Changes in Understorey Pasture Composition in Agroforestry Regimes in New Zealand

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CHANGES IN UNDERSTOREY PASTURE COMPOSITION IN AGROFORESTRY REGIMES IN NEW ZEALAND

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ABSTRACT

Long term Agroforestry trials were established in the North and South Islands of New Zealand between 1971-76. They compared a range of final tree stockings of *Pinus radiata* planted into pasture with open pasture control plots and were measured for tree growth parameters and agricultural production. This paper presents the results of pasture species changes over the period of tree age 10-22 years. Pasture species composition under *Pinus radiata* changed with time, dependent primarily on the rate of canopy closure. Changes occurred relatively rapidly in high tree stocked areas of 400 stems per hectare (sph) in the North Island trials where ryegrass (*Lolium perenne L*) and white clover (*Trifolium repens L*) were replaced with annual and native grass until canopy closure resulted in loss of all pasture by tree age 13 years. In lower tree stocked areas these changes occurred more slowly so that by tree age 19 years, pasture species such as Yorkshire Fog (*Holcus lanatus*) and annual grasses (*Poa Species*) still contributed to the ground cover. In the South Island trials, pasture persisted longer into the tree rotation. Open pasture (0 sph) retained similar pasture species to that at the trial commencement in all locations. A point analysis technique at one North Island site gave a good measure of ground surface cover over time.

KEYWORDS

Pasture, species composition, pasture production, tree stocking, *Pinus radiata*.

INTRODUCTION

Forestry is being planted onto pastoral agricultural land in New Zealand at a rate of 60-100,000 ha per annum (NZ FOI, 1995). In the 1970's and 1980's the interest was in planting trees widely spaced which had the effect of maintaining understorey pasture and associated animal production for longer durations than for close planted areas (Hawke, 1991). The interest is now shifting to higher tree stockings and woodlot planting because land can be managed more easily, timber quality can be better controlled, the potential profits are higher (Maclaren, 1993) and land retained in pasture is likely to be better managed. Changes to the contribution that ryegrass (*Lolium perenne L*) and white clover (*Trifolium repens L*) make and the ability of other pasture species to survive under pine trees is important in understanding the temporal pastoral productivity relationships in agroforestry. Initial results to tree age 9-11 and details of the trials located near Rotorua (Tikitere), Hamilton (Whatawhata) and Dunedin (Invermay and Akatore) were reported by Percival *et al*, Gillingham and Cossens (1984) respectively. Briefly, herbage dissection results from Tikitere showed a declining contribution of ryegrass and white clover with increasing tree stocking and age (Percival *et al*, 1984); e.g. at tree age 8, the 400sph treatment grew only 5% of the ryegrass and white clover compared with that of open pasture (0sph). At Akatore pastures generally improved in all tree stockings as the original tussock swards were replaced by grasses and clovers (Cossens 1984), but annual yields were still significantly lower than from the Tikitere site. At the high fertility site at Invermay, there was no reduction in ryegrass and white clover under the trees. Point analysis results from Tikitere showed a depression in ryegrass and white clover cover with increasing tree stocking. Yorkshire fog (*Holcus lanatus*) and annual grasses (*Poa* and native species) contributed more to the sward as tree stocking increased. Pine needle litter cover was 40% by tree age 9 at 400sph (Percival et al., 1984). These trials are now nearing maturity and it is an appropriate time to summarise and review the results to date.

METHODS

Pasture species composition was determined by two methods:

1. Herbage dissection: Analysis was based on the proportional dry weight contribution of each species (Lynch, 1966). Hand cut pasture samples were taken from within exclosure frames and dissected into Perennial ryegrass, clovers (predominantly white clover), other grasses and weeds. The regularity of measurements varied over time and between the four experiments. The Tikitere trial near Rotorua in the North Island, with 2 hectare treatment replicate blocks of 0, 100, 200 and 400sph was the most intensively measured experiment. Seasonal dissections were completed on each treatment for years 3-9. From year 10 (1983) spring and autumn dissections were carried out on selected treatments each year up to age 19. At Whatawhata Research Station, near Hamilton, North Island (with 1.25-2.45 ha blocks of 0, 100, 200 and 400 sph) and the two South Island sites (900km to the south) at Invermay Research Station (with 0.4 ha blocks of 0 and 100 sph) and Akatore in Eastern Otago (with 0.6ha blocks of 0, 100, 200 and 400 sph), herbage dissections were determined periodically up to tree age 24 and 19 respectively. The annual yields of pasture species were estimated using the spring dissection analysis and the measured total pasture yields. Results are also expressed as a percentage relative to open pasture.

