INVERMAY AGROFORESTRY TRIAL
RESULTS FROM 1974-1995

G.G. Cossens and G.S. Crossan

Report No. 27 **November 1995**

FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

EXECUTIVE SUMMARY

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The Invermay trial was established in 1974 on rolling cultivated downland. Final tree stocking treatments of *Pinus radiata* were 0, 80 and 105 sph, made up of 6 replicates of 0.4 ha plots. Grazing throughout the trial was with a non-resident sheep flock. Tree growth was measured regularly with no significant differences between the 80 and 105 sph treatments.

There was no significant effect of trees on pasture yield in the first 11 years. By year 16, there was a significant reduction in yield compared with open pasture, irrespective of tree stocking. Pasture composition also changed after year 11. By year 16 there were substantial reductions in rye grass and white clover in the tree treatments.

Livestock carrying capacity decreased from 95% of open pasture in the tree treatments at year 8 to 57% by year 16.

Soil phosphorus and sulphur levels have risen significantly under the trees over the latter years of the trial, while soil pH has decreased at tree age 21.

This report is an update of and replaces the Agroforestry Research Collaborative Report No. 11, May 1991.

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INVERMAY

The Invermay trial, established in 1974, was on rolling cultivated downland, the pasture having been sown out in 1952. Grazing was with sheep and initial tree densities were 0, 400 and 750 stems/hectare. Thinning and pruning were carried out in 3 lifts completed by 1984; the final pruned height being 6 m and the final density 80 and 105 stems/hectare. There were six replicates of 0.4 ha paddocks (plots) for the 3 initial and final tree densities.

Animal Stock

The trial was grazed by a non-resident sheep flock and careful management ensured the rotationally grazed pasture was seldom longer than 15 cms nor shorter than 3 cms. Between 1974 and 1986 the mean annual number of grazings for each replicate paddock (there are 6 replicates per treatment) was 4.0, 3.4 and 3.1 respectively at 0, 400 and 750 stems/hectare. The differences were due to slash cover on the ground and, at least until 1986 not to trees per se. The annual dry matter on offer over all treatments from 1983 to 1986 was 650 kg DM/su/ha; the range being 530 to 930. As stock were short term (1 to 2 weeks) visitors to the trial no stock performance data were recorded.

Tree Stock

Initial tree densities were 0, 400 and 750 sph (9.2 x 2.8 and 7.3 x 1.8 m spacing), and the final densities achieved after the 9th year were 80 and 105 sph. Tree growth rate, on this location (with a site index of 22) has averaged about 1m/year, the height now, at 21 years, being 22.1 m and the diameter at breast height 56 cms with no significant differences between 80 and 105 stems/hectare. The effect of slash in reducing pasture availability for grazing reached its maximum in 1985/86 with a 26 and 23% reduction at 400 and 750 sph respectively, decreasing to about 1% in 1994/95. Needle fall has been light and was assessed during 1989/93 when it amounted to 4.2 kg DM/day at 80 and 105 sph, with no difference between tree density. Indications are that ground cover of needles increased from 18 to 45% from 1990 to 1995 (Table 1).

Pasture Composition

During the first five years hay was taken off the trial leading to a decline in ryegrass and clover from 30 and 15% respectively, as components of the total herbage yield in 1974/75, to 15 and 5% in 1978/79. Once haying ceased in 1979 and strict rotational grazing was introduced, ryegrass increased to 45% and clover to 14% by 1982/83. These levels were maintained until 1985/86. There was no significant effect, among the various tree densities, on any of the herbage components with the exception of clovers in 1977-78 and 1985-86. There was a deterioration in under-tree pasture composition after 1986 and by 1990 the components were ryegrass 37, 19 and 21% respectively at 0, 80 (400) and 105 (750) stems and clover 15, 4 and 6%. At the last assessment in 1992-93 ryegrass was 31, 9 and 15%; and clover 8, 2 and 4% respectively at 0, 80 and 105 stems/ha the balance being mainly other grasses.

Pasture Yield

Disregarding slash there was no significant effect of trees on pasture yield as compared to open pasture until after 1985/86, that is in the first 11 years. By 1990 pasture under trees, irrespective of tree density, recorded a highly significant 41% reduction in yield as compared to open pasture. It is worth noting that for 50 percent of the years from 1974 to 1986 pasture within the trees gave a non-significant higher yield than open pasture (Table 1)

Soil Chemical Analysis

Soils within all treatments were analysed for pH, Ca, K, P, Mg, Na, S, C, N and there were no indications of any detrimental effect of trees. Because of annual topdressing with superphosphate at about 240 kg/ha soil P levels have risen from a low of 9 in 1974 to a level of 19 on control, 52 at 80 stems/ha and 46 at 105 stems/ha in 1995, this difference between control and trees being highly significant. There was a similar rise in soil sulphur levels from 7 in 1979 to 13, 22 and 19 respectively at 0, 80 and 105 stems/ha, again significant between trees and no trees. Soil pH has remained at 5.5 on control but tended to fall in the presence of trees to 5.3 in 1995. Soil organic carbon and nitrogen have remained steady at 5.3% and 0.38% over the life of the trial (Table 1).

TABLE 1 — Herbage yield, livestock carrying capacity, slash cover, soil pH, P. S.

	Invermay							
Year	**1**	**3**	**6**	**9**	**12**	**17**	**19**	**21**
Trees/ha	1974/75	76/77	79/80	82/83	85/86	90/91	92/93	1994/95
0								
DM kg/ha	8900	9120	8710	10570	10470	9400	7990	ND
pH	5.6	5.5	5.9	5.6	5.5	5.5	5.5	5.5
P	9	15	7	18	14	12	19	19
S	ND	ND	8	12	17	10	13	ND
400-80								
DM kg/ha	9200	9200	9920	8970	10540	5570	4810	ND
LCC %	100	100	100	95	79	55	57	ND
Slash %	ND	ND	ND	5	26	7	5	1
pH	5.5	5.6	5.8	5.6	5.5	5.4	5.4	5.3
P	9	20	13	22	20	16	24	52
S	ND	ND	6	8	16	11	22	ND
750-105								
DM kg/ha	9350	9070	8950	8620	9250	5990	5330	ND
LCC %	90	90	90	92	77	59	63	ND
Slash %	ND	ND	ND	8	23	7	5	1
Phd	5.5	5.6	5.9	5.5	5.6	5.5	5.3	5.3
P	10	19	13	22	19	22	31	46
S	ND	ND	7	9	16	11	19	ND

Livestock Carrying Capacity

The combined effect of trees and slash indicates an actual stock carrying capacity (compared to open pasture) from zero in the first year (because of possible tree damage by stock) to a maximum of about 95% irrespective of tree density of 80 to 105 sph in year 8 (1982/83) and after this declining to 57% by the 16th year 1990/91 and remaining about this until 1994/95 (Table 1). Note that the potential carrying capacity, disregarding possible tree damage by stock, ranged from 100% in the first year 1974/75 to 60% by 1992/93 (Table 1)

