ECONOMICS OF SAWLOG SILVICULTURE WHICH INCLUDES PRODUCTION THINNING

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ABSTRACT

The economics of radiata pine (**Pinus radiata** D. Don) afforestation on site index 95 are evaluated for a "normal" tempo of management of a regime prescribing a production thinning. One hundred and thirty of the initial 900 stems per acre (s.p.a.) are pruned in three lifts to 18 ft, stands being thinned to waste to 200 s.p.a. at 40 ft. Thinning to 80 s.p.a. at **ca.** 90 ft produces 2100 cu ft net per acre of pulpwood. The final crop is felled at **ca.** 136 ft, age 36 yr, the 23.5 in. diameter-at-breast-height (d.b.h.) trees producing 9440 cu ft per acre net on truck.

Values are based on mid-1967 levels and are charged from the mid-point of the year of origin. Interest rates of 3% to 12% are evaluated.

Net land expectation values (LEV) at 7% are -$5.7 when social items are included and $6.0 when they are excluded. Corresponding internal rates of return are 6.7% and 7.4%. The equivalent values for a direct (no production thinning) regime are $99 and $117, and 10.5% and 11.5% respectively. In comparison the production thinning regime needs the same labour; produces much the same total volume, but in poorer grades; incurs greater managerial and physical risks; delays most returns for a decade; and is fundamentally inefficient in timing the reduction of stand basal area.

An open ended pulp commitment can be met at increased profit by combination of pulpwood and direct regimes, in preference to production thinning.

Forest Service policy is to pursue those regimes prescribing production thinning.

INTRODUCTION

Production thinning—the sale of intermediate yields before final felling—has been implicit in nearly all New Zealand exotic forest management. One major difficulty has been to achieve the first production thinning at between 70 ft and 95 ft mean crop height at reasonable cost, a break-even cost of production usually regarded as "economic"; these and other difficulties are exemplified by discussions recorded in the two Forest Research Institute symposia on pruning and thinning (Bunn, 1963; Tustin and Bunn, 1970). A tentative schedule for tending Kaingaroa Forest radiata pine (*Pinus radiata* D. Don) included one or two production thinnings (Ure, 1949) and similar proposals still apply to this, and other forests. The 1969 Kaingaroa Forest schedule (Fenton, 1971) is typical. The profitability of such a regime is evaluated here, and comparisons made with a regime producing similar size final crop trees grown without the restraint of this thinning (Fenton, 1972a). Consideration of the fundamental economics of production thinning is made in a later paper (Fenton, 1972b).

The utility of the analysis is increased if comparability is maintained with other studies (Fenton, 1972a; Fenton and Dick, 1972a). Hence a "normal" rate of afforestation has been applied to the same area of site index 95 (Lewis, 1954). Similarly, the base year for the Forest Development Conference was 1967 and prices and costs are generally for that year. All these studies are nominative, and no stands have been managed for a rotation on the basis given.

TECHNICAL SPECIFICATIONS AND SILVICULTURE

The regime is required to produce (a) an intermediate yield of pulpwood at 87-90 ft, (b) a final crop whose butt logs (18 ft long) are pruned (c) framing timber recovery in second logs, and possibly in higher log height classes by some degree of control of branch size.

Silviculture is:

1. Planting sites are cleared and burnt before establishment as for the log trade model (Fenton and Dick, 1972a).
2. Initial spacing: trees 6 ft apart in rows 8 ft apart (900 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, which comprise 2200 acres net, a further operation is prescribed in the second year after planting. 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 300 s.p.a. : 16 ft mean tree height
   (b) Prune 8/14 ft 130 s.p.a. : 26 ft mean tree height
   (c) Prune 14/20 ft 130 s.p.a. : top height 36 ft. Thin to waste to 200 s.p.a. top height 40 ft. Production thin from 192 to 80 s.p.a.; 87 ft mean top height, gross yield 2600 cu ft per acre, net yield on truck 2100 cu ft per acre.
6. Protection: needle blight (*Dothistroma pini* Hulbary) prevention measures are as given earlier (Fenton, 1972a).
7. Clearfell at normality at age 36; 77 s.p.a.
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 16 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 70 yr 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 a third of the area; direct seeded from the air on a third; and naturally-regenerated on the remaining third. 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.

10. Each pruning step has been timed one year earlier than in the Rotorua Conservancy proposed schedule, otherwise the regime is much the same as the 1969 Kaingaroa schedule (Table 7 in Fenton, 1971).

