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FOREST FARMING: A MULTIPLE LAND-USE PRODUCTION SYSTEM IN NEW ZEALAND

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ABSTRACT

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Forest farming as practised in New Zealand involves growing widely spaced pruned radiata pine (*Pinus radiata* D. Don) on pasture to merge livestock farming and exotic forestry into a two-tier production system.

Research has shown that to increase tree survival and growth pasture should be sprayed in strips or spots with herbicide prior to planting. Livestock were excluded for 6 months after planting to avoid browsing damage, and then sheep were grazed amongst the trees for limited periods. Trees which were browsed by sheep in the first year recovered quickly provided the sheep were excluded for the remainder of the growing season. Planting large seedlings did not prevent browsing by sheep in the first spring and summer after planting. In the first 3 years after planting grazing returns were obtained of 20, 40 and 80%, respectively, of those achieved from open pasture. Cattle have been successfully grazed amongst radiata pine which was more than 3 years old. Trials have been started for measuring the effects of sawlog crops of radiata pine throughout a rotation on pasture production and livestock performance.

Although in its infancy in New Zealand, the concept has been shown to be technically feasible, and on suitable hill-country farms it promises higher financial returns than from pastoral farming alone. Initial interest in the concept came from forest companies, but recently agriculturists have also shown interest in this means of diversifying hill-country farm production. This blending of farming and forestry offers a more stable rural economy, more aesthetic plantations, and co-operation rather than conflict over best land-use.

INTRODUCTION

This paper describes the concept of forest farming as it is practised in New Zealand, and provides results from recent research work. Forest farming involves the growing of widely spaced trees on pasture to merge farming and exotic forestry into a single, two-tier production system. Only radiata pine (*Pinus radiata* D. Don) has been considered at this early stage. Initial interest in the concept came from forest companies who appreciated the advantages of very early agricultural returns, easy stand access, simpler stand management, and reduced fire risk. Recently, however, agriculturists have also shown interest. They acknowledge the role that tree crops could play in diversifying farm production, reducing market and biological risk, promoting soil stability, ameliorating the microclimate, providing an asset free of death duties, and in utilising farm labour during slack periods — all this while maintaining an acceptable stock-carrying capacity.

ECONOMIC AND HISTORICAL BACKGROUND

New Zealand's 26.9 million ha are populated by 3 million people and 56 million sheep (Anonymous, 1975a). Agricultural exports provide more than 80% of total overseas income, and diversification of products and destinations is now seen as essential to provide long-term stability in an export-dependent economy. Exotic forestry and tourism are two sectors of future importance.

Before the impact of man, much of the country was covered by forest, but it has been steadily reduced to the current level of 6 million ha. A large proportion of this indigenous forest is on steep terrain and will be permanently reserved as protection forest (Rockell, 1975). To the early settlers, indigenous forest was not only an exploitable resource but also a hindrance to large-scale agricultural development. Partly as a result of their efforts, 50% of the land area (mostly on hilly or steep terrain) is now in agricultural production (see Table I).

When compared with agriculture, exotic forestry with 2.4% has claimed only a small share of the land resource. An inventory of indigenous forest resources in 1923 indicated that virgin softwoods could be exhausted by

TABLE I

New Zealand land classification 1974 (Anonymous, 1974a)

	ha (× 1000)	%
Forested land		
Indigenous forest	6249	23.2
Exotic forest	651	2.4
Sub-total	6900	
Non-forested land		
Agricultural land	13530	50.4
Scrub land and other non-forested land	6090	22.6
Minor islands	80	0.3
Sub-total	19700	
Lakes, rivers, etc.	300	1.1
Total area	26900	100.0

1965. This stimulated the large-scale planting of exotic species (predominantly radiata pine) by both the government and the private sector.

The goal was national self-sufficiency, and a plan for increasing the exotic forest area from 25 000 ha in 1925 to 120 000 in 1935 was proposed (N.Z. Forest Service, 1969). In fact, nearly 280 000 ha were established in this period, made possible by special employment schemes during the depression years (N.Z. Forest Service, 1974). Policy at this stage was to afforest non-agricultural soils, and large areas of flat or rolling scrub land were available because mineral deficiencies precluded their agricultural use. Since then plantation forestry has continued to be largely relegated to land not required by or usable for agriculture, and allocation of New Zealand's land resource (and hence labour and capital as well) has been made primarily on the basis of whether or not it would grow grass (Fenton, 1965). Fig. 1 illustrates the increase in new planting since 1925, including the second period of large-scale afforestation beginning in the nineteen-sixties. The current plantation estate (651 000 ha) is expected to continue to expand at a maximum target rate of 55 000 ha/annum. This target could be achieved and sustained for some time and is the recommendation of a recent Forestry Development Conference (Anonymous, 1975b). It is now accepted that self-suffiency in wood products has been superseded by "generation of export earnings" as the main objective for the programme. This aim has evolved with the realisation that New Zealand had wood surplus to local requirements and that forestry could play a useful role as an earner of overseas exchange (Conway et al., 1974). The steady increase in export earnings by the forestry sector is illustrated in Table II.