FOREST GRAZING TRIAL - INVERMAY

MAF Project I313	Commenced August 1974
MOF Project S489	

LOCATION, SOIL, ENVIRONMENT

Location:		Invermay Agriculture Centre, Mosgiel
Map Reference		NZMS 1 S163 063 728 NZMS 260 I44 075 798
Land Capability		LoNo-Wr-C lIIe12 1Sh-Pl,2ll
Soil		Warepa Silt Loam
Altitude		80 to 108 m
Rainfall		775 mm
Aspect		NE and SW easy rolling
Initial Vegetation		22 year old Ryegrass, clover pasture
Previous Fertiliser		250 kg/ha superphosphate annually + lime + molybdenum as required
Previous Stocking		Sheep at 15 su/ha/year
Trial Design	*Initial*	3 Tree densities: 0 400 750 stems/hectare Tree spacing m 9.2 x 2.8; 7.3 x 1.8 m
	Final	3 Tree densities: 0 80 105 stems/hectare 6 replicates of each treatment
	Area	18 Plots (paddocks) 0.4 ha each = 7.2 ha
	Total Area	7.3 (includes lanes)

INVERMAY FOREST GRAZING TRIAL I313
SUMMARY FOR YEARS 1974 TO 1995

METHODS

1. LOCATION, SOIL, ENVIRONMENT

The trial was established at Invermay Agricultural Centre in August 1974 (Figure 1) with final observations in 1995. The site (Figure 2) of 7.3 ha was divided into 18 paddocks (plots) of 0.4 ha each and Pinus radiata trees were established at 3 densities. The trees were planted into an existing 22 year old [sown 1952] high fertility improved grass-clover pasture on an easy rolling yellow-grey earth, a Warepa silt loam. The plots varied in altitude from 80 to 108 m and straddled both sides of a ridge whose axis ran NNW.

Mean annual (23 years) pasture production for a Warepa soil at Invermay of altitude 90 metres, was 10650 kg DM/ha (Cossens 1990). The climate was humid in character, the mean January, July and annual temperatures being 14.7, 5.0 and 10.1°C respectively. The warm season of the year from November to April inclusive had 1453 growing degree days greater than 5°C and 569 greater than 10°C. Temperatures at the Invermay forest grazing site, altitude approximately 90 m, can be accurately predicted [Chiew - 1976] from the Invermay climatic station [NZ Met Service I50835].

2. CULTIVATION AND TOPDRESSING [Table 1]

At planting the 22 year old pasture had been topdressed annually with approximately 250 kg/ha superphosphate, and this was continued with few exceptions until 1995. Originally the paddock was ploughed out of old browntop pasture in July 1950, limed and sown with swedes in November 1950. Rape was sown in November 1951 and the present pasture sown on 25 November 1952 using the following seed mixture.

Perennial Ryegrass	17 kg/ha)		
Short rotation Ryegrass	12 kg/ha)		
Cocksfoot	6 kg/ha)	Grasses	39 kg/ha
Timothy	3 kg/ha)		
Dogstail	1 kg/ha)		
White Clover	3 kg/ha)		
Montgomery Red Clover	2 kg/ha)	Clovers	7 kg/ha
Cowgrass (Red Clover)	2 kg/ha)		
TOTAL SEED MIXTURE	46 kg/ha		

Details of the complete historical time sequence of pasture topdressing are given in Table 1. Trial I 9/0 which commenced on the block in 1961 and concluded in 1970, had as its treatments, 2 rates of superphosphate (125 and 375 kg/ha) x two stocking rates. Molybdenum was applied in 1953, 1954, 1969, 1974, 1985, and DDT for grass grub and porina control was applied in 1955, 1959 and 1961.

The superphosphate topdressing was equivalent to 244 kg/ha or approximately 21 kg P and 31 kg S annually for the 46 years 1950 to 1995. From 1950 to 1971 fertiliser was applied by ground spreading and from 1972 to 1995 by aerial application. Lime was applied only twice, once at ploughing in 1950 and again in 1964, the application rate at each of these two dressings being a little over 2 tonnes/ha.

Most topdressing was usually carried out in the August - September period of each year.

3. **EXPERIMENTAL** [Figures 1, 2, 3 and 4]

Initial tree densities at planting on 22 August 1974 for the Pinus radiata stock were 0, 400 and 750 stems per hectare (S.P.H), corresponding to spacings of 9.2 x 2.8 m and 7.3 x 1.8 m respectively (Table 1a, Fig. 3). There were six replicates of each treatment and the 0.4 ha plots (paddocks) were partially randomised so that the tree plots were generally on the middle to upper slopes of the block and the control plots on the lower slopes. This procedure and the access lane arrangement was adopted in order to partially overcome any effect on the pasture from the diurnal shading of the sun by the trees. The plots were individually fenced and it was proposed to have early and late grazing treatments: the former by introducing sheep in the first autumn (1975) after planting and the latter in the third autumn (1977). Because of severe damage to trees the "times of introduction" were abandoned after the first autumn grazing. In March 1981, slash and no-slash (that is all slash physically removed from the trial) treatments were introduced within the tree densities. The control treatments from this time still had 6 replicates but the various tree densities and their corresponding slash treatments had only three.

4. **CLIMATIC EFFECTS** [Tables 2, 3, 4]

Soil moisture levels in the 0-8 cm soil depth were monitored by gravimetric sampling at three weekly intervals on all treatments from 1979/80 to 1981/82 (years 5-7), Table 2. Daily wind run was also recorded and converted to wind speeds. The anemometers were 13 cm diameter - 3 cup instruments, mounted 50 cm above ground. In 1978/79 they measured the effect of grass hedges and trees on wind run and in 1979/80 of the differing densities of trees (Table 3).

All other meteorological information was recorded at the Invermay Meteorological Station [NZ Met Service I50835] at 30 m altitude some 500 m from the forest grazing trial site. This data included air and soil temperatures as well as wind velocity and direction, solar radiation and rainfall (Table 4).

5. **GRAZING MANAGEMENT** [Tables 5, 6]

The trial was grazed by a non-resident flock, the visiting stock coming from Invermay farm, and they rotationally grazed the individual treatments. Because of damage, not only from sheep, but also from hares and rabbits, trees were protected by flexinet fencing from autumn 1976 (and in winter 1977 by electric grass fences on one replicate) until the end of the 1979/80 season. Hay was cut from all replicates during the first three years of the trial, however, no cut was possible in summer 1975/76 because of drought conditions. Grazing was intermittent until spring 1979 when haying ceased. The annual number of grazings shows that under this system 400 and 750 stems/hectare gave 78 and 73% respectively of the open pasture (control) grazing (Table 5); however pasture production per unit area was not affected by the presence of trees, the loss in grazing area being due to the presence of the fences and slash from thinning in 1977.