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 One	Release Cutting Two	Slasher Thinning	Pruning One	Pruning Two	Pruning Three	Thinning To Waste	Poison Overwood
1	578												
2	578				578	578							
3	578						578						
4	578												
5	578								578P				
6	578												
7	578									578P			
8	578												
9	578										578P		
10–17	578											578P	
18	174	444	404										
19,20		578	578										
21–30			578										
31			578				332*						
32			578				578*						
33			578				578*						444
34	444		134				578*						578
35	578						134*						578
36	578												
37			193P	193P	578	578							
38					193P	193P							
39								385P					

* Periodic, occurring every rotation (36 years)

P = In perpetuity

YIELD PREDICTIONS

Growth projections have been calculated independently by R. N. James of the Forest Research Institute and by Rotorua Conservancy staff. The final crop trees lose the equivalent of one year's diameter increment as they are selectively pruned before the thinning to waste. At rotation age of 36 yr final crop trees are 23.5 in. in d.b.h. and 138 ft tall, the 77 crop trees yielding 10 300 cu ft per acre to a 6 in. top or 9440 cu ft net-on-truck. Kaingaroa staff advise some 3% of the area initially planted is later occupied by the roading and landings required for production thinning.

Although the final tree d.b.h. is 0.8 in. smaller than from the direct regime (Fenton, 1972a), the same volumes per log-height-class have been allotted to the sawlogs (as no better data are available). So butt logs of 39 cu ft, second logs of 29 cu ft and third logs of 20 cu ft have been assumed. Recoverable volume of pulpwood from top logs has been taken as 34.7 cu ft. Actual results after production thinning are covered in the sensitivity analysis.

LABOUR REQUIREMENTS: DIRECT COSTS

Where appropriate, these costs are parallel to those of the direct regime (Fenton, 1972a). 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 as in the companion paper (Fenton, 1972a). 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. Clearfelling labour needs are based on a man-hour production of 100 cu ft.

Direct labour requirements are given in Table 2, staff and indirect labour in Table 3, and total labour in Table 4. Thinning yields, labour needs, and equipment are listed 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 protection costs are in Table 7. Unit *Dothistroma* protection costs are as given earlier (Fenton, 1972a).

The payment of a net stumpage for thinnings should mean the exclusion of all thinning costs from the analysis. The need to maintain comparability between the studies makes this undesirable for estimating social costs if different proportions of the total manpower are housed or are allocated single accommodation, and if allocations vary markedly through time. The convention followed in the models to date (Fenton and Tustin, 1972; Fenton and Dick, 1972a, b, c, d) has been to accommodate all except 10 men in houses up to the start of logging. Then a camp is built, and further houses are added so that 44% of all labour have houses available. These are arbitrary decisions, and as stated earlier (Fenton and Dick, 1972c) it is preferable to transport workers where possible from towns which have social facilities. In this model, cost of accommodation required for the thinning labour has been excluded up to year 37 (when clearfelling begins). Full accommodation costs are then charged—which assumes the camp and all the houses required are built in year 37. Detailed costing of the accommodation for the thinning labour is considered in a later paper (Fenton, 1972b). Social costs include roading and services (Table 8), and accommodation (Table 9). 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 $8400 each, huts $700. Maintenance of buildings costs 1¼% of capital annually.

INDIRECT COSTS

Staff salaries are given in Table 10; external overheads have been taken as 60% of these amounts. A forest building programme is given in Table 11 and vehicles and stores are listed in Table 12. Net charges for "services and general" costs, with those of general administration, are on a per acre basis, and are given in Table 13.

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 as given earlier (Fenton, 1972a).

RETURNS

Pulpwood Returns

Originally a stumpage of 3.75c per cu ft was allowed for pulpwood, but current stumpages of 3.0c have been used in this model for thinnings and clearfelling, as there have been no signs of increased stumpages since pulpwood utilisation began in New

TABLE 2—Direct labour requirements, forest growing and tending (man-days)

Year	Planting Machine	Planting Hand	Blanking	Release One	Cutting Two	Slasher Thinning	Pruning One	Pruning Two	Pruning Three	Thinning To Waste	Poison Overwood	Total Days	Total Years
1	90											90	1
2	90		173	387								650	3
3	90		173	387	387							1,037	5
4	90		173	387								650	3
5-6	90		173	387			578P					1,228	5
7-8	90		173	387				809P				2,037	9
9	90		173	387					809P			2,846	12
10-17	90		173	387						1,156P		4,002	17
18	96	250	173	387								4,258	18
19-20	90	358	173	387								4,360	18
21-30		358	173	387								4,270	18
31		358	173	387	222*							4,492	19
32		358	173	387	387*							4,657	20
33		358	173	387	387*						297	4,954	21
34	69	83	173	387	387*						387	4,838	20
35	90		173	387	90*						387	4,479	19
36	90		173	387								4,002	17
37		120P	173	387								4,032	17
38			58P	129P								3,659	16
39						258P						3,917	17

* Periodic, occurring every rotation

P = In perpetuity

TABLE 3—Staff and indirect labour requirements

	Year:	1	2-3	4-8	9	10-17	18	19-36	37	38+
	STAFF									
Forest:	Officer in Charge	1								1
	Forester		1							1
	Ranger/Foreman		1			1		1t		3
	Clerk	1								1
	Clerk/Stores							1t		1
Logging:	Officer in Charge						1t			1
	Ranger/Foreman							1T	1-2	2-3
	Clerk							1t		1
Roading:	Officer in Charge	1								1
	OTHER LABOUR									
	Men	2					1t			3
Fleet:	Mechanics	1						2T	2	4
	Drivers	1								
Other:	Tractor driver	1								1
	Fire lookout			1						1
	Fire storekeeper			1						1
	Camp attendant							1t		1
	Carpenter/Painter	1							1	2
	H.Q. gang				1			1t	1	3
	Tool maintenance	1								1
TOTAL		10	12	14	15	16	18	26	33	

