given in Table 14. Depreciation is allowed for by charging the cost of the asset concerned at the end of its service life. The service lives are given in Table 15.

TABLE 11—Salaries ($/year)

Year	1 - 2	3 - 34	35	36 - 55	56
A. **Forest Staff**					
Officer in charge	6 357	6 790	7 237	7 237	7 705
Forester	—	4 851	5 067	5 067	5 497
Ranger/Foreman	—	—	—	—	5 283
Roading ranger	4 475	4 475	4 636	4 636	4 851
Clerk	4 291	4 291	4 517	4 517	4 740
Stores clerk	—	—	—	4 291	4 496
Forest Total	15 123	20 407	21 457	25 748	32 572
B. **Logging**					
Officer in charge	—	—	5 283	5 283	6 357
Ranger	—	—	—	4 636	5 283
Foreman	—	—	—	—	9 372
Clerk	—	—	—	—	4 291
Logging Total	—	—	5 283	9 919	25 303

TABLE 12—Capital works

Item	Year	Cost ($)
Office and store	1	12 100
Petrol store	1	5 100
Telephone	1	3 000
Water supply	1	4 200*
Garage, workshop	2	25 000
Water supply	2	4 200*
Water supply	3	1 850*
Office extension	55	12 100
Garage extension	55	25 000

* An equal amount is charged to social costs.

TABLE 13—Miscellaneous vehicles and equipment

Year	Description	Cost ($)	Charged to
1	½-tonne truck*	2 700	Forest
	Gang truck (small)	6 000	Forest
	Tip truck	8 500	Forest — half Roading — half
	HD6 tractor	20 000	Forest
	Consumable stores†	336 p.a. for 50 yr	Forest
	Class 'A' stores†	456 p.a. for 50 yr	Forest
3	Office car*	2 700	Forest
20	½-tonne truck*	2 700	Forest
	Gang truck (small)	6 000	Forest
27	½-tonne truck*	2 700	Roading
	Grader	28 000	Roading
55	Tip truck	8 500	Forest — half Roading — half
	Miscellaneous plant and equipment†	6 900	
	½-tonne trucks (3)	2 700 each	Forest

* Annual charges, excluding depreciation, on these vehicles are $1270.
† Adjusted by index applied to 1967 data.
p.a. = per annum.

TABLE 14—Costs for each year ($/ha) in established forest, for services and general assets, repairs and maintenance (A); and general administration (B).

Year	A	B	Year	A	B	Year	A	B
1	4.68	5.19	18	2.60	2.88	35	1.59	1.84
2	4.58	5.19	19	2.52	2.75	36	1.56	1.83
3	4.45	5.19	20	2.44	2.66	37	1.52	1.83
4	4.34	5.19	21	2.36	2.59	38	1.49	1.83
5	4.24	5.19	22	2.28	2.59	39	1.46	1.82
6	4.20	5.19	23	2.18	2.59	40	1.44	1.80
7	4.15	5.19	24	2.10	2.59	41	1.40	1.75
8	4.04	5.19	25	2.04	2.59	42	1.38	1.71
9	3.84	5.19	26	2.01	2.59	43	1.36	1.68
10	3.58	5.10	27	1.98	2.53	44	1.34	1.66
11	3.26	4.80	28	1.94	2.36	45	1.32	1.62
12	3.11	4.20	29	1.88	2.16	46	1.28	1.60
13	3.01	3.95	30	1.82	2.06	47	1.26	1.59
14	2.94	3.60	31	1.74	1.98	48	1.26	1.59
15	2.88	3.43	32	1.71	1.92	49	1.23	1.58
16	2.80	3.20	33	1.67	1.87	50	1.235	1.58
17	2.70	3.06	34	1.64	1.84	51*	1.235	1.58

* No change after year 50.