After 1979 intensive rotational grazing was introduced. Each rotation of the trial took about a month, the non-resident flock numbers, of ewes or wethers, being adjusted from the main Invermay flock to suit pasture growth. Stocking rate was such that pasture was generally kept well grazed to about 3 cms. If pasture growth was rapid additional stock were placed on the trial and it was very rare that pasture was ever longer than 15 cms. At no stage was the trial overgrazed, nor was there any feeding-out on trial paddocks or lanes. All stock movement was controlled by the farm shepherd.

Records of movement and numbers of stock were kept from June 1983 until November 1986. A summary and analysis of these is shown in Table 6. The information must be regarded as reasonably approximate, mainly as the factors used to convert various types of stock to stock units were applied generally to sheep of varying weights and ages.

The conversion factors used were:

Ewe and lamb	= 1.0 SU	Hogget	= 0.7 SU
Ewe	= 1.0 SU	Wether	= 0.7 SU
Ram	= 0.9 SU	Lamb alone	= 0.4 SU

Since stock were not continuously resident on the trial it was not practical to monitor their performance. A line of stock may have been on the trial for as little as a few days or as long as two to three months. There were no indications that stock performance was in any way impaired by the presence of trees, slash, or needles on the ground as needle fall was very light. There was some slight debarking of trees, but it was never severe.

It is possible to make a comparison between grazing days and dry matter production (excluding and including slash) and this is noted on page 16 and in Tables 5a, 6. There were 18 plots of 0.4 ha each in the trial giving a total area of 7.2 ha (lanes are not included). "Slash" and "no slash" tree plots, had 3 replicates and their combined area was 1.2 ha; the control or nil tree plots however have 6 replicates.

Since Table 6 gives a mean value for all treatments the actual SU/ha and number of grazing days for the year or season is obtained by multiplying data in Table 6 for -

Nil-trees by 6 (6 reps for nil trees)
Plus or minus slash by 3 (3 reps for trees + slash or Trees - slash)
Plus Trees by 6 (6 reps for any tree density)

The carrying capacity in SU/ha = $\dfrac{\text{grazing days}}{\text{Area grazed} \times \text{no.of days grazing}}$

That is total stock grazing days Table 6 = $\dfrac{\text{Mean grazing days} \times 6(or 3)}{0.4(or 1.2)}$

The year is from June to the following May, with the number of days per season thus:

Winter 92 days		**Spring 91 days**		**Summer 90 or 91**		**Autumn 92**		**Year**
June	30	Sept	30	Dec	31	Mar	31	365 or
July	31	Oct	31	Jan	31	Apr	30	366
Aug	31	Nov	30	Feb (29 in 84)	28	May	31	

It should be noted when grazing days and dry matter production are compared that:

(i) There were drought conditions from January to March 1985.

(ii) There were drought conditions in January 1986 and as the data for stock grazing days were unreliable they were omitted for that month.

(iii) No dry matter or herbage dissections were made in 1986-87 because of financial and staff constraints.

6. TREE MANAGEMENT [Figures 2, 3, 4; Tables 7, 8, 9, 10]

Pinus radiata were used as stock; the initial plan at Invermay was to thin in three operations from 750 or 400 to 200 stems per hectare, later changed to 100 stems per hectare. No production thinning was undertaken.

Pasture at Invermay was spot sprayed on 16 August 1974 prior to planting on 22 August 1974. Subsequently first year tree release was by hand-mowing or spraying. Damaged trees were blanked in August 1975; a further release spraying was made in January 1976. Damage to trees following stock introduction is recorded in Table 7.

The best trees were to be thinned to the final density and pruned to 6 m in height (Table 8). Trees at Invermay were 9.4 years old when pruned to 6 m in height and thinned to their final density of between 70 and 110 stems per hectare (Table 8). Tree heights (Table 10) were available during the life of the trial and permanent sample plot measurements from May 1981, the permanent sample plots being 1000 m^2 in area. Slash cover from thinning and pruning debris was determined, usually in March and October, in four random 50 m line transects per plot along which the availability of pasture to stock was visually assessed at 1 m intervals (Table 8). The data in Table 8 are presented as the percentage of the pasture area available for grazing. In general this is given by:

100 — % area covered by slash = % available pasture.

Full details as to the techniques used to estimate slash cover are given in Appendix 1.

<u>Needle fall:</u> was assessed only from November 1989 as prior to this visual observations indicated light needle fall. 1 needle box 1 x 1 m was placed in each tree plot and the Dry Matter yield of needles assessed every three to four months. This means there are six replicates to estimate needle fall for each of the two tree densities. Measured needle fall (DM kg/ha) over various periods from 1989 to 1993 was as follows:

1989 - 90 Stems/ha	**80**	**105**
27.11.89 to 30.4.90		
(154 days)	500 kg	647 kg
DM kg/ha/day	3.3	4.2
1990 - 91		
17.10.90 to 17.12.90	49 kg	45 kg
(61 days)		
18.12.90 to 1.7.91	738 kg	877 kg
(195 days)		
17.10.90 to 1.7.91	787 kg	922 kg
(256 days)		
DM kg/ha/day	3.1	3.6
1991 - 92		
1.7.91 to 30.11.91	875 kg	853 kg
DM kg/ha/day	5.8	5.6
(152 days)		
1992 - 93		
21.9.92 to 5.7.93	1217 kg	1136 kg
DM kg/ha/day	4.2	4.0
(287 days)		

In terms of DM yield of needles as kg/ha/day there has been little variation from November 1989 until July 1993, the yield being within the range 3.1 to 5.8 kg DM/ha/day. Assuming 4.2 kg DM/day this would amount to 1530 kg DM/year. Visual observations of ground cover of needles below the tree measurement plots by June 1995 indicate irregular needle cover of 20 to 70% at those sites. Point analysis earlier on 5.11.90 shows tree plots to have 3 to 26% of needle cover, a mean of 17.5%. Herbage dissection on 24.5.93 estimated needles at 3.3 to 40.6% of the total pasture with a mean of 21.6%. Ground needle cover on the basis of these rather irregular observations would indicate a slow increase over the years 1990 to 1995 from 17.5% to 45%.

7. HERBAGE DRY MATTER YIELD [Figures 6, 7; Tables 11 to 17]

Pasture production was measured by mowing 3.3 x 1.5 m movable pasture exclosure frames (Figure 5). The Australian difference technique was used at Invermay from 1974 to 1980/81, and the standard rate-of-growth method for 1981/82 to 1985/86 (Lynch 1960) (Tables 11 to 15). Comparisons of haying and non-haying pasture yields are shown in Table 11 (see also pages 7 and 8).