Export orientation in particular infers a need for efficiency at all stages of production, fast tree growth, and the location of forests and utilisation plants close to ports. The importance of these factors has been emphasised by the development of a profitable export-log trade to Japan since 1958.

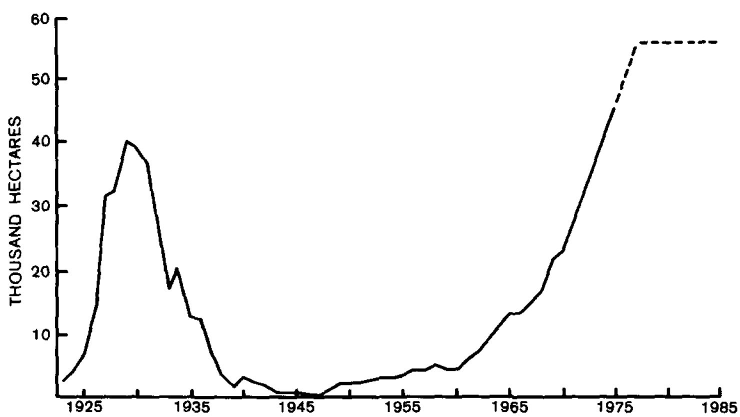

Fig. 1. Exotic forest new planting 1925—1985.

TABLE II

F.O.B. values for New Zealand's principal exports ($ M) (Department of Statistics, Monthly Abstracts of Statistics)

Year	Meat	Butter	Cheese	Wool	Forest products
1963	173	91	37	214	19
1966	196	110	42	232	25
1969	309	115	43	212	58
1972	400	184	66	229	82
1973	540	135	79	424	90
1974	535	107	62	363	108
1975	440	122	48	262	119
1976	586	204	78	456	167
1977	756	254	85	649	220
1978	757	241	77	580	234

High export-sawlog prices have also boosted a tendency for forestry land values to exceed those of agriculture in some regions. As a result, some private forestry companies have purchased farm land on the open market as part of their expansion programmes. Simultaneously, some farmers have become more aware of forestry as an investment. Hence, while these two major land-uses have evolved separately, with agriculture usually having priority, competition between them for land can be expected to intensify in the future, along with more planting on farm land.

SILVICULTURAL BACKGROUND TO THE CONCEPT

The profitability of adopting shorter sawlog-rotations for radiata pine by maximising growth on pruned final crop trees has been demonstrated by Fenton (1972). Short-rotation sawlog management entails freeing crop trees from competition at an early age. Intermediate yields from thinnings are foregone but the stands are sufficiently open to maintain a grass sward, enabling intermediate yields to be obtained from grazing. The realisation of this has led to further silvicultural refinements aimed at reducing shade, debris, and costs by planting fewer trees at wider spacing, by more timely pruning of fewer trees, and by earlier removal of culls. The main differences between conventional radiata pine silviculture and forest farming silviculture are the preparation of the site prior to planting, very wide inter-row spacing at planting (7 m instead of 3 m), more intensive pruning (to 6 m at least and preferably to 8 m or 11 m), and very early non-commercial thinning. All these are essential to the concept as the cumulative effect is an open stand beneath which pasture can be grown for most or all of the rotation (see Fig. 2).

Fig. 2. Sheep among a stand of 12-year-old radiata pine near Putaruru, Waikato. The stand has been thinned to 200 stems/ha, and pruned to 11 m.

RESEARCH COMPLETED

Current interest, investment, and research effort in forest farming are based on the expectation that the net financial return will be higher per unit area than from either forestry or agriculture alone. Few financial studies have been attempted to verify this because of the lack of a sound physical data base. Hence, most research has concentrated on proving the technical feasibility of the concept, identifying management techniques, and resolving data gaps. Throughout, the assumed management objective has always been a balanced approach to pasture and wood production, even though some practitioners will undoubtedly favour one at the expense of the other. Because the concept is new, the greatest conflict between agricultural and forestry objectives has come at the tree establishment phase, and it is on this part of the production cycle that much research effort has concentrated. Results to date and the experience gained are detailed below.

SITE PREPARATION AND PLANTING

The conventional method of site preparation on pasture has involved removal of the turf from the planting spot with a spade at the time of planting. With this method, regrowth of grass and weeds in the spring and summer after planting tends to smother the young seedlings, often necessitating either further expensive releasing by hand or herbicide application by aircraft. Complete spraying by aircraft increases the possibility of damage to growing trees and also harms a larger area of pasture than is necessary to release the seedlings from competition. These disadvantages are unacceptable where grazing is intended, since tree foliage must be out of reach of livestock as soon as possible and pasture must be of reasonable quality.