TABLE 15—Service lives

Item	Charge 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	—	Depreciation covered in services and general charge
Fire store	Protection	65	
Fire engine; tanker	Protection	10	
Pumps; radio	Protection	10	
$\frac{1}{2}$-tonne trucks; car	Forest vehicles and equipment	10	1 $\frac{1}{2}$-tonne truck to logging; 1 $\frac{1}{2}$-tonne truck to roading
Gang trucks	Forest vehicles and equipment	10	2 to forest; 4 to logging
Tip trucks	Forest vehicles and equipment	10	1 to forest; 2 to logging; 1 to roading
HD6 tractor	Forest vehicles and equipment	6	
Miscellaneous equipment	Forest vehicles and equipment — half; Logging — half	10	
D7 tractors	Logging	6	
Skidder	Logging	6	
Crawler stacker	Logging	6	
Field service units	Logging	10	
Miscellaneous equipment	Logging	3	
Chain saws	Logging	$1\frac{1}{2}$	
Grader	Social — roading	10	

Returns

Realisations from sawlogs are complex, being the net result of the cost of sawing and the conversion from a range of log sizes. Analyses were made of sales from mills which produced 50-55% of the total cut of Douglas fir, and a median was taken of the sizes sawn and the market destinations of 120 000 m^3 of timber sales (mills have different major export markets, and differing prices apply). In 1973, 45% of Douglas fir timber production was exported, and this proportion was used in allotting sales and calculating realisations.

Sawing costs were prepared by R. K. Grant and are summarised in Appendix 2.

Chipwood recovery has been allowed, using current State mill recoveries, but current details of the realisation figures are confidential and estimates had to be used. The average log size of thinnings is 20.1 cm small end diameter(s.e.d.) and clearfellings average 29.7 cm. Net log realisations are given in Tables 16 and 17 for thinnings and clearfellings respectively.

TABLE 16—Calculation of loaded-on-truck realisations ($/m^3) for thinnings

Size	Export Sales (45%) A %	*Price (f.o.b.)	Value	Domestic Sales (55%) B %	Price (green sawn)	Value
25 mm boards	25	66.73		20	32.07	
51, 76 and 102 × 51 mm	56	66.73		63	52.33	
127 - 305 × 51 mm	12	74.99		13	67.20	
76 and 102 × 76 mm	5	66.73		2	56.56	
Large-dimensioned timber	2	77.96		2	69.19	
	100	67.95		100	50.63	
				55		= 27.84
Less 45% of Mill handling		1.91		Less 2½% cash discount		0.70
Transport		3.14				
All wharf costs		3.43				27.14
		8.48		Plus differential in freight to Auckland		0.05
		59.47				
	45		A = 26.77			B = 27.19
Price at mill = A + B			53.96			
Less cost of milling including mill profit allowance			32.20			
			21.76			
Log conversion	43.3		9.42†			
Plus chip credit			0.74†			
Less log cartage forest to mill 40.2 km			1.16†			
Net loaded at forest			9.00†			

* Taking mean of two export price lists.

† Values in $/m^3 for logs, all other figures refer to sawn timber.

TABLE 17—Calculation of loaded-on-truck realisations (\$/m³) for clearfellings

Size	Export Sales (45%) A %	*Price (f.o.b.)	Value	Domestic Sales (55%) B %	Price (green sawn)	Value
25 mm boards	10	66.73		10	32.07	
51, 76 and 102 × 51 mm	60	66.73		59	52.33	
127 - 305 × 51 mm	20	74.99		20	67.20	
76 and 102 × 76 mm	5	66.73		1	56.56	
Large-dimensioned timber	5	77.96		10	69.19	
	100	68.94		100	55.01	
				55		= 30.25
Less 45% of Mill handling		1.91		Less 2½% cash discount		0.75
Transport		3.14				
All wharf costs		3.43				29.50
		8.48		Plus differential in freight to Auckland		0.05
		60.46				
	45		A = 27.19			B = 29.55
Price at mill = A + B			56.74			
Less cost of milling, including mill profit allowance			21.19			
			35.55			
Log conversion	52.5		18.66†			
Plus chip credit			0.70†			
Less log cartage forest to mill 40.2 km			1.16†			
Net loaded at forest			18.20†			

* Taking mean of two export price lists.
† Values in \$/m³ for logs, all other figures refer to sawn timber.

The volume of sawmill slabs available from thinnings is 10 000 m³, which is insufficient on today's standards to justify a full barking and chipping installation, and the total slab volume of thinnings plus clearfellings is 37 000 m³. So an unbarked slab disposal credit of \$0.353/m³ has been allowed on thinnings from year 35 to 55, and the full amount thereafter.

Rents have been allowed as social returns; house rents are credited at \$330 per year and hut rents at \$45.

Costs and returns have been discounted to the year of origin of the forest and charged from the mid-point of the year in which they occur.