Annual reductions and/or increases of the pasture area available to stock because of slash are outlined (Tables 12, 13) as also are tree effects (Tables 14, 15) as shading and roots. The last two tables also report adjusted herbage dry matter yields when allowing for both slash cover and tree effects, and further detailed in Table 17 when grazing days were available (see also Table 6).

During the period 1978 to 1982 residual herbage and herbage consumed above, or below, mower height (2.5 cms) was determined from 0.25 or 0.1 m2 quadrates taken from pre and post grazing frames. Mowing interval from 1981/82 to 1985/86 was generally three weeks during the September to April period with longer intervals in the winter. Above and below mower height components given for 1981/82 (Table 17) were characteristic of trends on Invermay and in order to be more representative of the period of the trial post-grazing residues have been collated with other Invermay data, with which they showed a similar pattern, and combined (Figure 7) to span the period 1974 to 1982 (Cossens 1990). Annual production data was from 1 June to 31 May with winter as June, July, August.

Because of financial restrictions there were no estimates of herbage yield from the 1986/87 year until 1989/90. Herbage yield was estimated again in 1990 - 91 and in the 1992 - 93 period by means of an electronic pasture probe. Estimates of yield in 1990 - 91 and 1992 - 93 are weak because of lack of detail in herbage components, in particular the proportions of needles present. Needle yield as a percentage of total herbage yield was taken as 17.5% in 1990/91 and 21.6% in 1992/93 based on point analysis and herbage dissection respectively

8. PASTURE COMPOSITION [Table 18, Figure 8]

Pasture composition was assessed by herbage dissection at each mowing cut for the period 1974/75 to 1985/86. Point analyses of pasture composition was made in November 1990, and finally by herbage dissection on 24.5.93 as noted in the previous paragraph these latter two analyses of pasture components do not give a reliable indication of the yearly proportions of herbage. They give an indication only.

9. PASTURE DIGESTIBILITY [Table 19]

Spring, summer and autumn samples of herbage, above mower height, on offer to sheep at Invermay were analysed for digestible organic matter over the 1979/80 to 1981/82 seasons (Table 19).

10. HERBAGE CHEMICAL ANALYSES

No analyses were made on either pasture or tree herbage.

11. SOIL CHEMICAL ANALYSES [Tables 20, 21, 23]

Soil nutrient status in the 0-7.5 cm soil depth was determined annually by analysis for pH, Ca, K, P, Mg and less frequently SO_4 - S The long term historical time sequence for the pre-agroforestry period is given in Table 20 (1953 - 1974). General analyses of the soil nutrient status for the agroforestry years 1974 to 1995 are shown in Table 21, and in more detail for the years 1983 to 1995 in Table 22.

Analyses for soil nitrogen and carbon were available from Trial I 9/0 (stocking & fertilizer rates) in 1963 and soil nitrogen in I313 (agroforesty) for 1978 and for soil organic carbon and nitrogen in 1990 (Table 23).

12. RESULTS AND DISCUSSION

Note: In all discussions the "farming year" is taken as from June to the following May; the seasons are:

Winter — June, July, August; *Spring* — September, October, November
Summer — December, January, February; *Autumn* — March, April, May
Warm Season — November to April inclusive

Climatic Observations

(i) Soil Moisture

Soil moisture monitoring at Invermay over the three years 1979 to 1982 (Table 2) showed a seasonal and annual trend that was significant in 1979/80 and in 1980/81, for moisture levels to increase with increasing tree density. The effect was not accentuated by periods of moisture stress and had all but disappeared after the trees were thinned and pruned in March 1981. It is possible the denser planting and canopy prior to that date was acting as a mist screen, collecting additional rainfall then precipitating it on the ground and raising soil moisture levels. Reduced wind speed within the trees may also have raised soil moisture by reducing evapotranspiration.

(ii) Wind Speed

The value of the data on wind speed (Table 3) were reduced by lack of information on wind direction. The relative effect of the grass hedges on wind speed taken between November 1978 and March 1979 showed that:

$$\frac{\textit{The wind speed in rows sided by grass hedges and trees}}{\textit{The wind speed in rows sided by trees only}} = 0.63$$

However, there were no consistent yield increases in dry matter production as might have been expected from those areas protected by grass hedges. The general, but non-significant trend, was for wind speed to be greater on the ridge and southwesterly aspect and in the absence of trees.

(iii) Rainfall

Rainfall at the trial site (Table 4) from 1974 to 1990 showed the dry periods to be as follows, assuming that:

the "cool" season of the year is May to October inclusive
the "warm" season of the year is November to April inclusive
50 mm less than normal in winter, spring, summer or autumn is "dry"
100 mm less than normal in the warm season, i.e. November to April is "dry"
150 mm less than normal in the yearly total from June to May "is dry".

Thus dry periods were:

Winter: 1982, 1987
Spring: 1975, 1976, 1981, 1985, 1988
Summer: 1975/76, 1980/81 [50% of normal], 1984/85, 1994/95
Autumn: 1975, 1976, 1981, 1985 [39% of normal], 1988, 1990 [55% of normal]
Warm Season: 1974/75, 1975/76, 1984/85, 1988/89
Year: 1975/76, 1984/85, 1988/89.

The "rate-of-growth" data from the trial do not always reflect any serious pasture production decline because of "dry" periods. Such a situation can arise for two reasons on this trial:- firstly the "rate-of-growth" data came from cuts which until 1979/80 were rather infrequent and come into the category of the "haying period" from 1974 to 1979 (see Table 11 and page 7) and: secondly the soil moisture storage from the immediately preceding period may be sufficient to maintain pasture growth well into the dry spell. Rate-of-growth data from a trial adjacent to the Invermay Agroforestry trial showed no really notable drops in spring production from 1974 to 1986. Substantial decreases in pasture yield occurred in summer 1974/75, 1975/76, (see page 7 with reference to hay making), 1981/82, 1984/85, 1985/86, 1988/89. The drop in yield in 1985/86 and 1988/89 was largely a reflection of a very dry spring followed by a moderately dry summer (February 1986 was very wet, Table 4). However it must be noted that observations of low pasture yield in 1988/89 are from actual farming practice in the movement of stock on and off the trial and from visual checks during the season. There were no actual production cuts from 1986/87 to 1989/90.

Autumn production was well below normal in 1977 - not a "dry" year - yet not notably low in the other "dry" years, even 1985 with 39% of normal autumn rainfall.

On the other hand those years with rainfall exceeding 900 mm were generally the higher yielding in exceeding 10500 kg DM on controls i.e. 1978/79, 1982/83, 1983/84. An exception was 1985/86 which although having a dry spring had a wetter than average summer and autumn.