T = required for thinning operations in perpetuity
t = required for thinning operations up to year 37

TABLE 4—Total manpower (man-years)

Year	Forest	Staff and Indirect		Man Years Thinning T	Clearfelling		Total
1	1	10					11
2	3	12					15
3	5	12					17
4	3	14					17
5-6	5	14					19
7-8	9	14					23
9	12	15					27
10-17	17	16					33
18	18	18	(2t)				36
19-30	18	26	(10t)	23			67
31	19	26	(10t)	23			68
32	20	26	(10t)	23			69
33	21	26	(10t)	23			70
34	20	26	(10t)	23			69
35	19	26	(10t)	23			68
36	17	26	(11t)	23			66
37	17	33	(3T)	23	(33)	31*	104
38	16	33	(3T)	23	(33)	31*	103
39	17	33	(3T)	23	(33)	31*	104

T = required for thinning operations in perpetuity
t = required for thinning operations up to year 37
* Assuming 3% loss of area

TABLE 5—Thinning yields, labour, equipment and costs

A. Yields. Stocking from 200 to 80 s.p.a. at 87 ft
2,600 cu ft gross, 2,100 cu ft net per acre
Total yield 1.2138 million cu ft per year

B. Labour. Man hour production 32 cu ft
= 53,760 cu ft per year
Total labour 23 men per year

C. Basic equipment — permanently costed to thinning

No.	Item	Life (yr)	Unit cost ($)
1	D7 tractor	6	53,000
4	Timberjacks (wheeled)	5	13,000
2	Loaders (wheeled)	10	30,000
14	Power saws	2	150
2	Gang trucks	10	5,000
—	Miscellaneous	10	1,500

D. Equipment charged initially to thinning, subsequently to clearfelling*

1	Trekka truck	10	1,700
1	10 cwt truck	10	2,000
1	Tip-truck	10	4,500

E. Costs. Direct cost 10c per cu ft
Additional marginal costs
Salaries as shown in Tables 3 and 10, plus external overheads
Earlier road metalling years 18 to 35, less cost in years 54 to 71 inclusive
Accommodation costs (Table 9)
Earlier construction of office and garage extensions, years 19-36

F. Returns. Logs 3c per cu ft net
Accommodation rents

* From years 18 to 35

TABLE 6—Logging equipment for clear felling

Year	No.	Item	Unit Cost ($)
36	1	D7 tractor	53,000
	2	Tip trucks	4,500
	1	Trekka truck*	1,700
37	1	D7 tractor	53,000
	6	D6 tractor	35,000
	6	Arches	5,000
	4	Loaders	35,000
	4	Gang trucks	5,000
	24	Power saws	150
	2	Field service units	5,000
	—	Miscellaneous	4,600
	—	Stores (purchase)	5,000

TABLE 7—Fire protection costs

Item	Year	Cost $
Firebreak preparation	1-36	108.3 p.a.
Fencing	1-6	416.6 p.a.
Telephone	4	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	4	5,500
— depreciation		65 yr life
Garage and store — capital	6	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—Social costs: Roading and Services

Roading

Formation	$2,932 p.a. from year 1 to 36 inclusive		
Maintenance	$0.30 p.a. per planted area		
Metalling	$2,666.7 p.a. from year 18 to 53 inclusive		
Machinery	Tip-truck (½)	year	1
	Grader	year	18
	10-cwt truck	year	18
	Tip-truck	year	18

Differential cost of thinning

Metalling	Cost in years 18 to 35, less cost in years 59 to 71 inclusive
Machinery	Tip-truck in years 18 to 35, less cost in year 36 in perpetuity

Services

Water supply	$2,500 in years 1 and 2; $1,100 in year 3
Site preparation	$1,000 in year 1; $1,200 in year 3

Services "not elsewhere indicated" $436 p.a. years 1 to 36 inclusive

Share of "services"; this is based on planted acreage, ranging from $0.22 per acre for 5.78 acres, to $0.06 per acre for areas of 16,000 acres and over.

