PROFITABILITY OF "NORMAL" AFFORESTATION FOR THE OVERSEAS LOG TRADE ON SITE INDEXES 95 AND 110

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ABSTRACT

The economics of radiata pine afforestation for the export log trade are evaluated for scrub-covered country of easy topography of site indexes 95 and 110, using normal management steps. Net yields are of 8235 cu ft per acre at the end of the 23- and 20-yr rotations on the two site indexes. Silviculture aims at producing two 39-ft logs to a 6 in. s.e.d. by planting at 10 × 7 ft, thinning (probably to waste) to 150 s.p.a. at 35-ft top height and clearfelling at 110 ft.

Profitability of normal compared with accelerated tempos of afforestation is lower in terms of land expectation values at the interest rates of 3% to 14% evaluated; and internal rates of return were correspondingly reduced from 11.1% to 10.2% on site index 95 and from 13.2% to 12% on site index 110. Cost of production per cu ft and return/cost ratios were slightly better for normal afforestation at interest rates of 6% and under, but were increasingly poor at higher interest rates.

The advantages of evaluating a normal as against an accelerated pattern of management are ease of analysis, and stricter comparability between different models. The disadvantage is the inapplicability of results if afforestation is accelerated.

The limitation of determining the annual charge in the Faustmann formula is overcome by the budget method, but this charge can never be constant, hence the Faustmann formula can only give approximate answers in theory, as well as practice. The cost of annual charges rises as interest rates decrease; values at 7% interest, in dollars per acre are:

	S.I. 95	S.I. 110
Excluding social costs	2.53	2.57
Including social costs	3.68	3.84

The implications for national planning are that concentration of planting in predominantly one area at a time and on the best site index would be more profitable, especially at high interest rates.

INTRODUCTION

Profitability studies on the overseas log trade have been completed for three site indexes (Lewis, 1954); these evaluated rapid rates of initial afforestation (Fenton and Tustin, 1972; Fenton and Dick, 1972a; 1972b). The profitability of accelerated planting (and consequent heavier, early yields) was known to be higher than for the normal pattern of forest development evaluated in this paper for two site indexes. However,

experience has shown that evaluation of normal patterns of management facilitates comparisons of profits from alternative silvicultural schedules. A "normal" rate of forest management is one in which an equal area, found by dividing the total forest area by the rotation, is treated annually. On site indexes of 95 and 110, the rotations necessary to meet the technical requirements of the log trade are 23 and 20 yr respectively.

The limitations in the models are that they are nominative; forests are not generally managed on this basis. The primary aim of the studies is to produce standards for comparison with other afforestation models. Only radiata pine (*Pinus radiata* D. Don) is considered.

ASSUMED CHARACTERISTICS OF THE AREA

The area initially evaluated has been described (Fenton and Grainger, 1965). It is assumed that 20 800 out of 25 000 acres gross are planted; initial cover is largely inflammable scrub; topography is easy to rolling; and the port is 89 miles by road from the centre of the forest.

TECHNICAL SPECIFICATIONS, SILVICULTURE AND MANAGEMENT

The minimum log small end diameter under bark (s.e.d.) required is 6 in.; the minimum ratios of volume by log length are 60% : 39 ft; 35% : 26 ft; 5% or less of 13 and 20 ft. Logs should be reasonably straight. (The tolerance of 5% volume down to a 5.5 in. s.e.d. has been ignored). The mean tree yields two 39-ft lengths to a 6 in. s.e.d. at clear felling.

Silviculture is:

(1) Planting sites are cleared and burnt before establishment.

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

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

(4) Release cutting: site index 95: one operation in the year after planting; on steeper sites which comprise 2200 acres net a further operation is prescribed in the second year after planting. A second operation has also been costed in year 2, as the sites would have been burnt only once.

On site index 110 one operation is prescribed in each of the first and second years after planting.

(Blanking and release-cutting operations can only be nominal in these studies, as they depend on local circumstances).

(5) Thinning (to waste): at 35-ft top height to 150 s.p.a.

(6) For *Dothistroma pini* needle blight protection, stands would be aerially inspected each year with closer ground inspection of suspect areas; planted stands would be sprayed when 8-10 ft, and 18-25 ft high. It is possible a

third spray would be required after thinning at 35 ft. Regenerated stands would have an extra spray when trees are 3-4 ft high.

(7) Clearfelling: at normality at 110-ft top height.

(8) 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 spraying against *Dothistroma* and slasher-thinning cum release-cutting at age 2. Sown and regenerated stands are not blanked. Treatment of stands of all origins is the same from about 5 ft in height onwards.

(9) It has been assumed on the lower site index 95 that 1600 acres net are of frost flats, and *Pinus contorta* planted at 20 × 7 ft spacing would form an initial shelterwood; this would be poisoned at about age 11 and radiata pine planted in the gaps between the rows. Further rotations could be re-established on old frost flats without undue trouble; as subsequent rotations begin at least 45 yr after the year of origin of the forest, the financial effect of frost flat re-establishment will be slight.

Areas of each operation are given in Table 1. Yield predictions (by Mr W. R. J. Sutton) are given elsewhere (Fenton and Tustin, 1972). The net volume logged is 8235 cu ft per acre, giving annual yields of 7 444 440 cu ft on site index 95, and 8 564 400 cu ft on site index 110.

LABOUR REQUIREMENTS; DIRECT COSTS

The labour content and costs of operations are given in Table 2. The full details on which these direct and all other costs are based are given in Fenton and Tustin, 1972. Direct costs comprise wages and production bonus; compensation and holiday pay; direct stores charges; and transport and machinery hire. Supervision and indirect costs are charged separately. The land preparation needed is scheduled in Table 3, and corresponds with that for the accelerated planting models (Fenton and Tustin, 1972). The major clearing operations have not been scheduled on "normal" bases, as even on "normal" forests it would be desirable to clear much of the gross area as early as possible and convert it to easily-burnable (and hence cleared) scrub. The costs of controlling small annual burns would be disproportionately high.

Total direct labour needs by years are in Table 4; total supervisory staff, and indirect labour are scheduled in Table 5; total manpower required is summarised in Table 6.

The logging equipment needed, and its costs, are listed in Table 7 (based on Appendix 4 of Fenton and Tustin, 1972).

PROTECTION

This comprises fire and *Dothistroma pini* (needle blight) prevention and control; and some minor items. Fire prevention costs are summarised in Table 8 and *Dothistroma* costs in Table 9.