Stock and Grazing Management

The time of introduction and removal of stock is critical in preventing serious tree damage in any given forest grazing operation. Tree damage from grazing stock can be prevented in three ways:

(i) by physical removal of stock

(ii) by fencing out tree rows and grass strips with temporary fencing, or

(iii) by using a repellant on trunks.

The first two systems were used at Invermay, however both had disadvantages: in one case tree damage was excessive and in the other competition from grasses was a serious problem unless trees were released by herbicidal control of grasses.

During the "haying regime" from 1974 to 1979 a record was kept of the number of grazings within each tree density (Table 5). The decline in the number of grazings, from 0 to 750 stems/ha, is a reflection of the decreased area of land available for grazing as tree density increases; that is the area excluded by the grass or the electric fences. The higher number of grazings on Replicate 1 (4.1 compared to 2.8 or 3.1) is a result of the more intense grazing on this as compared to Replicates 2 or 3.

From 1983 to part 1986 the number of sheep grazing days was kept for each paddock and the general means of over the period for slash and tree density treatments are given in Table 5a. If 0 stems/ha (that is control or open pasture) is regarded has having a value of 4.0 grazings, then the equivalents for 185 and 230 sph during 1983 to 1986 were 3.6 and 3.2. The two latter ratios were slightly higher than given by the mean number of grazings from 1974 to 1979 for similar treatments (Table 5) of 3.1 and 2.9 and would indicate the greater grazing area available after removal of grass and electric fences and the thinning of trees, or more effective herbage utilisation.

Because of the high variability in the grazing day analysis (Table 6), there were no significant differences between treatments except for (230-S x 185+S) and (230-S x 0) in summer 1983/84. All of which would tend to show that the presence of slash on the ground was having very little effect on carrying capacity. The 1983/84 to 1985/86 mean potential estimates of livestock carrying capacity (LCC) in Tables 14 and 15 show these to be 0.85 of open pasture at 185 sph and 0.82 at 230 sph. The actual paddock livestock carrying capacity (Tables 14,15) varied somewhat from the `potential' (or estimated) carrying capacity. The 185 sph + slash in 1985/86, being particularly much higher in actual stocking rates than even the control treatment (Table 16) and the estimated livestock carrying capacity in tables 14, 15 accordingly appears too low. Evidently pasture loss from slash cover was being compensated for by greater grazing intensity on the dry 1985/86 summer and more effective herbage utilisation. On means, summer 1985/86 was not `dry', however Dec '85 and Jan '86, were dry and February very wet (Table 4). Stock rates which were very high during 1983/84 (a "wet" year) tended to fall in the "dry" 1984/85 year and this was reflected in the pasture available per stock unit (Table 16). Stock numbers however were not increased in 1985/86 following the very dry autumn of 1985 and mean dry matter available per SU was 489, 723 and 739 kg/ha respectively for 1983/84, 1984/85, 1985/86.

Stocking rates were surprisingly high, the mean adjusted (for area decreased because of slash) stocking rates being, 21.1, 16.3 and 13.9 SU/ha respectively for 1983/84, 1984/85 and 1985/86.

Following the 1985/86 year no stock records were kept; however, the trial block was always well stocked so that the pasture was seldom much more than 15 cms nor less than 2 cms in height. It was particularly noticeable that the tree canopy was having a marked effect on pasture growth after 1986/87. Unfortunately financial restrictions prohibited further measurements until 1990/91 and 1992/93. From then on till the trial concluded in June 1995 there were no further pasture growth measurements..

Tree Management

Silviculture operations and tree growth were supervised and recorded by New Zealand Forest Service until 1988 (co-ordinated by Mr Leith Knowles, FRI, Rotorua) and then by their re-organised group as the New Zealand Ministry of Forests, or the Forest Research Institute, Rotorua.

Tree Damage

Damage recorded at Invermay up until 1980 (Table 7) is the net damage to planted and blanked trees at the time of observation and appears unduly high. Trees planted into the well established high fertility pasture were under considerable competition from grasses and this affected their rate of growth during the establishment phase and hence their susceptibility to browsing damage. Due to a combination of circumstances therefore, a large proportion of trees had poor form; these deficiencies included, butt swept trunks from poor planting, large branch size and debarking, the latter usually occurring during periods of rapid pasture growth in spring or early summer. The sheep at Invermay, not being a resident forest-grazing flock, may have contributed more to tree damage than would be the case of resident animals conditioned to trees. The damage in July 1980 was due to excessive stocking at up to 1500 SU/ha. Besides the damage recorded in Table 7 debarking occurred when the Invermay trees were 8.3 and 9.4 years of age, both periods of lush soft pasture growth. Debarking did not lead to tree death, only to butt damage from which the trees recovered.

Later damage after 1980 was as follows:

22/23 January 1983	Trees damaged by high winds
	Paddock 3 - 1 tree down - poor root system
	Paddock 6 - 1 tree down - poor root system
	Paddock 17 - 1 tree down - poor root system
6 March 1983	Paddock 2 - 1 tree down
	Paddock 3 - 1 tree down
10/11 July 1986	7 trees down due to high winds
14/15 August 1987	Trees damaged by high winds
	Paddock 2 - 2 down, 1 crown off
	Paddock 3 - 1 crown off
	Paddock 12 - 2 down, 1 crown off
	Paddock 13 - 3 down
	Paddock 15 - 3 down
	Paddock 16 - 1 down
January 1992	Branch damage due to high winds
July 1992	Branch damage due to high winds

Records are fragmentary after 1993

Pasture Dry Matter Yields

(i) Herbage above and below mower height

No significant differences in herbage dry matter yield between Control (open pasture) and either tree density were observed between 1974/75 and 1985/86 the last year during which a cage exclosure technique was used. Unfortunately there were no further pasture yield estimates until the 1990/91 season when the annual yield in the presence of trees showed a 38% reduction in dry matter production compared with control and no significant differences between the 80 (400) and 105 (750) stems/hectare treatments. In the final year of measurements (1992/93) pasture yield below trees was 63.5% that of control with no differences again between the two tree densities.

Some comment has already been made under Climate on the yield variability from season to season. The net herbage accumulation above trimming height was used to calculate rate of `growth'. Changes in below mower height (bmh) herbage mass are not considered. However, data from the Invermay Agroforestry trial allow some estimate of the magnitude of bmh herbage mass changes. As well as this trial, two other Invermay trials provide a large amount of data in bmh herbage mass changes.

Together, these three trials give a consistent picture of very substantial seasonal variation in bmh herbage mass. These changes need to be taken into account when extrapolating from the standard rates of growth to net accumulation above ground level. They are illustrated in Figure 7.