TABLE 9—Accommodation requirements

Year	No. to be Accommodated	Houses		Huts		Camp	
		New	Total	New	Total		
1	1	1	1				
2	5	4	5				
3	7	2	7				
4	6	-	7				
5–6	8	1	8				
7–8	12	4	12				
9	16	4	16				
10–17	22	6	22				
18	25	3	25				
19–30	56	13	38	18	18	Cookhouse	$10,700
						Caterer's house	$6,700
						Ablution block	$400
31	57			1	19		
32	58			1	20		
33	59			1	21		
34	58						
35	57						
36	55						
37	93	6	44	28	49	Cookhouse extension	$17,000
						Ablution block	$4,900
38	92						
39	93						

TABLE 10—Salaries, in dollars per annum

Category Year:	1	2-4	5-9	10-17	18	19-36	37*
A. Forest staff							
Officer in Charge	3,410	3,410	3,550	3,750	3,900	3,900	3,900
Forester		2,570	2,570	2,810	3,170	3,170	3,170
Foreman		2,250	2,250	2,360	2,360	4,610	4,610
Ranger				2,570	2,570	2,570	2,690
Roading ranger	2,250	2,250	2,250	2,570	2,570	2,690	2,690
Clerk	2,230	2,230	2,450	2,450	2,450	2,450	2,690
Stores clerk						2,450	2,450
Total A	7,890	12,710	13,070	16,510	17,020	21,840	22,200
B. Logging staff — Clearfelling							
Officer in Charge						3,410†	3,410
Foreman							2,360
Ranger							2,690
Clerk							2,230
Total B						3,410†	10,690
C. Allocation to production thinning Logging							
Officer in Charge					3,410	3,410	-
Foreman						2,360	-
Ranger							2,690
Clerk						2,230	2,230
Total C					3,410	8,000	4,920

* Required each year thereafter

† Year 36

TABLE 11—Capital works

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†
19	Garage extension	8,000‡
	Office extension	3,875‡
37	Garage extension	8,000
	Office extension	3,875

* An equal amount charged to Protection
† An equal amount charged to Social Costs
‡ Charged to Thinning to Year 36

TABLE 12—Miscellaneous vehicles and equipment

Year	No.	Item	Amount $	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
	1	Consumable stores	400 p.a. for 25 yr	Forest
		Class "A" stores	544 p.a. for 25 yr	Forest
3	1	Office car*	2,500	Forest
7	1	10-cwt truck*	2,000	Forest
	1	Gang truck	5,000	Forest
18	1	10-cwt truck*	2,000	Roading
	1	Grader	20,000	Roading
	1	Tip-truck	4,500	Roading — half Social — half
		Miscellaneous plant	9,200	Forest — half Logging — half
36	3	10-cwt truck*	2,000	Forest

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

TABLE 13—Services and general assets, general administration

Year	Total S and G Charge Per acre $	General Admin. Costs per acre $
1	1.09	1.152
2	1.05	1.152
3	1.01	1.152
4	0.95	1.152
5	0.9	1.152
6	0.875	1.152
7	0.833	1.152
8	0.79	0.576
9	0.75	0.576
10	0.7	0.576
11	0.66	0.576
12	0.625	0.576
13	0.59	0.576
14	0.56	0.576
15	0.525	0.576
16	0.5	0.576
17	0.475	0.576
18	0.46	0.408
19	0.43	0.408
20	0.3875	0.408
21	0.363	0.408
22	0.35	0.408
23	0.345	0.408
24	0.34	0.408
25	0.33	0.408
26	0.32	0.348 C
27	0.31	(in year 26)
28	0.305	
29	0.30 C	

C = Charge per established acre thereafter

Zealand. This excludes the costs of logging, and at clearfelling the direct costs of 3.0c have been added to the pulpwood stumpage in calculating results to a loaded-on-truck basis.

Sawlog Realisations

The value of the pruned butt log, being primarily a geometrical relationship, can be found from the grade results (Fenton *et al.,* 1971) for pruned logs; realisations are then the same as in the previous paper (Fenton, 1972a). Grade results directly applicable to the second and third logs are not available, although data for framing results (hitherto unpublished) can be extrapolated from the large-scale radiata pine grade study (Fenton, 1967). Summarised values per cu ft are given in Table 14.

TABLE 14—Summary of 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 cost Included	Excluded
Butt*	39	1.50	49.2229	49.8259
		1.99	45.9400	46.5430
Second	29			
Anticipated results		1.50	21.6814	22.2664
		1.99	18.4964	19.0814
Optimistic results		1.50	22.2167	22.4117
		1.99	19.0967	19.2917
Third	20			
1-in. sawing*†		1.99	17.6761	18.2161
2-in. sawing anticipated results		1.99	15.9249	16.1049

* From Fenton, 1972. † Grades from Fenton *et al.*, 1971

Social Returns

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

PROFIT CALCULATION: RESULTS

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 the earlier paper (Fenton and Tustin, 1972).

The land expectation value (LEV) equivalents, or the present net worth (PNW) per acre for major cost classes, and for rents, are given in Table 15. Returns and the net LEVs, the prices which could be paid for the land to break-even at the various interest rates with social items included are given in Table 16, and without social items in Table 17. Net LEV are graphed in Fig. 1.