For the combined concept it has been found best to check grass growth by spraying 0.8-m wide strips across the land 1—4 weeks before planting. On country too steep for tractors or four-wheel drive vehicles, spray is applied in 0.9-m diameter spots by hand-operated knapsack. In both cases the pasture is closely grazed prior to spraying. While paraquat by itself is adequate on some sites, for most conditions 3.4 kg active simazine (which gives longer-lasting weed control) is added to 1.2 kg of paraquat per sprayed ha. Waiting until late winter (August) to spray has two advantages: livestock can be kept on the pasture for most of the winter when fodder is scarce, and the simazine will still be effective for controlling new weed germination in spring so no post-planting treatment will be required. Consequently, trees grow faster unhindered by either weeds or chemicals. This pre-planting paraquat—simazine treatment requires less labour than the practice of hand-releasing planted trees from grass competition, is much less harmful to the surrounding pasture than spraying by aircraft, and is also cheaper than either of these methods.

Good planning is an essential ingredient for site preparation. It is difficult to control weeds among young trees, so intensive grazing and weed spraying need to be done *before* tree planting; control of feral animals (opossums, goats, rabbits, and hares) if present, is also best carried out before planting.

One trial compared the growth rates of small 1-year-old radiata pine seedlings and larger 1.5-year-old seedlings planted into vigorous pasture by three different methods. Some seedlings were planted by hand on a 0.8-m wide strip sprayed with the paraquat—simazine mixture 1 week before planting; others were machine-planted on a similar sprayed strip; the third group was planted on unsprayed pasture, using the same machine but with additional equipment for removing the turf from the planting line. The 1-year-old seedlings in this last treatment required hand-releasing after

TABLE III

Effect of seedling size and establishment method on tree growth (Anonymous, 1974b)

Establishment procedure	Mean hts. (cm) of seedlings at:				*
	Planting	7 months	11 months	18 months	
1-year-old seedlings planted by:					
Hand/paraquat strip	16	66	75	150	a
Machine/paraquat strip	15	64	69	141	a
Machine/no paraquat/hand releasing	18	54	59	113	b
1.5-year-old seedlings planted by:					
Hand/paraquat strip	44	99	113	216	a
Machine/paraquat strip	41	89	101	198	b
Machine/no treatment	48	80	85	156	c

*Treatment means of seedlings of the same age at planting with the same letter are not significantly different at the 99% level.

planting. Average height growth of all groups of seedlings, measured at intervals for 18 months after planting, are shown in Table III.

At all times, the mean heights of seedlings planted on sprayed strips were taller than those on unsprayed pasture. The good early growth of the older seedlings is particularly important where subsequent grazing is intended. Once trees are about 1 m tall, grazing management is simplified as the sheep are less likely to severely browse the tree leaders. Consequently, a combination of paraquat—simazine spraying and sturdy seedlings to produce faster growth allows an earlier return to full grazing of the site. This in turn means a quicker financial benefit from grazing, better retention of pasture species, and the best possible control of weeds.

One problem, associated with fast early tree-growth on fertile but exposed sites, is high winds blowing trees over. Even with sturdy seedlings, planted carefully to ensure that root systems are not bunched or distorted, some losses from wind seem inevitable.

MANAGEMENT DURING TREE ESTABLISHMENT

Several trials have been undertaken to find the best method of grazing management compatible with tree establishment. Preliminary trials showed that grazing during the first spring and summer invariably resulted in the trees being browsed; grazing during autumn and winter appeared safer. For this reason, season comparisons were used in most trials.

(a) Influence of season, and breed of sheep, on browsing damage

Results from trials when different breeds of sheep were grazed amongst young radiata pine in both spring and autumn are shown in Table IV. With all breeds grazing in autumn proved to be safer than in spring, although there were large differences between years and between breeds.

TABLE IV

Influence of season, and breed and age of sheep, on the percentage of seedlings browsed after 10 days' grazing (Gillingham et al., 1976)

Season	Year	Seedling hts. at planting (cm)	Type and breed of sheep			
			Dry Romney ewes (%)	Coopworth hoggets (%)	Romney hoggets (%)	Perendale hoggets (%)
Spring	1973	29	42	72	56	100
	1974	45	62	N.A.	N.A.	N.A.
Autumn	1974		22	18	24	6
	1975		34	N.A.	8	N.A.

Note: All data relate to a stocking rate of 20 animals/ha. Browsing figures are for damage to the terminal leader of the seedling, not lateral branches. A hogget is a sheep between 9 and 15 months of age.

(b) The incidence of spring and summer browsing damage by sheep on seedlings of different sizes

This trial used taller seedlings than normal in an attempt to eliminate or reduce the period of vulnerability to livestock. Radiata pine seedlings ranging in height from 35 to 130 cm were planted and the pasture grazed by sheep of various ages and breeds. In spring, all trees up to 58 cm high were severely damaged although the incidence of browsed terminal leaders declined with increase in height above 58 cm.

In summer, with a high grazing pressure applied (Rukuhia site), all trees were severely browsed — even those up to 130 cm in height. Some of these taller seedlings were also debarked. With a lower summer grazing pressure (Tikitere site), overall damage was less and the terminal growth of trees taller than 94 cm was only lightly browsed. The reduction of height increment with increasing size of seedlings in the control area is a reflection of their less rapid establishment due to an imbalanced root/shoot ratio. Results are shown in Table V. This trial has shown that large seedlings are still vulnerable to browsing and are not a solution to avoiding spring and summer browsing damage.