The trials considered were:

1. Invermay Flat Trial

Details of this trial may be found in a previous publication (Round-Turner et al. 1976). Standard measurements on this type of trial involve trimming areas which have been ungrazed for at least 2-3 weeks and mowing the regrowth on these areas 2-3 weeks later (Radcliffe 1974).

Additional measurements were conducted from 1979 until 1982, during which time bmh changes in the sward were monitored. One quadrat (0.1 m^2) was cut from each of three trimmed areas and from each of the three areas from which regrowth was mown. One tiller plug (78.5 cm^2) was also taken from each of these areas. The total number of grass tillers in each plug was recorded.

In the 1982/83 season, the bmh herbage was dissected into its components. Subsamples of 200-400 pieces (0.3 - 2.0 g dry matter were taken from each of the six quadrates and separated into leaf, sheath (plus enclosed stem), stolon and flowering stem (unenclosed by sheath). No distinction was made between live and dead material.

2. Invermay Farm Forestry Trial

Net herbage accumulation was measured in a total of 36 (1979-80) or 72 (1980-82) 5 m^2 frames, using the Australian difference technique (Lynch & Mountier 1954). This technique measures herbage to ground level and in this trial it was accomplished first by mowing, and then by cutting 0.1 m2 quadrates to ground level from the mown strips.

3. Mixed Grazing Trial

Data were also available from a five year trial which compared the effect on pasture production of six ratios of cattle and sheep under an intensive rotational grazing system (Boswell and Cranshaw 1978). Net herbage accumulation was measured in a total of 48 frames, using the Australian difference technique. As in the forestry trial, herbage was first mown and then sampled by cutting 0.1 m^2 quadrates from the mown strips.

In all three trials, the sward was cut with the same reel mower, leaving approximately 2.5 cm of herbage below mower height. Quadrates were cut to ground level using a portable motorised shearing unit. All quadrat material was washed before drying.

In the two trials using the difference technique, regrowth was measured from grazed pasture, so direct comparisons of above mower height regrowth with those derived from the trim technique used in the rate of growth trial, are difficult. However, comparisons of pre-grazing bmh herbage mass are valid because, in all trials, the sward was ungrazed for at least two weeks prior to being mown and sampled to ground level.

Changes Induced by Below Mower Height Herbage

In the Invermay Flat trial it was evident that rates of net accumulation during spring were higher when measured to ground level than when measured to mower height. It was also apparent that during late summer and autumn, rates to ground level may be lower than those to mower height.

These differences are of course due to changes in the bmh herbage mass. In the Invermay Flat trial this ranged from a winter low of around 300-500 kg DM/ha to a summer peak of about

2000 kg DM/ha. This excludes the rather exceptional year of 1981, when bmh herbage mass approached 3000 kg DM/ha. This was due to lax grazing combined with a dry summer which slowed the rate of herbage disappearance due to decomposition.

The two trials cut using the Australian difference technique (the forestry and mixed grazing trials) showed a similar pattern in bmh herbage mass. The farm forestry trial, measured over the same years as the Invermay Flat trial, showed a similar summer peak but a somewhat higher winter low. The mixed grazing trial showed more erratic changes in bmh herbage mass, but still had summer peaks of around 2000 kg DM/ha and winter lows of 700-900 kg DM/ha. The notable exception to this pattern was the very high herbage mass in June of 1976. This was a result of very high feeding allowances in March 1976 (6-8% of live weight per day compared with 3-5% for most grazings) and extremely dry conditions which caused ryegrass to wilt and die during early autumn of that year.

The mean annual cycle of accumulation and loss of bmh herbage for the three preceding sites is summarised in Figure 7 for the years 1974 to 1982. This means that standard rate of growth curves for above mower height herbage will be in error if they are used as estimates of net accumulation above ground level. This applied particularly to the period April-May, when losses of around 900 kg DM/ha (or 15 kg DM/ha/day) are more than 50 percent of the net rates of accumulation above mower height. Differences in the spring will also be substantial, with an increase in bmh herbage mass between September and December of about 1000 kg DM/ha, or 8 kg DM/ha/day. This is approximately 10-20 percent of the rate of accumulation above mower height.

There are a number of possible reasons for these changes:

(i) Changes in tiller numbers
(ii) Changes in the mass/tiller
(iii) Changes in the mass of litter.

Tiller numbers in the Invermay Flat trial showed little relation with bmh herbage mass and so the components of bmh herbage mass were separated out in the last year of the trial. The increase in spring herbage mass appeared to be due principally to increases in the sheath and enclosed stem, with smaller contributions from leaf and stolon. No distinction was made between live and dead material, so unfortunately it is not possible to determine what proportion of the bmh increase in herbage mass was due to the production of new material and what proportion due simply to the accumulation of dead herbage.

Nevertheless, these results indicate how the choice of sampling technique can have a major effect on the recorded rates of net herbage accumulation. They also suggest that, at least during spring, the standard `rate of growth' curves may substantially under-estimate growth by ignoring bmh sheath and stem production.

Pasture yield under trees at Invermay was significantly 13% lower than open pasture in 1983/84 up until six weeks after thinning to the final density in January 1984. However pasture growth for the remainder of the autumn responded to the new low density and although total annual yield was 9% lower than control at 105 s.p.h. (4% at 80 s.p.h.) it just failed to reach significance (Tables 14, 15). The rapidity of the pasture response to the lower tree density is noteworthy.

Mean long term (31 years) `rate-of-growth' pasture production for a three weekly mowing interval at Invermay was 10,700 kg DM/ha (Cossens 1990) and gives a base comparison yield for the forest grazing trial whose eight year mean yield (1978-86) of control plots was 10,300 kg DM/ha. If pasture yield is divided into "hay" (1974-78) and "non-hay" years (1978-84) the increase in the latter period is apparent (Tables 14, 15). The higher pasture production from 1978/79 on, coincides with the introduction of strict rotational grazing and the abandonment of haying and as such was more closely related to the long term rate-of-growth yield than the 1974 to 1986 mean. Another feature was the initially higher dry matter yield from the Invermay tree treatments. Whether this was due to the number of grazings, location of control plots, or of soil chemical properties, (the tree treatments tended to have a higher soil P test than controls) is not clear. But it did mean the inherently greater pasture yield on the tree plots had to be overcome before the effect of trees on pasture yield decline became apparent.

(ii) Pasture Utilisation

The amount of herbage available at Invermay below mower-height as shown (Figure 7) had a mean annual value of 1090 kg DM/ha and annual residuals remaining after grazing were 1500 kg DM/ha; leaving a net balance after grazing of 410 kg DM/ha above mower height, indicating, generally, no grazing below mower-height and 4% overestimate of dry matter allowance.