TABLE 15—Land expectation values, summarised costs and social returns

LEV at interest percent:	3	4	5	6	7	8	9	10	11	12	13	14
FOREST 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	13.61	10.74	8.83	7.49	6.49	5.70	5.08	4.57	4.16	3.79	3.51	3.22
Tending	37.65	26.05	19.26	14.88	11.84	9.64	7.98	6.70	5.68	4.87	4.21	3.65
Total Direct	54.90	40.32	31.55	25.73	21.62	18.55	16.20	14.35	12.87	11.64	10.65	9.75
Protection												
Dothistroma	6.55	4.64	3.51	2.78	2.26	1.87	1.59	1.36	1.17	1.03	0.90	0.81
Fire	11.68	8.22	6.25	4.98	4.12	3.54	3.04	2.68	2.40	2.15	1.96	1.91
Total Protection	18.23	12.86	9.76	7.76	6.38	5.41	4.63	4.04	3.57	3.18	2.86	2.62
Administration												
Salaries and external overheads, etc.	53.51	38.24	29.35	23.64	19.63	16.74	14.54	12.85	11.49	10.38	9.46	8.69
Buildings, vehicles	13.22	9.72	7.69	6.40	5.54	4.88	4.42	4.05	3.76	3.52	3.34	3.14
Total Administration	66.73	47.96	37.04	30.04	25.17	21.62	18.96	16.90	15.25	13.90	12.80	11.83
Total Growing Costs	139.86	101.14	78.35	63.53	53.17	45.58	39.79	35.29	31.69	28.72	26.31	24.20
Logging												
Salaries and external overheads	7.84	4.13	2.34	1.39	0.85	0.53	0.34	0.21	0.14	0.10	0.06	0.05
Machinery	39.30	21.55	12.62	7.74	4.89	3.14	2.08	1.40	0.93	0.63	0.44	0.29
Extraction	69.01	35.87	19.94	11.61	6.97	4.26	2.68	1.73	1.10	0.73	0.48	0.31
Total Logging	116.15	61.55	34.90	20.74	12.71	7.93	5.10	3.34	2.17	1.46	0.98	0.65
Total Forest Costs	256.01	162.69	113.25	84.27	65.88	53.51	44.89	38.63	33.86	30.18	27.29	24.85
Social												
Roading	11.39	7.94	5.93	4.63	3.74	3.10	2.64	2.27	1.99	1.77	1.56	1.42
Accommodation	20.85	15.05	11.82	9.82	8.43	7.48	6.75	6.15	5.68	5.31	4.97	4.71
Total Social Costs	32.24	22.99	17.75	14.45	12.17	10.58	9.39	8.42	7.67	7.08	6.53	6.13
Social returns (rents)	5.41	3.57	2.57	1.96	1.55	1.27	1.05	0.90	0.78	0.68	0.60	0.54
Net Social Costs	26.83	19.42	15.18	12.49	10.62	9.31	8.34	7.52	6.89	6.40	5.93	5.59

TABLE 16—Returns and net LEV—including social items

Interest Rate %	Clearfellings Log Height Class Butt	Second	Third	Top*	Sub-Total	Thinnings	Total Log Return	Net LEV
3	375.63	123.03	69.17	40.74	608.57	28.10	636.67	353.83
4	197.98	64.84	36.46	21.47	320.75	17.62	338.37	156.26
5	111.68	36.58	20.57	12.11	180.94	11.81	192.75	64.32
6	65.84	21.56	12.12	7.14	106.66	8.26	114.92	18.16
7	40.05	13.12	7.33	4.34	64.89	5.95	70.84	–5.66
8	24.95	8.17	4.59	2.71	40.42	4.38	44.80	–18.02
9	15.84	5.19	2.92	1.72	25.67	3.28	28.95	–24.28
10	10.21	3.35	1.88	1.11	16.55	2.49	19.04	–27.11
11	6.67	2.19	1.23	0.72	10.81	1.92	12.73	Negative
12	4.40	1.44	0.81	0.48	7.13	1.49	8.62	Negative
13	2.94	0.96	0.54	0.32	4.76	1.17	5.93	Negative
14	1.98	0.65	0.36	0.21	3.20	0.92	4.12	Negative

* Including logging cost

TABLE 17—Returns and net LEV—excluding social items

Interest Rate %	Clearfellings Log Height Class Butt	Second	Third	Top	Sub-Total	Thinnings	Total Log Return	Net LEV
3	380.21	126.35	71.28	40.74	618.58	28.10	646.68	390.67
4	200.40	66.59	37.57	21.47	326.03	17.62	343.65	180.96
5	113.04	37.57	21.20	12.11	183.92	11.81	195.73	82.48
6	66.64	22.14	12.49	7.14	108.41	8.26	116.67	32.40
7	40.54	13.47	7.61	4.34	65.96	5.95	71.91	6.03
8	25.25	8.39	4.73	2.71	41.08	4.38	45.46	–8.05
9	16.03	5.33	3.01	1.72	26.09	3.28	29.37	–15.52
10	10.33	3.44	1.94	1.11	16.82	2.49	19.31	–19.32
11	6.75	2.25	1.27	0.72	10.99	1.92	12.91	Negative
12	4.45	1.48	0.83	0.48	7.24	1.49	8.73	Negative
13	2.98	0.99	0.56	0.32	4.85	1.17	6.02	Negative
14	2.00	0.68	0.37	0.21	3.26	0.92	4.18	Negative