TABLE V

Growth and incidence of browsing by sheep on six classes of radiata pine seedlings (Gillingham et al., 1976)

Seedling age at planting (years)	Mean ht. at planting (cm)	Mean ht. increment in the 9 months after planting (cm)		
		Rukuhia control (no grazing)	Tikitere (11 E.E./ha)*	Rukuhia (12.5 E.E./ha)*
1	35	+71	+21	−13
1.5	45	+69	+19	−10
1.5	60	+58	+26	− 7
2	90	+53	+32	+ 2
2	115	+43	+33	+15
2	130	+40	N.A.	+14

*E.E. = ewe equivalent (Coop, 1965).

(c) Changing the composition of the pasture and its effect on browsing damage by sheep

One possible explanation for the lower incidence of browsing damage occurring in autumn is that the mixture of clover and rank grass which occurs then offers the livestock a wider range of diet. For this reason, changing the pasture composition by spraying with the herbicide propyzamide prior to tree planting to encourage red and white clover (*Trifolium pratense* and *T. repens.*) was tested to see if sheep could be diverted from browsing radiata pine. Six 2-ha paddocks were used. The propyzamide was applied in the autumn at the rate of 1 kg active ingredient in 120 l of water/ha to three of the paddocks. Radiata pine seedlings were planted at 1500/ha in all paddocks in the winter, and sheep of mixed age and breed were grazed among the trees in the following spring and autumn (paddocks 1, 2 and 3) or the autumn only (paddocks 4 and 5). Sheep in paddock 1 were also fed hay as a source of roughage. One paddock was not grazed as a control. Results are shown in Table VI.

Although the pasture in paddocks 1, 2 and 4 became clover-dominant, there was no benefit in terms of reduced browsing of trees (and therefore increased tree growth) compared with the trees in the unsprayed paddocks. Grazing for the first time in the autumn, 6 months after planting, gave less browsing damage compared with spring and autumn grazing, but there was also no benefit from clover encouragement. As Table VI shows, feeding out hay was also unsuccessful in reducing browsing damage.

(d) Protection of trees from sheep

Mechanical guards have been used as methods of avoiding tree damage by sheep and retaining desirable pasture species by continuous grazing

TABLE VI

Effect of clover encouragement on the incidence of browsing of radiata pine by sheep

Paddock No.	Treatment	Mean seedling ht. at planting (cm)	% of trees browsed		Grazing achieved (E.E./ha)	Mean tree ht. at 1 year (cm)
			Spring (37 days' grazing)	Autumn (39 days' grazing)		
1	Propyzamide + hay	46	93	99	5.4	43
2	Propyzamide	46	93	97	5.7	46
3	No propyzamide	45	98*	88	4.9	56
4	Propyzamide	47	not grazed	39	2.7	88
5	No propyzamide	46	not grazed	32	2.7	93
6	Control — no propyzamide, no grazing	46	not grazed	not grazed	0	115

*30 days' grazing.

(Gillingham et al., 1976). Although the guards did protect the trees from browsing, they were too costly to be justified. To be satisfactory, the guard must protect the tree until it is about 1.5 m tall, and to be economic each guard should cost not more than 0.07% of the net full potential annual grazing return per ha. This is calculated on the basis that 750 seedlings/ha will be planted and that without tree protection in the first 3 years an average of 50% of potential pasture grazing will be lost. Even the most simple guards cost more than this break-even amount.

(e) The effect on pasture composition of not grazing during spring and summer

Under normal farming conditions, prolonged spelling (not grazing) of ryegrass—white clover pasture is not normally advocated. Trials have shown that the main effects of spring and summer spelling on pasture composition have been a rapid build-up in dead herbage, a temporary drop in the legume content, and a tendency for ryegrass to be replaced by Yorkshire fog (*Holcus lanatus*), browntop (*Agrostis tenuis*), and *Danthonia* (Gillingham et al., 1976). This latter trend is especially apparent where these alternative grass species are noticeably present at the time of planting. If autumn grazing is successful in reducing the bulk of standing dry matter accumulated in the first 2 years, the clover content appears to be quickly restored. Experience to date indicates that spelling of pasture can help to reduce the flat weed component but taller weeds such as blackberry (*Rubus fruticosus* agg.), gorse (*Ulex europaeus*), and bracken (*Pteridium aquilinum* var. *esculentum*) flourish. For this reason the concept appears to be limited to swards with relatively few scrub weeds present.