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

Year	Planting						Sowing		Blanking		Release Cutting				Slasher Thinning		Thinning to Waste		Poison Overwood	Clearfelling	
	Machine			Hand							One		Two								
S.I.:	95	110		95	110		95	110	95	110	95	110	95	110	95	110	95	110	95	95	110
1	904	1,040																			
2	904	1,040							904	1,040	904	1,040									
3	904	1,040							904	1,040	904	1,040	904	1,040							
4	904	1,040							904	1,040	904	1,040		1,040							
5	904	1,040							904	1,040	904	1,040		1,040							
6	904	1,040							904	1,040	904	1,040		1,040							
7	904	1,040							904	1,040	904	1,040		1,040				1,040P			
8	904	1,040							904	1,040	904	1,040		1,040							
9	904	1,040							904	1,040	904	1,040		1,040			904P				
10,11	904	1,040							904	1,040	904	1,040		1,040							
12	56	160		848	880				904	1,040	904	1,040		1,040							
	800*																				
13	800*			904	1,040				904	1,040	904	1,040		1,040							
14-17				904	1,040				904	1,040	904	1,040		1,040							
18				904	1,040				904	1,040	904	1,040		1,040							
19				904	1,040				904	1,040	904	1,040		1,040							
20				904	1,040				904	1,040	904	1,040		1,040							
21				904	346P			346P	904	1,040	904	1,040		1,040					696		1,040P
22	696			208					904	346P	904	346P		1,040					904		
23	904								904		904			346P		693P					
24				301P			301P		904		904									904P	
25									301P		301P		904+		603P						
26													904+								
27													392+								

P = Operations carried out in perpetuity

* = Planting P. contorta on frost-flats

\+ = Periodic, repeated in every rotation

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	4.00	Contractor
Heavy scrub	6 + 17	Contractor
Bush-felling	32 + 16	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
Thinning to waste	22.20	1.5
Slasher thinning regeneration	6.50	0.67
Poison overwood	7.50	0.67
Clearfelling	294.00	14.70

TABLE 3—Land preparation

Site Index	Year	Operation	Area acres	Rate per acre $
95, 110	1	Cut heavy scrub	1,500	17.00
		Crush heavy scrub	1,500	6.00
		Crush light scrub	6,000	4.00
		Overall burn	24,000	0.06
110	4	Overall burn	14,000	0.50
95		Overall burn	17,000	0.50
95, 110	5-10	Annual burns	2,000 p.a.	0.50
110	6	Felling bush	500	32.00
110	7	Burning felled bush	500	1.00
95	8	Felling bush	500	32.00
95	9	Burning felled bush	500	1.00
110	9	Bulldozing bush slash	500	16.00
95	11	Bulldozing bush slash	500	16.00

TABLE 4—Direct labour requirements, forest growing and tending

Year	Planting				Blanking		Release Cutting				Thinning Slasher		Thinning to Waste		Poison Overwood	Clear Felling		Totals years	
	Machine		Hand				1st		2nd										
S.I.:	95	110	95	110	95	110	95	110	95	110	95	110	95	110	95	95	110	95	110
1	140	161																1	1
2	140	161			271	312	606	697										4	5
3	140	161			271	312	606	697	606	697								6	8
4–6	140	161			271	312	606	697		697								4	8
7	140	161			271	312	606	697		697				1,540P				4	15
8	140	161			271	312	606	697		697								4	15
9	140	161			271	312	606	697		697			1,356P					10	15
10,11	140	161			271	312	606	697		697								10	15
12	133	25	526	546	271	312	606	697		697								12	16
13	124		560	645	271	312	606	697		697								12	17
14–17			560	645	271	312	606	697		697								12	17
18			560	645	271	312	606	697		697								12	17
19			560	645	271	312	606	697		697								12	17
20			560	645	271	312	606	697		697								12	15
21			560	215P	271	312	606	697		697					47		15,290P	12	79
22	109		129		271	104P	606	232P		697					61			11	76
23	140				271		606			232P		464P						10	76P
24			187P		271		606									13,300P		66	
25					90P		202P		606*									64	
26									606*		202P							65P	
27									263*										

P = Operations carried out in perpetuity

* = Periodic, each rotation, excluded from totals

TABLE 5—Staff and indirect labour schedule (in perpetuity from the years given)

STAFF	S.I. 95:	Year 1	2	3-8	9-22	23	24	TOTAL
	S.I. 110:	1	2	3-6	7-19	20	21	
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
Ranger/Foreman							2	2
Clerk							1	1
Roading								
Officer in charge		1						1
OTHER LABOUR								
Roading								
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
H.Q. gang				1			2	3
Tool maintenance		1						1

TABLE 6—Total manpower

Year	Forest*		Staff and Indirect†		Total	
S.I.:	95	110	95	110	95	110
1	1	1	10	10	11	11
2	4	5	12	12	16	17
3	6	8	15	15	21	23
4-6	4	8	15	15	19	23
7-8	4	15	15	16	19	31
9-11	10	15	16	16	26	31
12	12	16	16	16	28	32
13-19	12	17	16	16	28	33
20	12	17	16	18	28	35
21	12	79	16	32P	28	111
22	11	76P	16		27	108P
23	10		19		29	
24	66		32P		98	
25	64				96	
26	65P				97P	

P = in perpetuity
* = From Table 4
† = From Table 5

TABLE 7—Logging equipment

Year	No.	Item	Unit Cost $
	A. Site Index 110		
20	1	D7 tractor	53,000
	2	Tip trucks	4,500
	1	Trekka truck	1,770
21	1	D7 tractor	53,000
	10	D6 tractors	35,000
	9	Arches	5,000
	5	Loaders	35,000
	4	Gang trucks	5,000
	40	Power saws	150
	2	Field service units	,5,000
		Miscellaneous equipment	4,600
		Stores (purchase)	5,000
	B. Site Index 95		
23	1	D7 tractor	as above
	2	Tip trucks	
	1	Trekka truck	
24	1	D7 tractor	
	9	D6 tractors	
	8	Arches	
	4	Loaders	
	4	Gang trucks	
	36	Power saws	
	2	Field service units	
		Miscellaneous equipment	
		Stores (purchase)	

TABLE 8—Fire protection costs

Item	Year	Cost
Firebreaks — preparation S.I. 95	1-23	$170 p.a.
Firebreaks — preparation S.I. 110	1-20	$195 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
Fire store — capital	5	$4,400
— depreciation		65 yr life
Annual charges		
$0.81 per ac up to 7,500 ac		
$0.53 per ac from 7,500 to 13,000 ac		
$0.46 per ac above 13,000 ac		

TABLE 9—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 (say)*

* The range of costs is for large-scale operations over 15,000 ac areas; the mean is very close to $3

Fire annual costs include stand-by and routine patrols, lookout wages, break maintenance, building maintenance, and operation and maintenance of equipment; these are roughly proportional to the area planted.