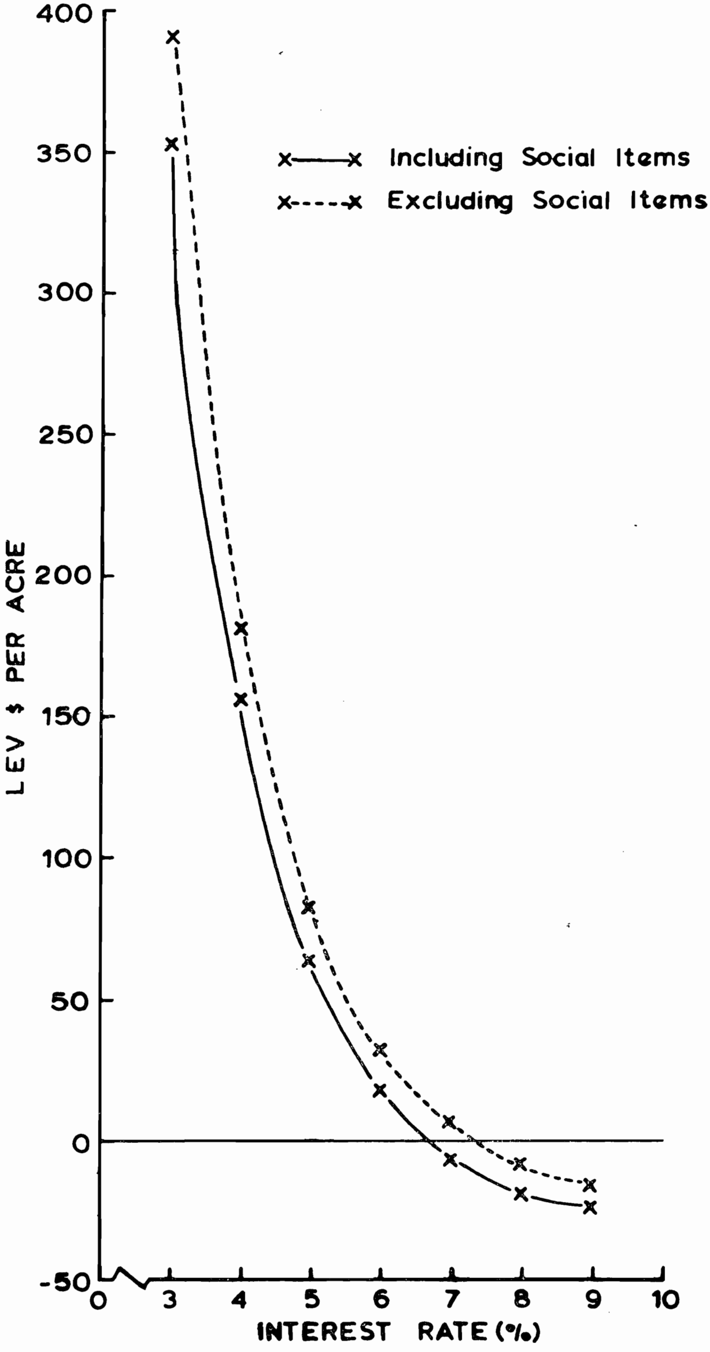

FIG 1—Net land expectation values

The internal rates of return (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 6 2/3% (6.7%)

(b) excluding social costs — nearly $7\frac{1}{2}$% (7.4%)

The break-even growing costs are given in Table 18; these are the forest cost of production per net unit of wood (viz. the volume which is finally extracted and loaded) at the interest rates of 3% to 14%.

The utility of "break-even growing costs" as a criterion decreases with both the increasing number of final log qualities, and the production of intermediate yields. The calculation here is for the cost of production of the final crop logs only, and excludes any consideration of the thinning yield. Hence, comparisons with results of other models need to be qualified.

The effect of a higher sawing cost ($1.99 per 100 bd ft) for butt and second logs is shown in Table 19. The "e" values of all indirect costs of administration and protection, with or without social costs, are given in Table 20. 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 relatively narrow from $3.52 at 3% to $2.88 at 14%, including social costs; this constancy is presumably due to the compensatory effects of different cost items through time. The values are naturally lower than those for shorter rotation (Fenton, 1972a). If afforestation follows a "normal" tempo, values decrease with rising interest rates.

The yields per acre by end products at rotation age are given in Table 21.

DISCUSSION

In comparison with the direct regime (Fenton, 1972a), the production thinning regime requires much the same total labour, the men required for production thinning being balanced by those required by the faster tempo of planting and clearfelling, and for second-log pruning.

The production thinning regime produces more pulpwood quality logs, although in the direct regime diversion of third logs from sawmilling to pulping is feasible. Arguments for production thinning have been partly based on the requirement of meeting a pulpwood commitment; this is an open ended commitment with no demonstration that full production costs are paid. The requirement can be met more cheaply by growing specific pulp crops on some areas and direct regime crops on the remainder.