(f) Effect of sheep browsing on radiata pine

Table VII shows the effect of browsing by sheep on the growth and recovery of radiata pine seedlings on four different sites. At two of these sites, Reporoa and Whatawhata, grazing in the first year continued until mid-summer, resulting in more tree damage and height loss in the first year than was caused at the other locations. Because of the careful livestock

TABLE VII

Browsing damage and tree recovery during the establishment phase (Anonymous, 1975c)

	Time since planting (years)	Mean tree ht. (cm)			
		Mamaku	Matahina	Reporoa	Whatawhata
Leaders unbrowsed	0	53	42	50	53
	1	79	95	89	81
	2	133	180	130	157
Leaders browsed 1st spring only	0	54	44	49	46
	1	76	87	79	64
	2	130	173	113	137
Height loss		2%	4%	21%*	13%*
Leaders browsed 1st spring and autumn	0	44	36	43	43
	1	60	67	60	57
	2	88	117	82	109
Height loss		34%	35%	37%	31%
Leaders browsed 1st spring, autumn, and 2nd spring	0	47	36	41	43
	1	55	62	54	56
	2	72	94	67	91
Height loss		46%	48%	48%	41%

*Some damage occurred during summer.

management in these trial areas, probably less damage resulted than would occur in larger areas under more extensive grazing. Trees can recover from browsing of the leader provided they are not completely defoliated and no further browsing of new growth takes place. Height increment is severely affected by repeated leader browsing, especially if this takes place during the growing season.

On hill country, browsing damage tends to be concentrated around areas where sheep congregate, usually on ridge tops or small flat areas. Browsing of side branches but not the main leader has been found to have little effect on subsequent growth of radiata pine.

(g) Grazing returns during tree establishment

In several trials sheep were grazed after the pasture was planted in radiata pine and indicative grazing returns were obtained. The pattern of browsing damage was similar to that noted from the other trials already discussed, i.e. sheep tended to browse the trees more during the spring than in the autumn. Grazing diaries were kept and results are shown in Table VIII.

TABLE VIII

Grazing returns during tree establishment

Trial area	Mean tree ht. (cm)		Spring/ summer (E.E./ha)	Autumn/ winter (E.E./ha)	% of stock-carrying capacity without trees (autumn/winter only)
	Spring	Autumn			
A. Grazing obtained in the first year					
Mamaku	50	70*	0.6**	0.6	5
Matahina	40	95*	1.0**	3.2	27
Whatawhata	50	75*	2.4	2.9	26
Rukuhia	45	90	Nil	2.7	22
B. Grazing obtained in the second year					
Mamaku	70	115	0.9	4.0	36
Matahina	95	170	0.9	6.2	52
Whatawhata	75	130	2.7	3.4	31
C. Grazing obtained in the third year					
				All seasons	All seasons
Mamaku	115	190		7.4	67
Matahina	170	280		9.4	78
Whatawhata	130	255		9.2	84

*Excluding trees which were severely damaged.
**No grazing was done in the summer because of severe damage to trees in the previous spring. The Rukuhia site was purposely grazed in the autumn/winter period only.

(h) Conclusions and experience gained to date

A suitable grazing system for both weaned lambs and older sheep is to stock at 12—25 animals/ha in autumn (March) so that the pasture is eaten out by early spring (August/September), and then to remove the sheep for 3—4 months to prevent browsing during the critical spring period. By then the tree leaders are usually above browsing level and so further grazing is safe provided that over-stocking is avoided.

There are several reasons why autumn introduction of livestock is preferable to spring or early summer grazing. Trees which are browsed in their first spring have not developed extensive root or foliar systems. The browsed trees will often recover if the sheep are excluded but the rank sward that results defeats the main objective of spring grazing. On the other hand, trees which are browsed in the autumn have already completed the season's growth and do not appear to be seriously retarded when compared with unbrowsed trees. For this reason, the last column in Table VIII showing the grazing which was achieved during the autumn and winter is of most interest. Approximately 20, 40 and 80% of the potential livestock-carrying capacity without trees can be achieved in years 1, 2 and 3, respectively, if over-stocking with sheep is avoided, and if sheep are not grazed among the trees during the first and second spring/summer periods.

Often, incipient tree browsing necessitates a temporary cessation of grazing, even though there is an abundance of feed. Areas with poor tree growth, or where high levels of leader browsing have occurred in years 1 or 2, can still require careful grazing management after year 3. For this reason the tree crop must have priority in the early years. Unrestricted grazing by sheep in subsequent years is dependent on the tree leaders being beyond the reach of sheep, and the animals not debarking the trees. Sheep under some conditions, including feed shortages, can severely debark trees, particularly at tree age 2—4 years. Sporadic debarking also occurred when grazing with lambs and hoggets, particularly in the spring. When sheep are being grazed among trees less than 5 years of age frequent inspection is essential and the animals removed if necessary. Once bark thickens at age 5—6 years, it appears to become less palatable to sheep.

Dairy cattle (Fresian and Jersey) display a marked propensity to browse and debark trees, and so are not grazed among young pines. Beef cattle (Hereford and Aberdeen Angus) have been tried in several trials with varying results. Angus calves which were used to keep down rank pasture growth in the second autumn after planting did not damage trees, but they did debark several trees when used a year later on the same site. However, there is some evidence to suggest that cattle which have had recent experience of grazing among pines are less likely to browse or debark trees. Cattle have been used successfully when the trees reach 4 m in height (see Fig. 3).