Results

The land expectation values (LEV) or present net worth (PNW) per hectare for grouped cost elements are given in Table 18 for interest rates of 3% to 10%. Returns and the net LEVs, the prices which could be paid for land to break even at the various

TABLE 18—Land expectation values ($/ha) by cost/return classes (original land clearing schedule)

Interest rate (%)	3	4	5	6	7	8	9	10
Direct								
Land clearing	21.9	19.9	18.3	17.1	16.0	15.2	14.5	14.0
Establishment	55.5	38.5	29.1	23.4	19.5	16.8	14.7	13.1
Tending	19.2	11.8	7.8	5.3	3.8	2.7	2.0	1.5
Total direct	*96.7	70.2	55.2	45.8	39.3	34.7	31.3	28.6
Protection								
Fire	27.3	19.8	15.5	12.7	10.8	9.4	8.3	7.5
Noxious plants and animals	9.8	6.1	4.2	3.1	2.3	1.8	1.5	1.2
Administration								
Salaries and external overheads	178.1	126.3	97.1	78.5	65.8	56.6	49.6	44.1
Buildings and stores	10.9	8.7	7.5	6.7	6.2	5.8	5.5	5.3
Vehicles	34.1	24.3	18.8	15.4	13.1	11.5	10.2	8.3
Total administration	223.1	159.3	123.4	100.6	85.1	73.8	65.3	57.7
Total growing costs	356.8	255.5	198.3	162.1	137.5	119.7	106.4	95.0
Logging								
Salaries and external overheads	34.6	17.1	9.1	5.1	3.0	1.8	1.1	0.7
Machinery	89.6	47.7	27.7	17.2	11.3	7.8	5.6	4.1
Cost of logging operation	197.7	93.5	47.8	25.8	14.5	8.4	5.0	3.1
Total logging	321.8	158.2	84.6	48.2	28.8	18.0	11.8	8.0
Total forest costs	678.6	413.7	282.9	210.3	166.3	137.8	118.1	102.9
Social								
Roading	40.1	26.9	19.4	14.9	11.8	9.7	8.1	7.0
Accommodation	45.1	31.4	24.0	19.5	16.6	14.6	13.1	12.1
Total social	85.2	58.3	43.5	34.4	28.4	24.3	21.3	19.1
Total costs	763.9	472.0	326.4	244.7	194.8	162.1	139.4	122.0
Returns								
Production thinning	289.6	153.5	87.1	51.7	31.7	19.9	12.7	8.3
Clearfelling	1659.0	727.8	342.3	168.5	85.8	44.8	23.9	12.9
Total log returns	1948.6	881.2	429.4	220.2	117.4	64.7	36.6	21.2
Rent (social)	13.6	8.4	5.7	4.1	3.2	2.5	2.1	1.8
Total returns	1962.2	889.6	435.0	224.3	120.6	67.2	38.7	23.0

* Totals may not add because of rounding.

interest rates, are given in Table 19. Net LEVs are graphed in Fig. 1, with the internal rates of return (IRR), found from the graphs. They are nearly 6% (5.8) including social items and 6.2% excluding social items.

The negative values decrease in magnitude as interest rates increase; this is an arithmetical curiosity and as long as foresters use great caution in ranking any project once negative LEVs (or PNWs) are involved, it should not cause concern. The point is apparently unrecognised in some texts.

The criterion of break-even growing cost decreases in utility with the production of intermediate yields. The convention adopted here has been to take equal unit values for intermediate and final crop yields. These values are given in Table 20.

The effects of different land clearing schedules are shown in Table 19, but the differences are unimportant.

DISCUSSION

It should be reiterated that the results are favoured by the assumptions that frost flats can be successfully established (648 ha net) and, at the other topographical extreme, that the hill sites (890 ha net) can be extraction thinned. As these operations occur after years 50 and 85 respectively, the financial effects are not very great.

The release cutting needed is indeterminate in these analyses; the extra site preparation should reduce weed competition on such sites in the first rotation.