For example, for each 100 000 acres (net), an annual pulp yield of 17 144 000 cu ft would result from the production-thinned regime (after allowing for loss of final crop area). To obtain this volume from a combination of the direct regime and an export log regime:

$$X + y = 100\,000 \quad \text{(Area)}$$
$$358X + 107.4y = 17\,144\,000 \quad \text{(Volume per year)}$$

where X = area of pulpwood crop, taken as an interim measure from an export log model (Fenton and Dick, 1972a), and y = area of direct regime (Fenton, 1972a). The second equation is in terms of mean annual production of pulpwood. The result

TABLE 18—Break-even growing costs (cents per cu ft)

Interest Rate %	LEV Equivalent of 1c per cu ft	Break-even Growing Cost Social costs Excluded	Included
3	24.006	5.825	7.169
4	12.653	7.992	9.810
5	7.137	10.976	13.465
6	4.208	15.097	18.531
7	2.560	20.769	25.523
8	1.595	28.576	35.210
9	1.012	39.318	48.596
10	0.653	54.042	66.937
11	0.426	74.389	92.394
12	0.282	101.843	126.950
13	0.188	139.946	174.680
14	0.126	192.063	240.714

TABLE 19—Returns and net LEV—sawing costs $1.99 for butt and second logs

Interest Rate %	Clearfellings Log Height Class Butt	Second	Third	Top*	Sub-Total	Thinnings	Total Log Return	Net LEV
3	350.58	113.16	69.17	40.74	573.65	28.10	601.75	318.91
4	184.77	59.64	36.46	21.47	302.34	17.62	319.96	137.85
5	104.23	33.65	20.57	12.11	170.56	11.81	182.37	53.94
6	61.45	19.83	12.12	7.14	100.54	8.26	108.80	12.04
7	37.38	12.07	7.38	4.34	61.17	5.95	67.12	–9.38
8	23.29	7.51	4.59	2.71	38.10	4.38	42.48	–20.34
9	14.78	4.77	2.92	1.72	24.19	3.28	27.47	–25.76
10	9.53	3.08	1.88	1.11	15.60	2.49	18.09	–28.06

* Including logging cost

TABLE 20—Value of "e" in the Faustmann formula

Interest Rate (%)	Social Costs Excluded ($)	Included ($)
3	2.55	3.52
4	2.43	3.35
5	2.34	3.23
6	2.27	3.13
7	2.21	3.06
8	2.16	3.01
9	2.12	2.97
10	2.09	2.94
11	2.07	2.91
12	2.05	2.90
13	2.04	2.88
14	2.02	2.88

TABLE 21—Yields per acre by end products

		Third log sawn mainly to:	
A. Sawntimber (bd ft)		Boards	Framing
100% Clear		7,444	7,444
Superior Factory		6,438	6,438
Ordinary Factory		1,835	1,003
Superior Dressing		2,213	2,213
Ordinary Dressing		1,082	712
	Sub-total	19,012	17,810
Merchantable		6,309	4,461
Box		9,052	8,498
I Framing		5,199	6,493
II Framing		4,301	6,611
	Total Sawntimber	43,873	43,873
B. Pulpwood (negligible heartwood) (cu ft)			
100% clear sawmill slabs		616	
Knotty sawmill slabs		910	
	Total slabs		1,526
Top logs (roundwood)		2,672	
Thinning logs (roundwood)		2,100	
			4,772
	Total pulpwood		6,298

is 25 554 net acres of pulpwood regime and 74 446 acres of the direct regime. The difference in PNW is formidable. At 7% interest, excluding social items and taking the lower sawing costs, the PNWs are:

(1) Total pulpwood regime cost
 25 554 × growing cost per acre of \$54.27

(2) Total pulpwood regime return, 3.0c stumpage
 25 554 × \$26.01

(3) Direct regime, net
 74 446 × \$117.42

Total PNW = (3) + (2) — (1) = \$8.741 million.

In contrast the production thinning regime would have a PNW of only \$0.6 million (and is negative at interest rates above 7%).

The results can be further improved by pulping and not sawing the direct-regime third logs. The net increase in pulpwood yield, after allowing for loss of sawlog slabs, would be 45.2 cu ft per acre, and results would be:

(4) Total pulpwood regime cost
 9181 × growing cost per acre, \$54.27

(5) Total pulpwood regime return, 3.0c stumpage
 9181 × \$26.01

(6) Direct regime, net
90 819 acres; third log return reduced from \$22.17 to \$7.30 (allowing for direct logging cost plus stumpage); to give \$102.55 per acre.
Total PNW = (6) + (5) — (4) = \$9.054 million
If the full area was in the direct regime the PNW would be
100 000 × 117.42 = \$11.742 million.

If the pulp and paper industry is profitable, it is difficult to see why it cannot pay the cost of production of its raw material—this question has been ignored for too long. However, by appropriate manipulation of the direct regime, in combination with a minimum area of pulpwood forest, a far less costly solution is found to meeting a pulpwood commitment than by attempting to obtain some pulpwood from production thinning.