INTER-ROW CROPPING OF HAY AND ENSILAGE

Cropping hay or ensilage has been found to be a useful alternative to grazing as a means of utilising the pasture in the first and second summers after planting. It provides spring and summer pasture control without the problem of browsing damage. Sheep can still be used for limited autumn and winter grazing. This technique is obviously restricted to flat or easy rolling farm land, and in New Zealand the area of land in this category available for tree planting is limited. However, even if variable topography allows only a part of the total area to be mown, this has been found to be beneficial in increasing the subsequent pasture utilisation by livestock. Contour planting with provision for access lanes is necessary on sloping ground to ensure movement of hay- or ensilage-making machinery (see Figs. 4 and 5). Main-

Fig. 3. Cattle grazing amongst 4-year-old radiata pine at Puketitiri in Hawkes Bay. The trees were planted at 4.3 X 1.8 m spacing (1250 stems/ha), and have been thinned to 400 stems/ha and pruned to 2 m.

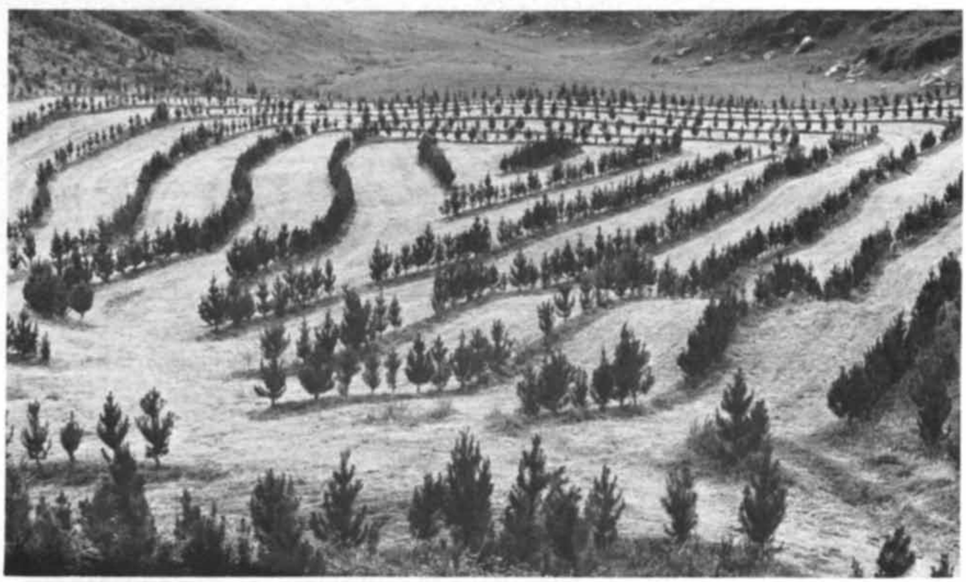

Fig. 4. Radiata pine 2.5 years old at Waotu in the Waikato. The trees have been planted at a spacing of 7.1 X 1.8 m to allow access for hay and ensilage harvesting equipment.

Fig. 5. Lambs stocked at 25 animals/ha grazing amongst radiata pine at 1250 stems/ha, 9 months after planting.

tenance topdressing of fertiliser must be continued to compensate for nutrient removal.

Trials using inter-row spacing of 7 m have shown that unmown areas within the tree rows amounted to 8% of the total area during the first year after planting. This area loss was reduced to 7% in the second and third years as tree rows became more easily identified. As with harvesting pasture not planted in trees, the quality and quantity of the yields obtained during the first 3 years are dependent on the vigour and composition of the pasture

TABLE IX

Agricultural returns from inter-row harvesting trials (Gillingham et al., 1976)

Year of rotation	Yields/ha from Trial 1*			Yields/ha from Trial 2**		
	Hay (bales)	Ensilage (tonnes)	Grazing (E.E./ha)	Hay (bales)	Ensilage (tonnes)	Grazing (E.E./ha)
1	150 (Dec.)	17 (April)	4.5 (July—Aug.)	128 (Feb.)	19 (Dec.)	0.7
2	128 (Feb.)	19 (Nov.)	7.9	0	19 (Nov.)	6.4
3	0	20	6.7	N.A.	N.A.	N.A.

*Radiata pine planted at 1000 stems/ha in rows 5.5 m apart.
**Radiata pine planted at 750 stems/ha in rows 7.1 m apart.

and the timing of the operation. A cut of hay or ensilage taken in early summer (November) will often stimulate clover growth which can be used to fatten lambs after weaning in mid-summer (December or January). The alternative of taking a later cut of hay (in December of January) will yield more hay (usually about 150 bales/ha compared with about 100), but the quality will not be as good and there is a possibility of clover suppression with the delayed cutting. Typical returns from two trial areas obtained in the first 3 years after planting are shown in Table IX. These returns are approximate only, as ensilage yields were estimated, and the weights of dry hay bales can vary between 20 and 40 kg.