For *Dothistroma* protection, crops are sprayed two to three times by age 14; regenerated crops receive an extra spray at height 5 ft, spraying frequency depending on aerial and ground assessments.

SOCIAL COSTS

These comprise roading, accommodation and minor items. Table 10 shows the items charged in roading (and minor items). The schedule of housing and other accommodation is given in Table 11; it has been assumed that 10 men can be recruited locally and they have not been housed on the forest. The final number of houses has been taken as 41 on site index 95 and 43 on site index 110 to maintain comparability with the studies of accelerated planting (Fenton and Tustin, 1972; Fenton and Dick, 1972a). The costs of running the camp have been taken as $122 per man per year. Houses cost $8400 each, have a 65 yr life, and incur a 1¼% annual charge for repairs and maintenance. Huts cost $700 each. The Services components (and miscellaneous items) of social costs are listed in Table 12.

TABLE 10—Social costs: Roading

				Year
Road formation	S.I. 95	$4,591 p.a.		1-23
	S.I. 110	$5,280 p.a.		1-20
Road metalling	S.I. 95	$4,174 p.a.		23-45
	S.I. 110	$4,800 p.a.		20-39
Road maintenance	$0.30 per acre of established forest			
Equipment	S.I. 95	Tip truck (½)	$2,250	1*
		Grader	$20,000	12
		10-cwt truck	$2,000	12
		Tip truck (½)	$2,250	23*
	S.I. 110	Tip truck (½)	$2,250	1*
		Grader	$20,000	10
		10-cwt truck	$2,000	10
		Tip truck	$2,250	20*

* The other half is charged to forest administration

TABLE 11—Accommodation requirements

Year	Houses S.I.: New 95	Total 95	New 110	Total 110	Camp	
1	1	1	1	1		
2	5	6	6	7		
3	4	10	5	12		
7	—	10	8	20		
9	5	15				
12	2	17	1	21		
13	—	17	1	22		
20			21	43	Site Index 110	
21					57 huts	
					Cookhouse	$27,700
					Caterer's house	$6,700
					Ablution block	$8,900
23	1	18			Site Index 95	
24	23	41			47 huts	
					Cookhouse	$27,700
					Caterer's house	$6,700
					Ablution block	$8,900
26					1 hut	

TABLE 12—Social costs: Services

Year	Water Supply* $	Site Preparation† $	Services N.E.I. S.I. 95 $	S.I. 110 $	Share of Services‡ S.I. 95 $ per acre	S.I. 110 $ per acre
1	2,500	1,000	683	785	0.22	0.213
2	2,500	—	683	785	0.20	0.195
3	1,100	1,200	683	785	0.19	0.178
4			683	785	0.18	0.165
5			683	785	0.155	0.150
6			683	785	0.14	0.135
7			683	785	0.13	0.123
8			683	785	0.12	0.111
9			683	785	0.11	0.10
10			683	785	0.105	0.092
11			683	785	0.10	0.083
12			683	785	0.09	0.075
13			683	785	0.085	0.071
14			683	785	0.08	0.068
15			683	785	0.07	0.063
16			683	785	0.07	0.063
17			683	785	0.065	0.06
18			683	785	0.06	0.06
19			683	785	0.06	0.06
20			683	785	0.06	0.06
21			683		0.06	0.06
22			683		0.06	0.06
23			683		0.06P	0.06P

N.E.I. = not elsewhere indicated
* These amounts are half the total cost; equal sums are allotted to "capital works"—Table 14. They apply to both site indexes
† These apply to both site indexes
‡ These amounts are half of the "Services" component of the repairs and maintenance charge — Table 16

INDIRECT COSTS

Staff salaries are given in Table 13; external overheads have been taken as 60% of these amounts. Forest building programmes are given in Table 14; vehicles and stores are listed in Table 15. Net "services and general" costs, and "General Administration" costs have been charged on a per acre basis, and are included in Table 16.

Depreciation is charged by allowing the cost of the asset concerned at the end of its service life. The service lives are given in Table 17.

TABLE 13—Salaries ($ per year)

Year	1	2	3–6	7–8	9–12	13–22	23	24+
Site Index 95								
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	2,690	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	13,070	13,940	16,510	17,020	17,260	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
Site Index 110								
C. 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	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	2,690	2,690
Clerk		2,230	2,230	2,450	2,450	2,450	2,450	2,690
Stores clerk								2,450
Total C		7,890	12,710	13,180	16,510	17,020	17,140	22,200
D. Logging Staff								
Officer in charge							3,410	3,410
Foreman								2,360
Ranger								2,690
Clerk								2,230
Total D							3,410	10,690

TABLE 14—Capital works

Year	Site Index	Item	Cost $
1	95 & 110	Office and store	7,750
		Petrol store	3,300
		Telephone	1,225*
		Water supply	2,500†
2	95 & 110	Garage/workshop	16,000
		Water supply	2,500†
3	95 & 110	Water supply	1,100†
21	110	Office extension	7,750
		Garage extension	16,000
23	95	Office extension	7,750
		Garage extension	16,000

* = An equal amount is charged to Protection
† = An equal amount is charged to Social Costs

TABLE 15—Miscellaneous vehicles and equipment

Year	Site Index	No.	Item	Amount $	Charged to
1	95 & 110	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
	95		Consumable stores	500 p.a. for 20 yrs	
	95		Class 'A' stores	680 p.a. for 20 yrs	
	110		Consumable stores	575 p.a. for 20 yrs	
	110		Class 'A' stores	730 p.a. for 20 yrs	
3	95 & 110	1	Office car*	2,500	Forest
7	110	1	10-cwt truck*	2,000	Forest
	110	1	Gang truck	5,000	Forest
9	95	1	10-cwt truck*	2,000	Forest
	95	1	Gang truck	5,000	Forest
10	110	1	10-cwt truck*	2,000	Roading
	110	1	Grader	20,000	Roading
12	95	1	10-cwt truck*	2,000	Roading
	95	1	Grader	20,000	Roading
20	110	1	Tip truck	4,500	Forest — half Roading — half
	110		Miscellaneous plant and equipment	4,600	Forest
	110	3	10-cwt trucks*	2,000 each	Forest — half
23	95	1	Tip truck	4,500	Forest — half Roading — half
	95		Miscellaneous plant and equipment	4,600	Forest
	95	3	10-cwt trucks*	2,000 each	Forest