Livestock carrying capacities as a percentage of open pasture yield (% LCC, Tables 14, 15) were obtained as that proportion of open pasture yield recorded in the presence of trees reduced by the amount of slash debris from pruning or thinning. The LCC assessed on this basis is the potential (or theoretical carrying capacity) as distinct from the actual as carried on the trial. The potential (that is tree effect x slash effect) livestock carrying capacity and the actual (that is the stocking rate as actually carried on the trial) where available are indicated on tables 14 and 15.

The carrying capacity was high from 1978/79 and, on average, available herbage per stock unit was 640 kg DM/ha/yr at 15.5 su/ha over the six years to 1984 or 613 kg DM/ha if residual above mower height is deducted. Utilisation 1978 to 1984 to ground level was 77% and above mower height 86%. Pasture utilisation was more difficult to assess during the haying regime as was carrying capacity, as sheep were used to clean up in autumn after hay-making. The haying regime was an attempt to obtain maximum pasture utilisation at a time when under-stocking was necessary to prevent tree damage. It was unsatisfactory because of the difficulty of manoeuvring machinery within rows and a lack of turning headlands at the ends of the rows. After the trees had been protected by grass fences pasture utilisation by stock in fenced paddocks was 46% of available herbage and in unfenced 21%. However the grass fences removed 19% of the total production and tree paddocks tended to be less frequently grazed than control plots from 1974 to 1979 (Table 5). Carrying capacity may be on the high side, as the non-resident flock used, would be off the trial from four to six weeks each year, compared to a possible all year resident flock.

The data from 1983 to 1986 (Table 16) show that the stocking rates on open pasture (Control or 0 SPH) were very high in 1983/84 at 22.5 SU/ha declining to 11.2 SU/ha in 1985/86. The general decline in stocking rate at all tree densities from 1983 to 1986 was related to drought in summer 1984/85 and 1985/86. There was no notable effect of trees on pasture yield until 1986/87. Unfortunately there are no measured data from this time until 1990/91 season, and only visual observations recorded this change. In winter 1990/91 pasture production under the tree densities (80 and 105 sph) was 59% and 64% of open pasture (Tables 14, 15).

The effect of slash in reducing pasture availability for grazing reached its maximum effect in 1985/86 with a 23 to 24% reduction at 750 and 400 S.P.H. respectively decreasing to about 3% reduction in 1992/93 The maximum livestock carrying capacity (i.e. pasture yield including slash effect x tree effect) was reached in 1982/83 and thereafter declined (Tables 12, 13, 14, 15).

Pasture Composition

Figure 8 shows the changes in pasture composition since the beginning of the Invermay trial until 1985/86. The proportions of each component: Ryegrass, cocksfoot, "other grasses" and clover were approximately 45%, 8%, 26% and 14% in 1982/83. This represents a major improvement in the quality of pasture since haying ceased at the end of the fourth year of the trial, at that time the proportions of the same components were 15%, 30%, 50% and 5%. The haying regime led to a marked decline in ryegrass and clover percent of total yield after the start of the trial, and to recovery of these species after haying ceased; conversely "other grasses" and cocksfoot increased and then decreased. Open pasture tended to have more ryegrass and clover and less "other grasses" and cocksfoot than pasture under trees. By 1985/86 the properties of each component were

Ryegrass 44.4%, cocksfoot 7.1%, other grasses 24.0% and clovers 11.8% (Table 18).

The clover showed most sensitivity to pasture management being significantly depressed by the trees as compared to open pasture in 1975/76 and 1977/78 during the haying regime, and just significantly in 1985/86 possibly as a tree effect. This latter is not certain as there are no subsequent data until 1990/91. Otherwise there are no significant effects of trees on the proportions of species on the total yield as compared to open pasture at least until 1985/86 - i.e. in the first 12 years of the trial. There was comparatively little dead matter on the pasture; weeds were few, 2% or less usually; and pine needles picked up by the mower were negligible in 1985/86 with a total of 41 kg DM/ha in a grand yield of about 10,000 kg DM. After 1989 the proportion of needles present increased to 17.6% in 1990/91 and to 21.5% in 1992/93.

The unequal number of grazings (Table 5) in the presence of haying for the various tree densities would tend to alter the herbage composition rather than the tree density per se. Herbage composition after 1978 would therefore more accurately reflect tree effects. Under the current rotational grazing, ryegrass continues to replace "other grasses" (mainly brown-top, sweet vernal, dogstail) in the sward while the proportions of cocksfoot and clover appear to have stabilised.

Pasture Digestibility

In vitro DOM results from Invermay (Table 19) showed no effect of trees and the usual trend for herbage digestibility to decrease in value from spring to summer to autumn.

Herbage Chemical Analyses

Neither tree nor pasture herbage were analysed for chemical composition.

Soil Chemical Analyses (0-8 cms)

Soil chemical analyses were available for the trial site for almost every year since 1953 (Tables 20,21,22) and trees showed no detrimental effect on any of the nutrients analysed. Since 1980 when high-stocking rotational grazing was introduced there has been a marked tendency for soil phosphate levels to rise from a mean Olsen P of 7 in 1980 to 39 in 1995 with a non-significant trend to 1995 (105 stems doubtfully significant in 1990) for these to increase with increasing tree density. Soil pH at Invermay from 1974 to 1991 has shown no change in the presence of trees nor open pasture (Tables 21,22), however from 1953 — 1995 there was a decline in open pasture from 6.4 to 5.5 pH (Figure 9), lime being applied at about 2.5 and 2.1 tonnes/ha respectively in 1950 and 1964 (Table 1).

The P levels at 105 stems/hectare were significantly higher than control in 1990 and 1995 (Table 22). P levels in open pasture were generally low (11-20) during the life of the trial, with for some reason unknown, very low (<10) levels in 1979 and 1980. As noted earlier P was topdressed at approximately 21 kg/ha annually (page 6, Table 1).

Soil pH values have not been effected by the presence of trees, until years 18 and 21. In years 18 & 21 (1992 and 1995), there was a significant reduction in pH under the trees — from 5.5 in open pasture to 5.3 at 105 sph.

Soil sulphur levels have slowly increased from a mean of 7.0 in 1978 (the first assessment) to 18 in 1995, (Tables 21,22) Levels which might be described as just adequate until 1985 after which soil S levels are adequate and significantly higher in tree treatments than control in 1992. S topdressing was approximately 31 kg/ha annually (page 6, Table 1).

There are no organic C and N analyses prior to 1990 relating to this trial but there was no significant effect of trees on soil organic carbon in that year, (Table 23). Soil nitrogen levels have almost doubled since the 1978 analysis but in light of analyses of earlier trials on this site in 1963 and 1967 there could be some doubt whether this is a real or chance effect of that year, 1978.