EARLY SILVICULTURE

Pruning and thinning research has concentrated on identifying the minimum number of trees required at each stage to achieve the required final crop, on means of minimising debris from pruned branches and culled trees, and on the effect of alternative practices on wood quality (especially on the size of the knotty core).

The most direct method of reducing the amount of debris, and also costs, is to plant and tend the minimum number of trees consistent with obtaining the desired number of final crop trees. Preliminary work has shown that about 15% of the trees in young stands of radiata pine can be upgraded by form-pruning double leaders and ramicorn branches to pro-

TABLE X

Effect of timing of early silviculture on the amount of debris produced

Mean tree ht. (m)	Regime 1*		Regime 2**	
	Operation	Percentage of each planted ha covered with debris†	Operation	Percentage of each planted ha covered with debris†
3	Prune 500 stems/ ha to 1.3 m	2.5	No pruning	—
3	Thin 250 stems/ ha to waste	2.1	No thinning	—
5	Prune 400 stems/ ha to 2.0 m	16.1	Prune 400 stems/ ha to 2.0 m	22.9
5	Thin 100 stems/ ha to waste	3.3	Thin 350 stems/ ha to waste	11.6
	Total debris	24.0	Total debris	34.5

*Regime 1: plant 750 stems/ha, prune and thin at 3 m (age 3 years) and 5 m (age 4 years).
**Regime 2: plant 750 stems/ha, delay pruning and thinning until 5 m (age 4 years).
†Area obtained by measuring the debris in a single layer, i.e. not piled up.

duce an acceptable crop tree. Thus, fewer trees are required initially.

Table X compares the areas covered by debris when pruning to 2.0-m height was completed in either one or two operations. Approximately two-thirds of the debris produced from this early silviculture comes from pruned branches. Treating the stand at 3 m and again at 5 m, instead of waiting until 5 m for a single operation, reduces the area of slash from 34.5 to 24%. Recent work suggests that poison-thinning may further reduce the amount of debris, as cull trees decay standing. Annual pruning may also be used. Reductions in debris covering the ground not only assist pasture utilisation and productivity, but also reduce opportunity for weeds to grow and spread from ungrazed debris concentrations. However, as cattle will readily eat the wilted foliage on pruned branches and severed cull trees without any apparent ill-effects, judicious grazing management can also assist.

The early pruning at 3-m height did not give a smaller knotty core because sheep had browsed the lower branches to 1 m. In the absence of intensive pruning the branches above 1 m will be large and so pruning may have to be an annual operation on the best sites. Pruning only the largest branches in the lowest remaining branch whorls is being tested as a means of avoiding over-pruning while reducing the size of the knotty core at the next pruning lift. The recommended tending regime is shown in Table XI.

TABLE XI

Recommended tending regimes for sawlog crops of radiata pine on pasture

Mean crop ht. (m)	Thin*		Prune residuals**	
	from (stems/ha)	to (stems/ha)	from (m)	to (m)
3	750	500	0	1.3
5	500	400	1.3	2
7	400	300	2	3
9	300	200	3	4.5
11		200	4.5	6
14		200	6	8

*Thin malformed, leaning, and suppressed trees.
**Prune the residual stand element when the crop reaches the heights indicated in the schedule.

CURRENT RESEARCH

The most important knowledge gap, and hindrance to economic evaluation of forest farming, concerns the relationship between the final crop numbers/ha of radiata pine, pasture dry matter production, and animal performance. The shape of the graph in Fig. 6 is especially important for land-use comparisons between forest farming and farming or forestry alone. Accordingly, a long-term project has been started to clarify these aspects. For example, one trial covers 100 ha, contains five treatments (viz., open pasture and radiata pine at 50, 100, 200 and 400 stems/ha final crop stocking), and two grazing regimes (approximately 12 and 9 ewe equivalents/ha). Groups of sheep will be grazed in succession around four replicates within each treatment and assessed for live-weight gain and wool production. Pasture and wood yields will also be measured. This experiment, which will run for 25 years, is a joint study by agricultural and forestry researchers. Other trials involve comparing pasture species to evaluate whether or not more shade-tolerant species are an improvement on the traditional ryegrass—white clover sward.

One problem has been that stands older than 8 years with adjacent open pasture controls are neither well-represented nor available for formal research trials. The approach adopted has been to set up comprehensive long-term trials and at the same time install complementary treatments in older stands to provide interim data. The success of this work is dependent upon close collaboration between forest researchers, agricultural researchers, government departments, private companies, and interested individuals. An inter-departmental research working group has assisted by co-ordinating the programme. Future research, associated with the long-term trials, will attempt to evaluate and quantify the tree/pasture/animal interactions more closely. Interactions worthy of investigation include the effect of trees on microclimate and the effect this has on grazing animals; the effect of the