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

TABLE 16—Services and general assets: repairs and maintenance; and administration costs

Year	Total S and G Charge (per acre $)		General Administration (costs per acre $)	
S.I.:	95	110	95	110
1	1.09	1.063	1.152	1.152
2	1.03	0.975	1.152	1.152
3	1.00	0.888	1.152	1.152
4	0.90	0.825	1.152	0.576
5	0.75	0.75	0.576	0.576
6	0.70	0.675	0.576	0.576
7	0.66	0.613	0.576	0.576
8	0.61	0.55	0.576	0.408
9	0.56	0.50	0.576	0.408
10	0.50	0.462	0.576	0.408
11	0.48	0.413	0.576	0.408
12	0.46	0.375	0.408	0.408
13	0.42	0.351	0.408	0.348C
14	0.39	0.338	0.408	
15	0.35	0.325	0.408	
16	0.32	0.313	0.408	
17	0.31	0.301	0.348C	
18	0.31	0.30C		
19	0.30C			

C = charge per established acre thereafter

TABLE 17—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 — half Protection — half	—	Depreciation covered in Services and General charge
Fire lookout; store	Protection	65	
Fire engine; tanker	Protection	10	
Pumps; radio	Protection	10	
10-cwt trucks; car; Trekka trucks	Forest vehicles and equipment	10	Trekka to logging; one 10-cwt 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	
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	

RETURNS

Returns are based on the export free-on-board price at port of $4.25 per 100 "Japanese Haakon Dahl" unit. Log cartage costs for a 178-mile round trip are 8.7c per cu ft. Export costs and returns are given in Table 18, and give the price loaded-on-truck at the forest of 20.8c per cu ft.

House rents of $3 per week for 50 weeks a year, and hut rents of $0.10 per week for 45 weeks a year comprise social returns.

TABLE 18—Log export costs, returns and price-on-truck

Cartage to Port (178 miles return)	96.6	cents per 100 JHD
Wharfage and storage	19.2	
Marshalling	23.5	
Stevedoring	53.5	
Inspection	1.25	
	194.116	cents per 100 JHD
Sale price FOB	425	cents per 100 JHD
Margin for price on truck	230.88	cents per 100 JHD
=	20.8	cents per cu ft

JHD = Japanese Haakon Dahl

FOB = Free on board

PROFIT CALCULATION; RESULTS

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

The land expectation value (LEV) equivalents, that is the discounted present net worth per acre, for each cost constituent have been calculated. They are summarised, with the returns and net LEV in Table 19 for site index 95 and Table 20 for site index 110.

The net LEV with and without social costs are graphed in Fig. 1, with the LEV results (including social costs) for more rapid afforestation evaluated earlier (Fenton and Tustin, 1972; Fenton and Dick, 1972a). The break-even growing costs per cubic foot are given in Table 21 and graphed in Fig. 2. The internal rates of return are given in Table 22.

DISCUSSION OF RESULTS

Comparative Profitability between Normal and Accelerated Programmes

Only one accelerated schedule has been evaluated for each site index, based on initial afforestation in a little under half the rotations (Fenton and Tustin, 1972; Fenton and Dick, 1972a); clearfelling, beginning on any scale, in 16- and 19-yr-old stands. These

TABLE 19—Land expectation values: Site Index 95

	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	18.69	14.75	12.23	10.47	9.13	8.11	7.29	6.60	6.03	5.54	5.12	4.76
Tending	23.53	16.03	11.67	8.88	6.97	5.58	4.55	3.77	3.15	2.66	2.27	1.95
Total Direct	45.86	34.31	27.36	22.71	19.39	16.90	14.98	13.45	12.21	11.18	10.32	9.59
Protection												
Dothistroma	10.15	7.24	5.52	4.39	3.59	3.00	2.55	2.21	1.91	1.68	1.48	1.32
Fire	13.00	9.34	7.21	5.82	4.85	4.16	3.63	3.19	2.88	2.61	2.38	2.19
Total Protection	23.15	16.58	12.73	10.21	8.44	7.16	6.18	5.40	4.79	4.29	3.86	3.51
Administration												
Salaries and external overheads	54.63	39.26	30.29	24.49	20.44	17.49	15.26	13.49	12.10	10.95	9.99	9.19
Buildings and stores	3.58	2.92	2.50	2.23	2.03	1.89	1.76	1.67	1.60	1.53	1.47	1.41
Vehicles	10.74	7.65	5.91	4.76	3.97	3.38	2.98	2.68	2.40	2.19	2.01	1.87
Total Administration	68.95	49.83	38.70	31.48	26.44	22.76	20.00	17.84	16.10	14.67	13.47	12.47
Total Growing Costs	137.96	100.72	78.79	64.40	54.27	46.82	41.16	36.69	33.10	30.14	27.65	25.57
Logging												
Salaries and external overheads	11.80	6.90	4.42	2.96	2.03	1.44	1.04	0.75	0.56	0.42	0.30	0.24
Machinery	72.05	44.73	29.67	20.52	14.62	10.66	7.91	5.94	4.52	3.45	2.67	2.09
Extraction	171.53	101.48	64.20	42.38	28.84	20.09	14.24	10.26	7.47	5.47	4.07	3.05
Total Logging	255.38	153.11	98.29	65.86	45.49	32.19	23.19	16.95	12.55	9.34	7.04	5.38
Total Forest Costs	393.34	253.83	177.08	130.26	99.76	79.01	64.35	53.64	45.65	39.48	34.69	30.95
Social												
Roading	13.91	10.24	7.99	6.47	5.38	4.55	3.90	3.43	3.04	2.71	2.44	2.20
Accommodation	23.48	17.26	13.60	11.25	9.61	8.37	7.46	6.74	6.15	5.70	5.31	4.98
Total Social Costs	37.39	27.50	21.59	17.72	14.99	12.92	11.36	10.17	9.19	8.41	7.75	7.18
Total Costs	430.73	281.33	198.67	147.98	114.75	91.93	75.71	63.81	54.84	47.89	42.44	38.13
RETURNS												
Logs	1,030.65	615.93	393.47	262.38	180.34	126.79	90.74	65.88	48.40	35.93	26.91	20.31
Rent (social)	5.48	3.63	2.60	1.97	1.53	1.24	1.02	0.86	0.74	0.64	0.56	0.50
NET VALUES												
Excluding Social Items	637.31	362.10	216.39	132.12	80.58	47.78	26.39	12.24	2.75	-3.55	-7.78	-10.64
Including Social Items	605.40	338.23	197.40	116.37	67.12	36.10	16.05	2.93	-5.70	-11.32	-14.97	-17.32

accelerated schedules were adopted as they approximated to the likely pattern of national afforestation, on present-day plans. It is desirable to have increased production in the year 1980-95 (Forestry Committee, 1969). Naturally a large number of alternative time sequences could be evaluated.