2. Point Analysis: This method was used at the Tikitere trial site only. The method as described by Lynch (1966), estimates the amount of ground surface covered by the leaf spread of the different species using a needle point analyser and recording species on a first hit basis. At Tikitere, eight permanent 5m line transects were established in each plot in 1973. In open pasture (Nil sph) they were random for location and orientation, but in 100, 200 and 400 sph they were marked out along the interrow space. All transects were kept free of thinning and pruning debris for the duration of the trial measurements. Botanical cover was determined each spring on regrowth pasture about 6cm in height to tree age 9 years from 50 needle points per transect. From tree age 9 to 20 years, botanical cover was determined every 2-3 years on a first hit basis. All trial sites were regularly grazed by sheep and/or cattle from tree age 3-15, but then generally laxly grazed.

RESULTS

By tree age 10 at the Tikitere site there had already been a major decline of about 50% in ryegrass and about 75-80% in clover productivity at 100sph, and an even greater decline at 200 and 400sph stockings compared with the composition of open pasture (Table 1). There had also been a marked decline in the 'other grasses' component. These changes were predominantly driven by the fall in total pasture dry matter production by this time (Percival et al., 1984) in the agroforestry areas. Over the next eight years at Tikitere the pasture in the high tree stocked areas declined to zero. This occurred by age 14 in the 400sph and by age 18 in the 200sph treatment. The decline in ryegrass and clover content over the period of tree age 10 to 19 was more rapid than for the 'other-grasses' category. At 100sph at tree age 10, the proportional contribution of clover to total dry matter production at Tikitere was 19% (28% at age 12), whereas at Akatore and Invermay the proportions were 67% and 78%

respectively. These had fallen to 32% and 24% respectively at tree age 19 when the presence of clover at Tikitere had declined to about 2%. The proportional contribution by 'other-grasses' compared with the open pasture was high (75-111)% in the 100sph areas at all sites at tree age 10. By age 19 this had fallen to 37% at Tikitere and to 13% at Akatore but was still at 63% at Invermay. The relative difference between treatments at the Whatawhata site are not so easy to compare because of the lack of an open pasture site measurement on most occasions and the comparatively few measurements. However, between tree ages 14 and 16, there were large reductions in the yields of ryegrass and clover in the 100 and 200sph treatments and by tree age 22, there was negligible pasture remaining in any treatment. The point analysis results from Tikitere indicated that ryegrass cover was maintained in open pasture, but declined at increasing rates as tree stocking increased (Table 2). A similar trend occurred with clover, whereas pine needle litter increased, and was measured at 93% cover by tree age 20 at 200sph.

DISCUSSION

In the tree establishment phase of an agroforestry system, sudden marked changes in pasture management can modify the pasture composition. At Tikitere and Whatawhata which were closed from grazing for up to two years after planting, Yorkshire fog and dead matter increased. At Invermay, haymaking reduced ryegrass and white clover percentage, but increased cocksfoot and other species. However, once grazing resumed, higher quality pasture species returned. Composition was then modified by the increased tree growth and canopy closure. The estimate of the contribution of each species to total production at any one time was derived as the product of annual production and a herbage dissection measurement made in spring (Table 1). This approach was used, rather than just presenting percentage composition results, because of the dramatic decline in total dry matter production within the tree treatments over time. This factor caused the major effect on the dry matter contribution by each species to fodder availability and it was therefore considered the most appropriate method of presentation.

The decline of clover content in the pasture as a result of canopy closure is the component of most interest as this represents the basis for pasture production in the absence of any nitrogen fertiliser application. At Tikitere there was negligible clover present in the 400sph areas at tree age 10, in the 200sph areas at age 14 and in the 100sph treatment by age 19. The decline in ryegrass, a relatively high nitrogen demanding species, followed by a similar pattern to that for clover content. The more prolonged presence of other, often lower fertility demanding species, is not unexpected. The records from the other trial sites were less complete, reflecting the lower resources available. However, results from the southernmost Akatore and Invermay sites are of greatest interest in evaluating if the difference in latitude, and associated temperature, resulted in significant differences in the timing of species composition changes. This limited comparison suggests that clover production persisted for longer in the tree rotation at the southern sites. The effects on ryegrass are less clear but tend to suggest that this species was not so persistent, especially at Akatore.

The apparently later species composition changes which occurred at the southern sites, would be expected as a result of the slower tree growth, canopy closure and associated less needle fall than has been measured at the northern (Tikitere and Whatawhata) sites (Dean pers comm; Cossens and Hawke, in prep). The 'first hit' point analysis used at Tikitere to monitor species composition changes provided a similar linear trend to that derived in Table 1. The results obtained by this technique were however subject to variation in preceding needle fall which occurred in some years as a result of strong winds. The more needles that were on the surface then the less was the likelihood of the pasture species being recorded. This of course was more the case as the trees matured. Compared with open pasture the contribution of the high quality species, ryegrass and clovers to total available pasture, had declined considerably by years 10-12 in the 100sph treatment at Tikitere, e.g. in year 12 clover comprised 40% of the total production in open pasture, whereas in the 100sph treatment clovers contributed only 25% of total growth. Conversely Yorkshire fog and the lower quality 'other-grasses' such as browntop (*Agrostis capillaris*), sweet vernal grass (*Anthoxanthum odoratum*) and Poa species provided a greater contribution. The relative value of such pasture for grazing stock would therefore also be expected to have declined. This effect was more pronounced in the later years of pasture availability and so as a result of both lower production and low nutritional quality, would provide little useful pasture for the land manager. In general, where conifers are grown for timber production, the economics necessitate high wood volumes and small branching, requiring tree stockings of 250-350sph. In these situations in New Zealand, improved grasses will be gradually replaced by annual and native grasses until the tree canopy closes. Under complete canopy cover, the ground will be smothered by pine needles. This process appears to be slower by several years in the South compared with North Island sites.