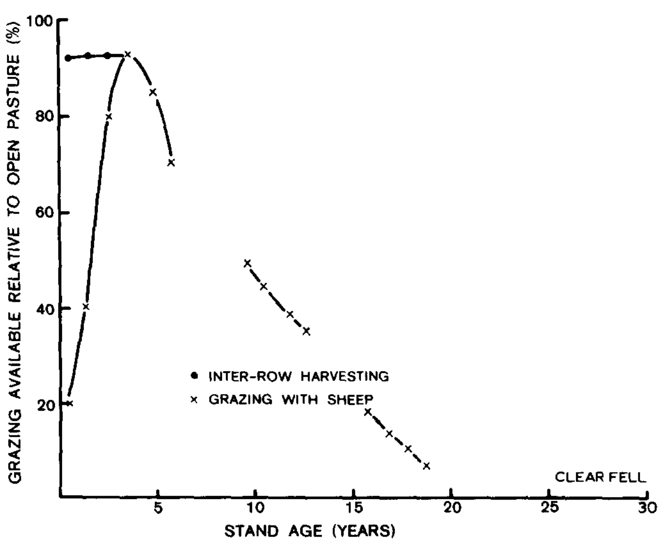

Fig. 6. Approximate pasture productivity beneath a radiata pine canopy (200 stems/ha).

tree crop on water yields, nutrient interception, and the cycling of elements normally lost to a surface-rooted pasture; the effect of wide-spaced trees in buffering soil erosion on land normally too unstable for agriculture; and the possibility of using other tree species (such as *Eucalyptus* spp.) on the fertile soils available under this concept.

APPLICATION OF FOREST FARMING

The areas of land involved in forest farming under different ownerships (farmers, forest companies, government departments) are not known. One recent review (Preest, 1975) has indicated that only 6% of new forest planting under major ownerships (i.e. excluding farmers) is on grassland, and much of this is with conventional forestry in mind. Hence application of forest farming is currently minor.

There are some variations in the implementation of the concept, depending on the objectives and viewpoint of each land manager. For example, farmers tend to favour planting trees on a paddock scale, financed from normal farm income, while forest companies purchasing developed farm land have planted the whole farm. In some cases companies plan to grow these crops for pulpwood. This does not require or justify pruning and results in a little long-term scope for pasture utilisation. However, where companies have decided that pruned sawlogs are the principal forest target, a balanced production system can be achieved. Properly applied, forest farming need not displace or seriously disrupt agriculture but can complement it by minimising wastage of capital works and pasture, causing only gradual changes in pastoral-based production. Forest companies appear sensitive to criticism of dense planting good farm land for pulpwood crops. In some cases they are leaving the most productive pasture land unplanted as a core area from which to extend forest farming, or they are selling such land to adjacent farmers.

Financial studies to establish the relative profitability of forest farming vs. grass or trees alone have been hampered by the lack of physical data on pasture production and livestock performance among radiata pine. The most comprehensive analysis to date was carried out by Jackman and Knowles in 1973. They concentrated on the hill-country farm situation because it is this part of the farming sector which is in greatest need of diversification; it also offers most scope for large-scale implementation. They concluded that forest farming was likely to be significantly more profitable than pastoral farming alone on a typical Wairoa (East coast, North Island) hill-country farm of 465 ha carrying 9 ewe equivalents/ha. The differences in profitability tended to diminish on smaller farm units of higher livestock-carrying capacity. Hence, from the farmer's point of view the concept is likely to be more readily applied and more attractive financially on larger units with moderate-to-low stocking rates. Cash flow problems were unlikely to be encountered where trees occupied less than 10% of the farm area. The analysis was most sensitive to forestry yields, forestry costs, distance to the sawlog market, and the prices of meat, wool, and wood. More work of this type is needed, but a better data base is required to reduce the range of assumptions at the outset and also to reduce the uncertainty in interpreting the results.

However, a lack of soundly based, financial calculations is not the main impediment to more widespread adoption of forest farming. Tustin and Knowles (1975) identified problems arising from conservatism on the part of land managers and administrators. Some people, accustomed to regarding farming and forestry as distinct alternatives, cannot easily accept them as an integrated form of land-use. Examples of this are vigorous opposition by farming interests to the acquisition by forest companies of pastoral land ideally situated for forestry, the lack of interest by the same farming groups in adopting forestry themselves, and the attitude of some foresters who have persisted in dense planting pastoral land. Other impediments include the lack of forest management expertise in the farming community, a scarcity of competent forestry contractors, and an under-developed forestry advisory service. Borrowing for farm forestry development is difficult, and forestry expenditure by a farmer is not tax deductible in the year in which it occurs. If these impediments were rectified and forest marketing services for the private grower were improved, the acceptance and expansion of forest farming would be greatly facilitated.

Of the 13.53 million ha of agricultural land in New Zealand shown in Table I, approximately 4.5 million ha can be classed as hill country (Brougham, 1973). It is the authors' opinion that between 5 and 10% of this land could be used for forest farming without seriously disrupting the present agricultural industry. An evaluation of this proposal, including profitability and market prospects, is urgently needed as a means of offering hill-country farming some income stabilisation in the long term. If only 5% (225 000 ha) of New Zealand's pastoral hill country was phased into forest farming on an individual paddock basis over the next 25 years, the annual income from the trees as export sawlogs, at today's F.O.B. prices, would be about N.Z. $ 200 000 000.

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