Summarised comparative results of the normal and accelerated programmes are given in Tables 21 to 23. The LEV (at interest rates of from 3% to 14%) show greater values for the accelerated programmes, and the internal rates of return (IRR) are 1% or more higher. Comparison of the break-even growing costs and return/cost ratios, however, show slightly greater costs for the accelerated planting at interest rates up to 6%. This reflects that while net costs of production per cu ft are slightly (at most 4%) lower for normal than for accelerated afforestation, the greater volumes produced by accelerated planting give higher LEV and IRR. At interest rates from 7% to 14%

TABLE 20—Land expectation values: Site Index 110

	LEV at interest rate %											
	3	4	5	6	7	8	9	10	11	12	13	14
	$ per acre											
COSTS												
Direct												
Land clearing	3.59	3.52	3.44	3.35	3.31	3.23	3.17	3.11	3.07	3.01	2.97	2.92
Establishment	25.15	19.90	16.54	14.17	12.41	10.99	9.87	8.94	8.16	7.48	6.90	6.40
Tending	28.49	19.75	14.65	11.34	9.05	7.39	6.15	5.17	4.41	3.80	3.29	2.88
Total Direct	57.23	43.17	34.63	28.86	24.77	21.61	19.19	17.22	15.64	14.29	13.16	12.20
Protection												
Dothistroma	11.91	8.59	6.59	5.28	4.37	3.68	3.15	2.73	2.39	2.12	1.88	1.69
Fire	11.31	9.62	7.46	6.05	5.06	4.35	3.80	3.34	3.02	2.73	2.49	2.30
Total Protection	25.22	18.21	14.05	11.33	9.43	8.03	6.95	6.07	5.41	4.85	4.37	3.99
Administration												
Salaries and external overheads	55.66	40.13	31.05	25.14	21.01	17.99	15.71	13.88	12.44	11.26	10.28	9.45
Buildings and stores	3.71	3.04	2.60	2.34	2.13	1.97	1.85	1.75	1.66	1.58	1.52	1.46
Vehicles	11.04	7.93	6.14	4.96	4.16	3.56	3.12	2.79	2.51	2.29	2.08	1.91
Total Administration	70.41	51.10	39.79	32.44	27.30	23.52	20.68	18.42	16.61	15.13	13.88	12.82
Total Growing Costs	152.86	112.48	88.47	72.63	61.50	53.16	46.82	41.71	47.66	34.27	31.41	29.01
Logging												
Salaries and external overheads	12.56	7.76	5.12	3.52	2.50	1.81	1.34	1.01	0.75	0.58	0.45	0.35
Machinery	87.06	55.65	37.99	27.03	19.83	14.85	11.32	8.76	6.82	5.39	4.28	3.43
Extraction	215.84	131.51	85.65	58.19	40.77	29.22	21.31	15.76	11.79	8.92	6.80	5.22
Total Logging	315.46	194.92	128.76	88.74	63.10	45.88	33.97	25.53	19.36	14.89	11.53	9.00
Social												
Roading	14.61	10.90	8.58	7.03	5.93	5.06	4.37	3.85	3.43	3.07	2.79	2.53
Accommodation	27.82	20.85	16.76	14.05	12.16	10.75	9.66	8.76	8.06	7.49	6.96	6.56
Total Social Costs	42.43	31.75	25.34	21.08	18.09	15.81	14.03	12.61	11.49	10.56	9.75	9.09
Total Costs	510.75	339.15	242.57	182.45	142.69	114.85	94.82	79.85	68.51	59.72	52.69	47.10
RETURNS												
Logs	1,295.65	797.06	524.01	359.51	254.15	183.74	135.18	100.87	76.16	58.07	44.66	34.61
Rent (social)	6.47	4.42	3.26	2.51	2.01	1.65	1.38	1.18	1.02	0.90	0.80	0.71
NET VALUES												
Excluding Social Items	827.33	489.66	306.78	198.14	129.55	84.70	54.39	33.63	19.14	8.91	1.72	-3.40
Including Social Items	791.37	462.33	284.70	179.57	113.47	70.54	41.74	22.20	8.67	-0.75	-7.23	-11.78

the break-even costs of normal afforestation are higher and increase more rapidly for normal than for accelerated planting.

The results show differences in ranking with different criteria in contrast to the uniform ranking given by the criteria LEV; IRR; cost of production per cu ft; and return/cost ratios in comparing results from different site indexes (Fenton and Dick, 1972c). The cost of production per cu ft is itself a type of return/cost ratio as it expresses the return per cu ft required to give a ratio of 1 : 1 for any given interest rate. Only growing costs—excluding logging—are involved, whereas logging costs are included in evaluating return/cost ratios for the overall project. The advantages of normal over accelerated afforestation given by the two criteria of cost of production,

TABLE 21—Break-even growing costs (c per cu ft)

Interest Rate %	S.I.: Regime:	Including Social Costs 95 N	95 A*	110 N	110 A†	Excluding Social Costs 95 N	95 A*	110 N	110 A†
3		3.54	3.69	3.14	3.28	2.78	2.86	2.45	2.55
4		4.33	4.47	3.76	3.91	3.40	3.43	2.94	3.02
5		5.31	5.38	4.52	4.62	4.17	4.10	3.51	3.54
6		6.51	6.45	5.42	5.44	5.11	4.87	4.20	4.13
7		7.99	7.69	6.51	6.36	6.26	5.76	5.03	4.80
8		9.80	9.20	7.81	7.42	7.68	6.86	6.02	5.55
9		12.04	10.96	9.36	8.62	9.44	8.12	7.20	6.41
10		14.80	13.01	11.20	9.97	11.59	9.59	8.60	7.37
11		18.17	15.45	13.42	11.53	14.22	11.33	10.29	8.48
12		22.32	18.31	16.06	13.29	17.45	13.36	12.27	9.71
13		27.38	21.67	19.17	15.30	21.38	15.76	14.63	11.12
14		33.56	25.66	22.90	17.55	26.20	18.58	17.43	12.70