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Table 1
Estimated pasture species yields (kg DM/ha) over the period of tree age 10-22 years from four Agroforestry trials in New Zealand. Relative yields compared with open pasture are shown in brackets.

	Location	Tikitere				Whatawhata				Akatore				Invermay	
Tree stocking (sph)		0	100	200	400	0	100	200	400	0	100	200	400	0	100
Tree Age (Years)	Pasture Species														
10	Ryegrass	2588	1220	379	71	-	-	-	-	226	80	164	147	4728	3958
			(47)	(15)	(3)					(35)	(73)	(65)		(84)	
12		2672	960	100	5	-	-	-	-	-	-	-	-	-	-
			(36)	(4)	(TR)										
14		3105	445	18	-[1]	-	202*	28*	-	280	56	0	36	-	-
			(14)	(1)							(20)		(13)		
16		3371	345	11	-	-	11*	1*	-	-	-	-	-	3760	1387
			(10)	(TR)[2]											(37)
18		2113	274	-	-	-	-	-	-	-	-	-	-	-	-
			(13)												
19		1870	39	-	-	-	-	-	-	326	11	11	0	2477	608
			(2)								(3)	(3)			(25)
22		-	-	-	-	3541†	16†	-	-	-	-	-	-	-	-
							(TR)								
10	Clover	791	152	103	18	-	-	-	-	1429	958	1149	735	1655	1286
			(19)	(13)	(2)						(67)	(80)	(51)		(78)
12		3224	907	100	14	-	-	-	-	-	-	-	-	-	-
			(28)	(3)	(TR)										
14		2462	333	18	-	-	77*	19*	-	419	226	152	107	1598	405
			(14)	(1)							(54)	(36)	(26)		(25)
16		1798	241	0	-	-	7*	0*	-	-	-	-	-	-	-
			(13)												
18		592	75	-	-	-	-	-	-	-	-	-	-	-	-
			(13)												
19		1955	39	-	-	-	-	-	-	326	108	0	0	639	152
			(2)								(32)				(24)
22		-	-	-	-	224†	0†	-	-	-	-	-	-	-	-
10	Other	2588	1931	1515	450	-	-	-	-	5264	5825	5665	5366	4846	4057
	Grasses		(75)	(59)	(17)						(111)	(108)	(102)		(84)
12		2119	1707	1426	129	-	-	-	-	-	-	-	-	-	-
			(81)	(67)	(6)										
14		2998	1408	819	-	-	481*	285*	-	5173	4625	4157	2706	-	-
			(47)	(27)							(89)	(80)	(52)		
16		4269	1586	348	-	-	128*	45*	-	-	-	-	-	3572	3006
			(37)	(8)											(84)
18		4225	897	-	-	-	-	-	-	-	-	-	-	-	-
			(21)												
19		3995	1492	-	-	-	-	-	-	3060	389	269	0	3516	2231
			(37)								(13)	(9)			(63)
22		-	-	-	-	7814†	213†	-	-	-	-	-	-	-	-
							(3)								

1 not measured
2 Trace (less than 1%)
* 8 weeks spring measurement of pasture growth
† 12 months measurement of pasture growth

Table 2
Ground cover (%) by pasture species in agroforestry treatments over the period of tree age 11-20 years at the Tikitere trial site (point analysis method)

		% Cover, First Hit				
Tree Stocking (sph)		0	100	200	400	S.E.D.
Tree Age (years)	Species					
11	Ryegrass[2]	33	28	14	3	4.1
13		33	17	8	1	3.0
15		37	10	4	-[1]	2.7
17		38	6	7	-	4.8
20		36	4	0	-	2.5
11	Clover[2]	33	15	12	6	3.8
13		29	20	10	1	3.3
15		20	11	4	-	2.4
17		25	9	4	-	3.7
20		24	2	3	-	1.2
11	Other Grasses[3]	24	33	36	10	NA
13		22	34	20	5	NA
15		30	37	18	-	NA
17		31	33	17	-	NA
20		32	23	12	-	3.9
11	Pine Needles	0	17	33	59	NA
13		0	28	62	86	NA
15		0	39	58	-	NA
17		0	46	63	-	NA
20		0	76	93	-	NA

Note (1) — Not measured, assumed 100% pine needles

Note (2) — Transformed angular analysis

Note (3) — Untransformed analysis