Although edge trees are of low grade, no allowance has been made for pruning

TABLE 19—Land expectation values ($/ha)

Interest rate %	Excluding social items: Douglas fir DSL (1)	Excluding social items: Douglas fir DSL (2)	Excluding social items: Douglas fir EL (1)	Excluding social items: Douglas fir EL (2)	Excluding social items: Radiata pine EL (3)	Including social items: Douglas fir DSL (1)	Including social items: Douglas fir DSL (2)	Including social items: Douglas fir EL (1)	Including social items: Douglas fir EL (2)	Including social items: Radiata pine EL (3)
3	1270	1271	1892	1893	4842	1198	1199	1820	1821	4722
4	468	470	741	743	2830	418	420	691	693	2740
5	146	150	275	278	1758	109	112	237	241	1687
6	10	14	73	77	1132	—20	—16	43	47	1073
7	—49	—44	—17	—12	744	—74	—69	—42	—37	694
8	—73	—68	—56	—51	494	—95	—90	—78	—73	451
9	—82	—76	—73	—67	328	—101	—95	—92	—86	290
10	—82	—76	—77	—71	215	—99	—93	—94	—88	182
Internal rates of return %	6.2		6.7		15.0	5.8		6.4		13.8

Figures are rounded

(1) With original establishment costs
(2) With amended establishment costs
(3) Fenton & Tennent, 1975
DSL = domestically processed logs; EL = export logs.

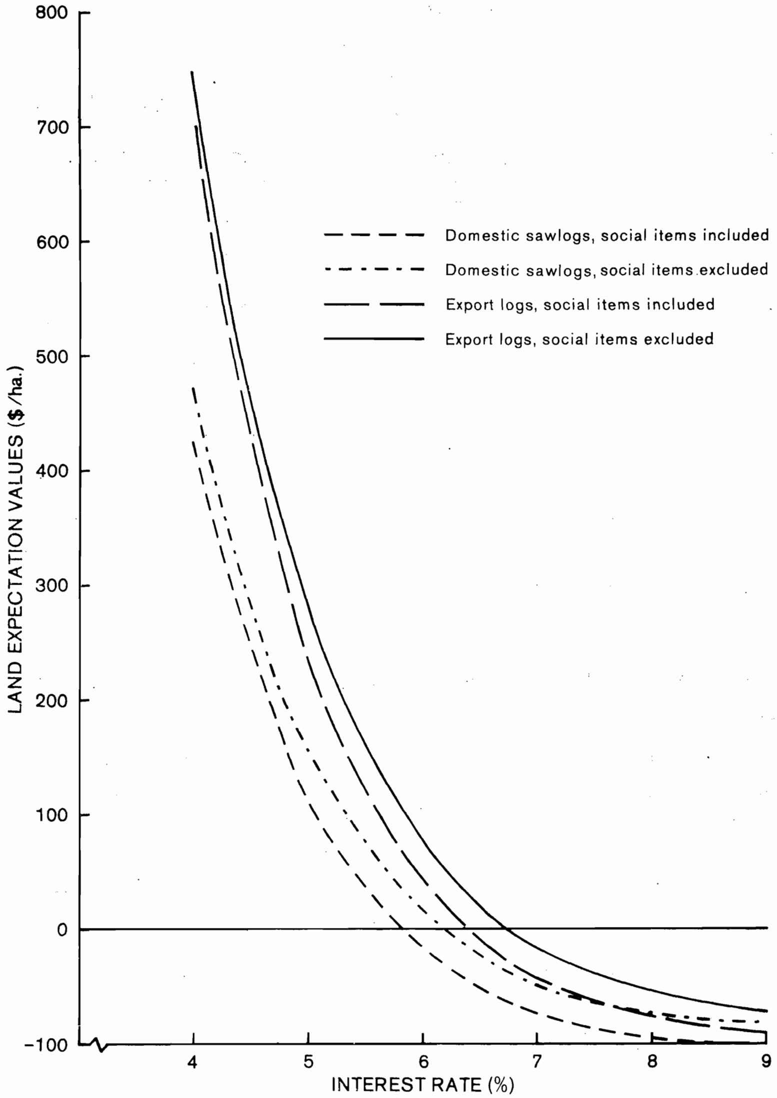

FIG. 1—Douglas fir land expectation values.

them. Similarly, returns exclude allowance for any low grade timber, but it is unlikely that none will be produced, and hence realisations are optimistic.

Sensitivity analyses have been restricted to considering land clearing alternatives, thinning-to-waste costs, losses in volume, increasing returns for export logs, and other price assumptions. The alternative land clearing schedules make little difference to the financial results.