N = Normal rate of initial establishment

A = Accelerated rate of initial establishment

* = Fenton and Tustin, 1972

† = Fenton and Dick, 1972a

TABLE 22—Comparative land expectation values and internal rates of return

Interest Rate %	S.I.: Regime:	Including Social Items 95 N	95 A*	110 N	110 A†	Excluding Social Items 95 N	95 A*	110 N	110 A†
		Land expectation values $ per acre							
3		605	661	791	832	637	700	827	873
4		338	388	462	504	362	419	490	537
5		197	240	285	324	216	266	307	352
6		116	151	180	215	132	174	198	239
7		67	95	113	145	81	116	130	166
8		36	57	71	97	48	76	85	117
9		16	32	42	64	26	48	54	82
10		3	14	22	41	12	30	34	57
11		—6	2	9	24	3	16	19	39
12		—11	—7	—1	11	—4	7	9	26
13		—15	—14	—7	2	—8	—1	2	16
14		—17	—18	—12	—5	—11	—6	—3	8
	Internal rates of return %	10.2	11.2	12	13.4	11.4	12.8	13.2	15.4

N = Normal rate of initial establishment

A = Accelerated rate of initial establishment

* = Fenton and Tustin, 1972

† = Fenton and Dick, 1972a

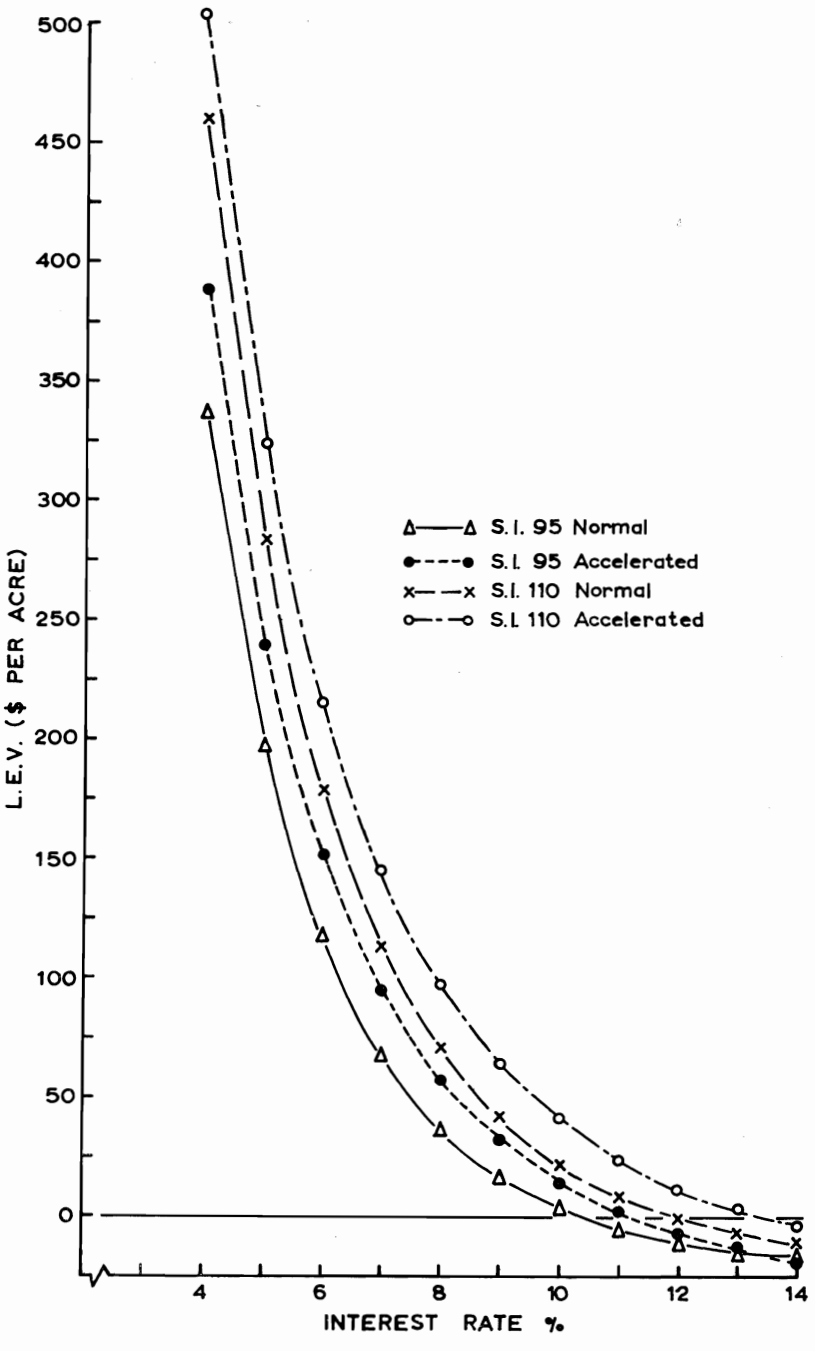

FIG. 1—Net Land Expectation values (including social items)