Risks have been discussed in the previous paper (Fenton, 1972a). Discussion here is limited to comparisons of the direct and the production-thinning regimes.

Biological risks remain difficult to quantify. The 10-yr-longer rotation incurred by production thinning results in loss of three stems per acre if past mortality trends are applicable (R. N. James, pers. comm.) and this has been allowed in the volume projections. The relative susceptibility of selectively pruned trees in the production thinning regime to *Sirex* attack compared with the wholly butt- and second-log pruned crop in the direct regime has not been quantified, nor has the relative effect of *Dothistroma.*

Production thinning at 90 ft has not been followed by any marked death of crop trees, as far as is known. Chances of physical losses through wind are thought to be higher for the production thinning regime for two reasons. Firstly, the final crop is 25 ft taller, and is at risk for 10 yr longer than in the direct regime. Secondly, the sudden opening up of the stand from 193 s.p.a. to 80 s.p.a. at 90 ft incurs both the risk of fairly general wind throw for a short period—three of the compartments so thinned have been salvaged and clearfelled in the last decade; and also a certain attrition through spasmodic throw and/or break for the subsequent 5 yr. Figures on the latter are difficult to obtain as the stands one or more years after production thinning are so full of native shrub regrowth (as the sites are far from exploited by the tree crop) that access is prohibitively expensive.

Fire risk is greater in the production-thinned regime as:

(a) a number of only 0/8 ft, or unpruned (Fenton *et al.,* 1965) trees remain in the crop after the thinning to waste, and could serve to convert ground fires to crown fires;
(b) the heavy slash after thinning provides, for about a year, fuel which is absent in the direct regime;
(c) the rotation is 10 yr longer, and the stands would be at risk for this longer period.

Managerial risk is considerable for both regimes as the timing and execution of pruning is critical for efficient production of pruned logs—the high value component. However, once the crops trees are pruned, the managerial risk remains high in the production thinning regime for the following reasons:

(a) the pruning is selective, and the pruned final crop element has to compete with a number of less-pruned trees;
(b) the production thinning then has to be attempted—this is to date, the greatest

risk in the production thinning regime—though working plan after working plan has duly prescribed this operation, e.g. as quoted in Penistan, 1960; Fenton and Familton, 1961; Brown, 1962; Bunn, 1963; Tustin and Bunn, 1970. Management must face the fact that these thinnings are not being done. The situation is not markedly different from that outlined by Spiers (1964): ". . . we have hardly approached the first thinning of *P. radiata* at all. Nearly all thinning in this species has been carried out at what would normally be second thinning stage, i.e. 25 years plus. However, many predictions of production in New Zealand are based on nearly complete utilisation of first commercial thinnings at about 15 years. What do we do then about extracting logs of very small piece size for pulpwood and round material, particularly if the stumpage of the latter drops—(quite a possibility)? All these stands have dense slash and small piece size and to date, except on easy country, it has been impractical to extract them at all except in those districts where fencing material stumpages have been particularly favourable." The net result is a gradually accumulating area of stands, containing upwards of 70 0/18 ft pruned stems per acre which are now losing value increment at increasing rates. The markets and/or the technical ability to execute production thinnings have been lacking. The evidence of the last 15-20 yr shows this risk is formidable, and it is contended that it has been insufficiently faced.

(c) The production thinning itself, if carried out, then has to attain the prescription. This has been achieved in the last 4 yr in some compartments, in contrast to earlier results (Fenton *et al.,* 1965). The risks are, loss of some of the pruned trees, a reduction in stocking below that prescribed, and physical damage to the final crop trees.

A further management risk is the necessity to clearfell either earlier or later than prescribed. If felling is earlier than prescribed the greater diameter of the direct regime trees, at all ages after 10, would result in lower utilisation (felling and sawmilling) costs. If the final stocking has to remain standing after the prescribed age, the value increment on the direct regime is superior as the second log is pruned.

The marketing risks are inevitably increased with a longer rotation. The framing grade potential of the second and third logs of the production thinning regime is problematical, and remains undemonstrated. In contrast, grade study results (Fenton *et al.,* 1971; Fenton, 1972c) are one of the corner stones of the direct regime, and it has been demonstrated (Fenton, 1971) that if framing is required, it can be obtained by finger jointing.

The general quality of sawn timber produced from the direct regime is, in any case, markedly superior to that produced from the production thinning regime.

Finally, about half the land being planted is too steep for production thinning except at unduly high cost. The direct regime can be applied to these areas, but production thinning regimes are improbable on current evidence.

CONCLUSIONS

The production thinning regime is fundamentally inefficient as it reduces the basal area of the valuable final crop element at 90 ft, against the 35 ft of the direct regime.

The adoption of production thinning results in a regime which is much less profitable than one eliminating this operation. It produces lower quality wood and delays returns for a decade, at greater risk.

Pulpwood, if required, is cheaper to produce by straight pulpwood crops grown in combination with the direct regime.

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