The thinning-to-waste cost is debatable as no such operations have been done, but

TABLE 20—Break-even growing costs, 1973 ($\$/m^3$); original land clearing schedules

Interest rate %	Excluding social costs		Including social costs	
	Douglas fir	Radiata pine*	Douglas fir	Radiata pine*
3	2.879	1.371	3.567	1.794
4	4.446	1.662	5.461	2.174
5	6.899	2.020	8.413	2.639
6	10.683	2.466	12.950	3.210
7	16.479	3.019	19.882	3.910
8	25.231	3.705	30.354	4.765
9	38.356	4.556	46.034	5.810
10	57.160	5.607	68.652	7.089

* Export log regime (Fenton and Tennent, 1975).

if it is reduced by two-thirds, the net LEVs at 6 and 7% are increased by $3.6 and $2.5, respectively.

A more serious limitation is the omission of *Phaeocryptopus* damage. Currently (September 1974) increment on stands of 40 years and older at Kaingaroa has been reduced to half of that projected; future effects are not predictable, but the results of changes in final crop volumes on returns can be indicated. For example, if final crop volumes decrease by 15%, major effects at interest rates near the IRR in terms of LEV are:

Interest rate %	Item decreasing by 15% Returns	Logging*	Net ($/ha)	Excluding social items old LEV	new LEV ($/ha)
5	—51.34	+3.87	—47.47	147	100
6	—25.28	+1.90	—23.38	10	—13
7	—12.67	+0.97	—11.70	—49	—61

* proportional only

This underestimates other effects; the final log size would be reduced and so sawing costs would rise (if rotations are constant).

Comparisons with an export log regime can be calculated using prices for 'A' grade (Southland) Douglas fir for the clearfellings. The realisation statement is given in Table 21; log haul costs are 20% less than for radiata pine as Douglas fir is lighter. (The thinnings would be 'D' grade or pulpwood and have been retained for domestic sales). Realisations (on truck) would be 37.5% greater than for domestic sawlogs. Net LEVs

TABLE 21—Realisation — clearfelling — export logs

Cartage to port (20% less than radiata pine)	88.89 c/100 JHD
Wharfage and storage	22.73
Marshalling	31.37
Stevedoring	75.00
Inspection	1.25
Documentation	2.00
Fumigation contingency	2.00
	223.24
Sale price F.O.B. — 'A' grade logs	1011.00
Margin for price on truck	787.76
	= $25.03 $/m^3$
(= 137.5% of domestic sawlog value — Table 17)	

JHD: Japanese Haakon Dahl unit.

are included in Table 19. The IRR increases from 5.8 to 6.4% when social items are included.

If returns are doubled throughout, and there are no apparent reasons for such an optimistic assumption for sawtimber, the IRR increases only to about 7.5%.

The effects of reducing thinning costs by two-thirds, of reducing volumes by 15%, of allowing for export log realisations, and of doubling returns, show that the IRR varies from less than 6% to 7.5%. Further sensitivity results will fall into much the same range.

CONCLUSION

Profitability is similar to that calculated earlier for accelerated afforestation for a wide range of rotations and price assumptions (Fenton, 1967b). Douglas fir afforestation, even on such favourable sites, is quite incapable of satisfying the New Zealand Treasury's minimum rate of 10% for investment projects.

ACKNOWLEDGMENT

The assistance of J. C. Park in the preparation of this study is gratefully acknowledged. Mr R. O'Reilly's help in obtaining logging costs, the growth projections of R. B. Tennent, and the sawing costs by R. K. Grant provided essential data for the study.

The availability of mill records from the large-scale producers, who wish to remain unidentified, clarified the question of the sizes of Douglas fir timber actually sold.

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APPENDIX 1

Prediction of Volume, Basal Area, and Diameter Class Distribution for Thinned Douglas Fir

Supplied by R. B. Tennent, Forest Research Institute, New Zealand Forest Service, Rotorua.

Yield prediction for Douglas fir is at an intermediate stage in New Zealand. Duff (1956) constructed yield tables for unthinned stands. Spurr (1963) modified Duff's results, and Elliott (1969) introduced a provisional variable density yield table for Douglas fir in Kaingaroa. Mensuration Section of Kaingaroa State Forest (1973) has updated the variable-density yield tables. The Kaingaroa yield model projects net basal area increment, total stem volume, and mortality on the basis of height, as does that of Beekhuis (1966) for *Pinus radiata,* and was used here. It includes factors for recoverable volume in relation to total volume.

The model has been programmed for a Hewlett-Packard calculator, and includes results for thinning yields.

The first input required is initial stocking, height, and basal area at age 20, when stands are thinned to waste. There are comparatively few data available, and an initial basal area of 57.8 m²/ha of a stocking 2224 stems/ha was assumed before thinning, with 27.2 m²/ha on 741 stems/ha after thinning to waste.