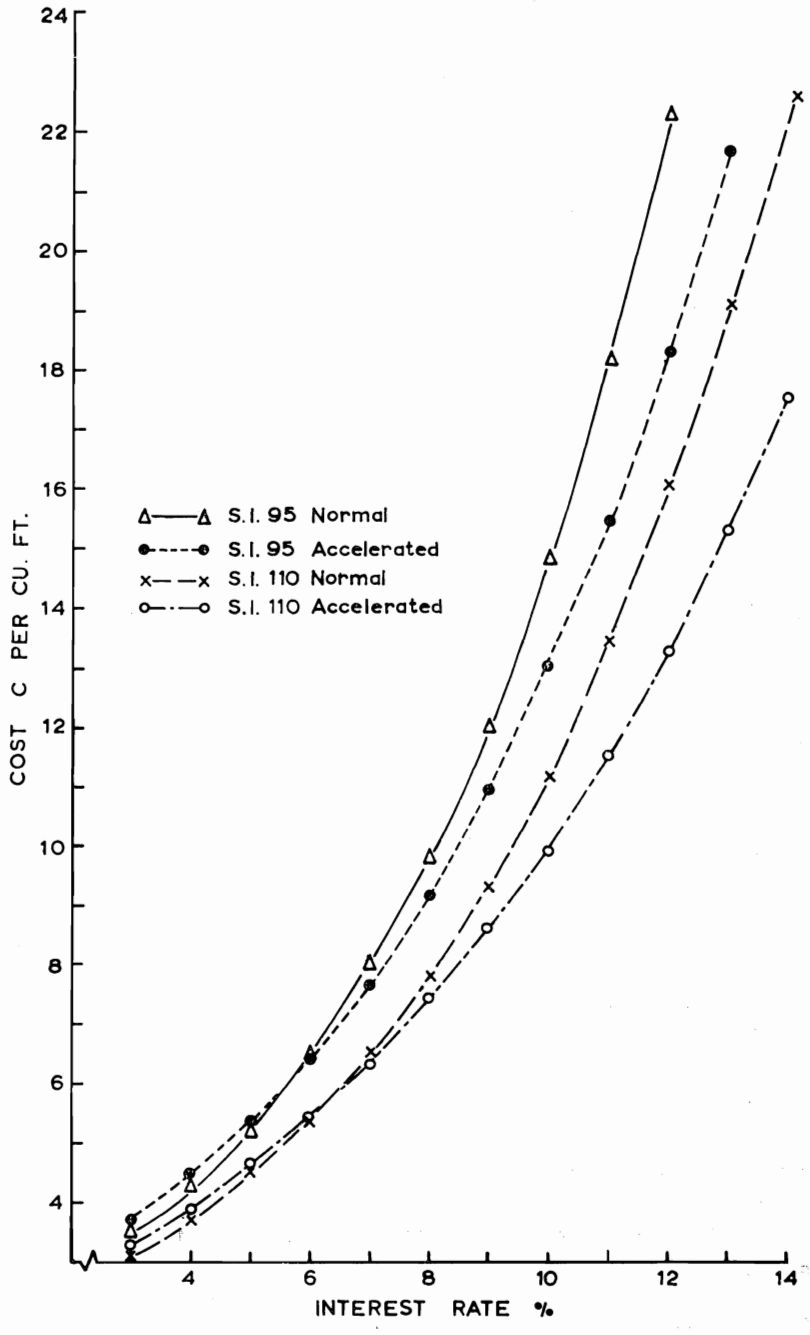

FIG. 2—Break-even growing costs (including social items)

TABLE 23—Return-cost ratios, including logging costs

Interest Rate %	S.I.: Regime:	Including Social Items 95 N	95 A*	110 N	110 A†	Excluding Social Items 95 N	95 A*	110 N	110 A†
3		2.41	2.36	2.55	2.50	2.62	2.59	2.77	2.72
4		2.20	2.17	2.36	2.32	2.43	2.41	2.59	2.56
5		1.99	1.98	2.17	2.15	2.22	2.24	2.41	2.40
6		1.79	1.80	1.98	1.98	2.01	2.06	2.23	2.24
7		1.58	1.63	1.80	1.82	1.81	1.89	2.04	2.09
8		1.39	1.46	1.61	1.67	1.60	1.72	1.86	1.94
9		1.21	1.30	1.44	1.52	1.41	1.56	1.67	1.80
10		1.04	1.16	1.28	1.38	1.23	1.40	1.50	1.65
11			1.02	1.13	1.25	1.06	1.25	1.34	1.51
12					1.14		1.12	1.18	1.39
13					1.03			1.04	1.27
14									1.15

N = Normal rate of initial establishment.
A = Accelerated rate of initial establishment
* = Fenton and Tustin, 1972
† = Fenton and Dick, 1972a

and return/cost ratios at interest rates of 3% to 6% are, in fact, slight. For practical purposes, there is little difference in cost of production between the two patterns of management, and at 7% and above the accelerated pattern is increasingly profitable in comparison. As rotations increase there is more uniform advantage to the accelerated planting. Further, the two criteria based on ratios do not incorporate the national benefit of earlier yields from accelerated planting, whereas this is reflected in the uniformly higher profitability given by LEV and IRR.

Comparisons between the Site Indexes

The results show afforestation of site index 110 is the more profitable, and all criteria (LEV; IRR; cost of production per cu ft; return/cost ratios) give the same ranking. Similar results were obtained in comparisons of accelerated planting (Fenton and Dick, 1972c). The differences are appreciable, for example the IRR is nearly 2% higher and the two LEVs at 10% are respectively $3 and $22 per acre (including social items).

Sensitivity Analyses

The effects of differences in costs, returns, location, and volume yields have been demonstrated in the accelerated models (Fenton and Tustin, 1972; Fenton and Dick, 1972a; 1972b). This work is not paralleled here, but the data permit such analysis if required. For example, the effect of 1000 cu ft per acre less could be calculated by multiplying the "log return" in Table 19 by $\frac{7235 \text{ (viz. new yield)}}{8235 \text{ (viz. old yield)}}$ and correspondingly reducing the logging cost. The amended LEV are found by appropriate totalling. The isolation of constituent cost and return elements facilitates a wide range of parametric analyses.

The Faustmann Formula

The familiar Faustmann formula has been a standard method of calculating LEV in forestry for over a century (e.g., Hiley, 1930); it has been used extensively as it is simple and convenient. Briefly, it consists of two algebraic expressions: [A calculation of net returns after allowing for direct costs] minus [capitalised annual costs]. The latter formula is: $\frac{e}{.0P}$

where e = annual administrative and indirect costs
P = interest rate.

There are two problems: (a) "e" is not often constant, and for afforestation distorted results can result (Grainger, 1968); (b) "e" is usually a guess. The budget approach used here demonstrates that in theory and practice "e" cannot be constant as, for example, capital assets are replaced intermittently depending on their service lives; and staff (plus concomitant housing) have to be allocated in specific years. Hence "e" can only be a convenient simplification. The second objection is fully answered in these budgets as "e" can be calculated for protection, administrative and, if needed, social costs. Table 24 contains "e" values derived from the LEV equivalents of these cost categories. Results show (for normal afforestation) "e" decreases as interest rates rise, and in this example "e" is relatively constant at interest rates of 7% and higher; and the assumption that "e" is constant is increasingly inaccurate at low (less than 6%) interest rates. Most economic evaluation in forestry has been by direct or indirect use of the Faustmann formula and at these low interest rates results will possibly contain irregularities due to the assumption that "e" is constant.

The results in Table 24 should be of direct use for rapid, approximate calculations; these data have not been available in New Zealand before. (Rates (local taxes) are excluded from the values in this paper; appropriate local values would have to be allowed for them).

TABLE 24—Value of "e" in the Faustmann formula

Site Index	Interest Rate % 3	4	5	6	7	8	9	10	11	12	13	14
	$ per acre											
	A. Excluding Social Costs											
95	2.76	2.66	2.57	2.50	2.44	2.39	2.36	2.32	2.30	2.28	2.25	2.24
110	2.87	2.77	2.69	2.63	2.57	2.52	2.49	2.45	2.42	2.40	2.37	2.35
	B. Including Social Costs											
95	3.88	3.76	3.65	3.56	3.49	3.43	3.38	3.34	3.31	3.28	3.26	3.24
110	4.14	4.04	3.96	3.89	3.84	3.79	3.75	3.71	3.69	3.66	3.64	3.63

Uses and Limitations of Evaluating a "Normal" Pattern

A major advantage of evaluating a normal pattern of management is the ease of analysis. Most decisions on the timing and scale of various investments, such as buying the logging equipment, are more straightforward than when an accelerated programme is investigated. As decisions are clear-cut and simpler, stricter comparability can be maintained in comparisons between different site indexes, or different objects of management.

The difficulties of extra work in analysis for accelerated patterns reflect, albeit palely, the real difficulties of management of forests with abnormal age-class distribution. The major limitation of normal patterns is that, in most circumstances, they are less profitable and results may be of less application to actual conditions (in New Zealand or elsewhere).

Results in Relation to National Planning

New Zealand forestry is now undergoing a planned expansion of planting, with a national target of about 55 000 acres annually. The amount and location of State planting of radiata pine and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco.) is shown in Fig. 3 (other species are unimportant). The data are from Annual Reports of the New Zealand Forest Service 1963-70. The State planting effort has, in general, been increased in all Conservancies, without particular geographical concentration. For example, planting in Nelson comprised about 17% - 20% of total State planting, in both 1963 and 1970. There are indications in this paper that accelerated afforestation is generally more profitable, and while only equal annual areas may be nationally possible, it would be more profitable to concentrate this planting in a given district and then to shift the emphasis elsewhere. The order of priority as found in the six export log trade studies (Fenton and Tustin, 1972; Fenton and Dick, 1972a; 1972b; 1972c; 1972d; and this paper) should be set primarily on site index, if profitability is considered the major criterion.

While more work is required, the relative importance of site index, location, initial ground cover, topography, and now time-scale of afforestation are becoming clear. The evaluation of different end-products, e.g. sawn timber and pulp products, is under way.

The clearest results of these studies are the high level of profit of growing crops for the export log trade, on present prices, and the relative dominance of site quality in determining profit. The cost of the current policy of phasing out the export log trade without demonstration of the benefits of domestic log processing can now be calculated.

REFERENCES

FENTON, R., and DICK M. MERLE. 1972a: Profitability of radiata pine afforestation for the export log trade—on site index 110. **New Zealand Journal of Forestry Science 2 (1):** 100-27.

——— 1972b: Profitability of radiata pine afforestation for the export log trade—on site index 80. **New Zealand Journal of Forestry Science 2 (1):** 69-99.

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

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

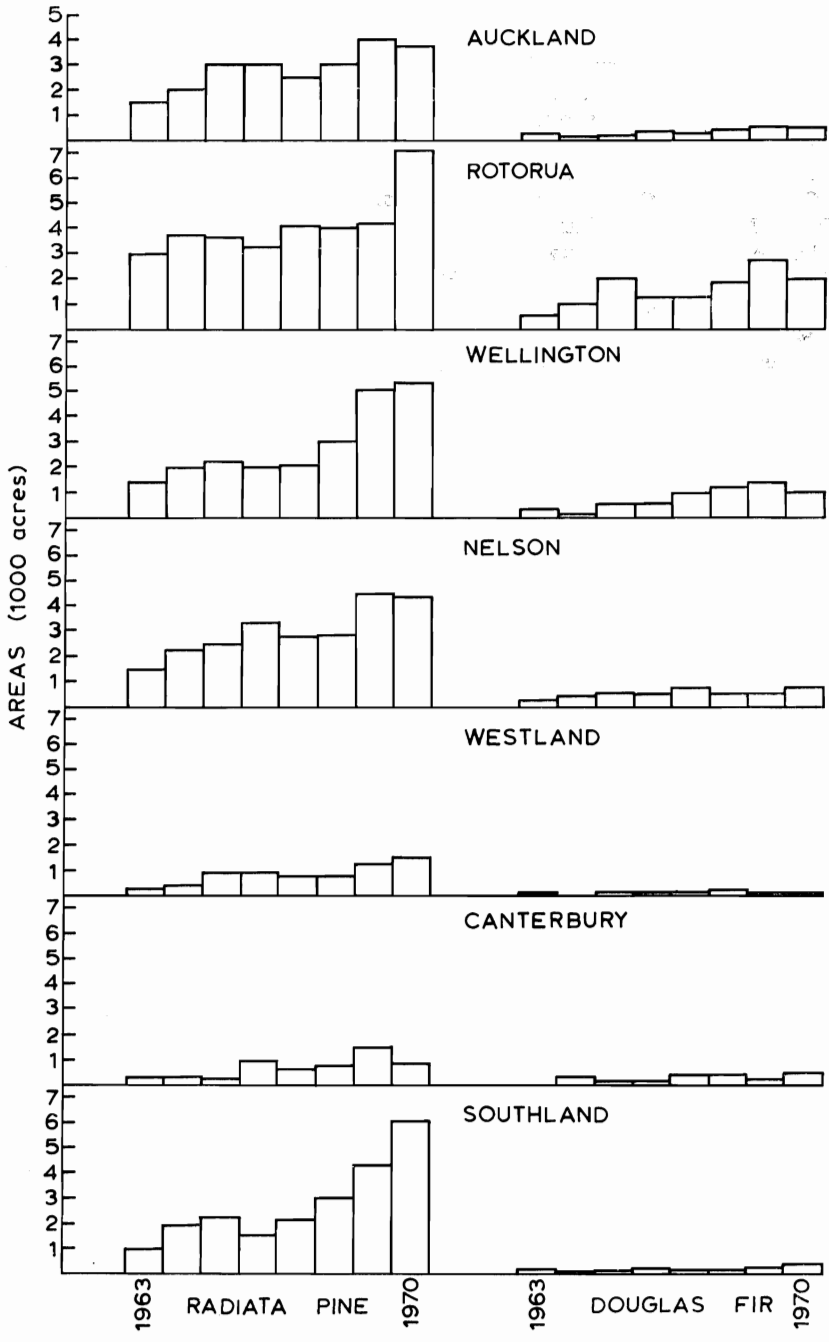

FIG. 3—Areas planted by Conservancies, 1963-1970

FENTON, R., and GRAINGER, M. B. 1965: Economic results from afforestation of the Maraetai blocks. **New Zealand Forest Service, Forest Research Institute, Silviculture Branch Report 31** (unpublished).

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. NDC 5, Wellington, New Zealand.

GRAINGER, M. B. 1968: Problems affecting the use of Faustmann's formula as a valuation tool. **New Zealand Journal of Forestry 13 (2):** 168-79.

HILEY, W. E. 1930: "The Economics of Forestry". Oxford University Press, Oxford.

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 FOREST SERVICE, 1963-1970: Annual Reports.