Top height in relation to age was taken from Kaingaroa data; this agrees with Spurr (1963) and Duff (1956) at age 35, and is similar to Spurr (1963) from ages 35 to 55. Table A1-1 gives the projected growth and yield data.

The d.b.h. distribution obtained from three Kaingaroa post-thinning plots gave very highly significantly different results ($\chi^2(19) = 46.7^{***}$) from the first yield table projections (Duff, 1956). The actual distribution was used in this analysis. The number of 4.88 m logs per hectare with 15.2 cm small end diameter inside bark (s.e.d.i.b.) was calculated from the diameter distribution of the thinnings, using taper tables (Duff, 1954). The result was a slightly different total volume from that projected from stand basal area and height, and which incorporated a gross/net yield factor as shown in Table A1-1. Hence the number of logs and total volume in each s.e.d.i.b. class was proportionately adjusted to represent the same total volume as the yield projection. The log size distribution was used in calculating sawing costs (Appendix 2).

Stem distribution at clearfelling was obtained from a stand which had a stocking and mean d.b.h. similar to the proposed regime. In this case the volumes found from taper tables for this stem distribution, and those projected from the yield table were very close and no further adjustment was made.

TABLE A1—1—Douglas fir yield prediction

Age (yrs)	Height (m)	Stems/ha	Basal area (m^2/ha)	Mean d.b.h. (cm)	Recoverable volume (m^3/ha)	percent gross volume
20	14.1	2224 (741)	57.8 (27.2)	17.6 (21.6)		
35	28.9	731 (370)	67.7 (42.0)	33.8 (38.0)	185.9	70
55	42.8	362	73.2	50.3	932.3	85

Data following thinning shown in parentheses.

APPENDIX 2

Cost of Sawing

Supplied by R. K. Grant, Forest Research Institute, New Zealand Forest Service, Rotorua.

(i) The log small-end-diameters (s.e.d.), in 2.5 cm classes for the tree d.b.h. distribution, were taken from taper tables for the thinnings and clearfellings. Log length was 4.88 m.

(ii) The total sawing time, by log s.e.d. class, was calculated taking 70% of the theoretical throughput.

(iii) Conversion factors were taken from unpublished work of C. H. Brown (pers. comm.).

(iv) Costs of sawing were taken from Grainger (1971), updating the figures by the rise in the wholesale price index. Costs used were $4.50 and $11.50/minute for the frame and band mills, respectively. A profit allowance of 15% on mill capital is included in these costs.

(v) The mean log from thinning had 20.1 cm s.e.d., and 0.218 m^3; the clearfelling average was 29.7 cm s.e.d. and 0.437 m^3. Summarised costs are given in Table A2-1.

TABLE A2—1—Cost of sawing

	s.e.d. (cm)*	Volume of logs (m^3)	%	Sawing time (hours)	% of frame time	Conversion factor %	Timber production (m^3)	%	Cost sawn ($/$m^3$)
Thinnings:									
Frame sawing	15 - 26	22 792	13	1 257	17	40.8	9 299	11	36.50
	27 - 37	5 739	3	216	3	49.2	2 824	3	20.70
	38 - 46	153	—	5	—	55.0	84	—	16.10
	Total	28 684	16	1 478	20	42.6	12 207	14	32.70
Clearfellings:									
Frame sawing	15 - 26	28 325	17	1 483	21	42.5	12 038	14	33.30
	27 - 37	55 929	32	2 186	30	50.8	28 412	32	20.80
	38 - 46	53 468	31	2 043	29	57.5	30 744	35	17.90
	Total	137 722	80	5 712	80	51.7	71 194	81	21.70
Band sawing	47 - 54	6 450	4	105	—	62.5	4 031	5	18.00
	C.F. total	144 172	84	—	—	52.2	75 225	86	21.50
All logs:									
Frame sawing	15 - 26	51 117	30	2 733	38	41.7	21 316	25	34.60
	27 - 37	61 668	35	2 402	33	50.0	30 834	35	21.00
	38 - 46	53 621	31	2 048	29	57.5	30 832	35	17.90
	Total	166 406	96	7 183	100	49.9	82 982	95	23.30
Band sawing		6 450	4	105	—	62.5	4 031	5	18.00
	Total	172 856	100	—	—	50.3	87 013	100	23.10

* Totals may not add because of rounding in conversion to metric sizes.