Those soil C and N analyses available from previous trials on the same site prior to 1974 and those taken from trial would indicate a slight increase in soil organic matter but no change or a slight decline in nitrogen from a mean 4.6% C and 0.41% N in 1963 to 4.9% C and 0.42% N in 1969 and finally to 5.1% C and 0.35% N in 1990.

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APPENDIX I — Methods of slash cover estimation

Slash estimates were made using two different techniques.

(i) For 1981 and 1982. A line transect method was used where 10 points were selected randomly along the length of each plot (excluding 10m from the end). A tape measure was stretched at right angles across the plots of these points, from the centre of a tree row on one side to the centre of a grass row on the other. The proportion of the tape intercepted by slash was then recorded for each transect.

(ii) For 1983 to 1995. Four random transects are made across the paddock (plot) (0.4 ha) at right angles to the line of trees. A starting point is picked and 50 paces (1m) taken from this point. Using a sheep counter (number counter) whatever is trodden on is recorded as either useable or non-useable. Useable being clear pasture; and non-useable being pine needles (of sufficient density to kill or drastically suppress pasture), branches and any other dead matter.

The classification into useable and non-useable "pasture", depends on the judgement of the observer. If pasture has been recently grazed there are few problems. It is more difficult to classify when pasture is rank and a decision has to be made whether stock will graze under any piece of debris. In practice experience with stock grazing habits indicates the classification of useable and non-useable is reliable.

The number of hits on non-useable material is recorded on the sheep counter making the method very rapid when estimating slash cover in large flocks. As the number of hits per 50 paces is known, percentage cover of slash or other debris is rapidly estimated.

TABLE 1 - Historical Time Sequence, Forest Grazing Site Topdressing of Mo, lime and Superphosphate

	Lime (t/ha)	**Superphosphate (kg/ha)**			**Superphosphate (kg/ha)**		**Superphosphate**
1950	Lime 2.5	375					
1951		250 Reverted	1971	Trial I 9/0 closed		1991	Delayed. Air strip wet.
1952	(Sown to grass Nov)	310 Reverted	1972		375 Super	1992 Feb	175 Super
1953	+ Mo	250 Mo Super + Cu	1973		250 Aerial Super	1992 Oct	150 Super
			1974	+ Mo	375 K Mo Super	1993	175 Super
1954	+ Mo	340 Mo Super + Cu	1974	I 313 Forest Grazing Start	250 Super	1994	180 Super
1955		250 DDT Super	1975		250 Aerial Super	1995	Nil to June 1995
1956		310 Super	1976		300 Potassium Super		
1957		250 Super	1977		Nil		
1958		Nil	1978		300 Aerial Mo Super		
1959		310 DDT Super	1979		500 Potassium Super		
			1979		250 Aerial Super		
1960		250 Super	1980		250 Potassium Super		
1961	(Super Rates Trial **)	134 + DDT 334	1981		500 Potassium Super		
1962		122 370	1982		250 Super (Flowmaster)		
1963		132 419	1983				
1964	Lime 2.17 (April)	125 377	1984		200 Super		
1965	(200 kg/ha KC1)	128 1149	1985	+ Mo	200 Mo Super		
1966		125 383	1986		Nil		
1967		142 384	1987		Nil		
1968		146 351	1988		230 RPR***		
1969	+ Mo	212 379	1989	+ Mo	230 Longlife + Mo (11,0,8)		
1970	Trial I 9/0 Concludes		1990		200 Longlife Super (11,0,8)		

* Pasture Mix (kg/ha) - Perennial Ryegrass 17, Cocksfoot 6, Timothy 3, Dogstail 1, Short Rotation Ryegrass 12, White Clover 3, Mont Red Clover 2, Cowgrass 2, Total 46

** Trial I 9/0 - 2 Rates Super 125 and 375 kg/ha x 2 stocking rates

*** RPR Reactive Phosphate Rock (14% P)

Mo applied 1953, 1954, 1969, 1974, 1985. DDT applied 1955, 1959, 1961. Topdressing is equivalent to 244 kg/ha annually for 46 years 1950-1995.

TABLE 1a — Paddock and treatment numbers, tree densities and randomisation

Paddock No	Treatment Number	Treatment stems/hectare (approx thinning)
1	1	0 (Control - open pasture)
2	2	400 + Slash (400-215-200-80)
3	3	750+ Slash (750-305-200-105)
4	4	0
5	1	0
6	6	750 - Slash
7	5	400 - Slash
8	1	0
9	4	0
10	2	400 + Slash
11	6	750 - Slash
12	2	400 + Slash
13	3	750 + Slash
14	4	0
15	6	750 - Slash
16	5	400 - Slash
17	3	750 + Slash
18	5	400 - Slash
Control	Paddock 1,4,5,8,9,14	Treatments 1,4
400 + Slash	Paddock 2,10,12	Treatment 2
400 - Slash	Paddock 7,16,18	Treatment 5
750 - Slash	Paddock 6,11,15	Treatment 6
750 + Slash	Paddock 3,13,17	Treatment 3
Control	Paddock 1,4,5,8,9,14	Treatments 1, 4
400	Paddock 2,7,10,12,16,18	Treatments 2, 5
750	Paddock 3,6,11,13,15,17	Treatments 3, 6

TABLE 2 - Mean annual soil moisture at three tree densities, Invermay

	Percent soil moisture (% ODW)* (0-8 cms depth)				
Stems/ha actual (initial)	0	215(400)	305(750)	SED	CV%
1979/81	38.5	41.1	44.0	0.4	2.0
1980/81	37.6	40.2	41.2	1.9	13.3
1981/1982 Stems/ha actual (initial)	0	185(400)	230(750)		
1981/82	31.2	32.6	31.9	1.3	18.1

*ODW = oven dry wt

TABLE 3 — Mean daily windspeed (km/hr), Invermay 1979/80

Aspect	**No Trees**	**Trees**	**SD**
Ridge	5.0	4.6	1.1
NE	3.5	3.3	1.0
SW	5.4	4.0	0.7
Mean	4.6	4.0	

TABLE 4 — Rainfall (mm) Invermay

	1974/75	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	1951-80 Normal
June	43	23	98	86	76	16	253	76	62	59	38	47	96	80	53	82	77
July	134	77	40	67	216	61	74	208	22	132	69	60	73	25	66	29	46
August	44	116	106	23	142	91	86	63	44	56	38	36	93	20	32	20	63
Winter	221	216	244	176	434	168	413	347	128	247	145	143	262	125	151	141	186
September	20	44	34	125	88	40	31	42	34	78	126	27	28	86	14	46	47
October	132	37	38	58	118	76	62	70	200	66	28	40	55	69	19	106	54
November	31	43	56	48	24	41	98	19	52	40	65	51	93	45	50	54	70
Spring	183	124	128	231	230	157	191	131	286	184	219	118	176	200	83	206	171
December	88	72	123	120	122	77	46	66	130	112	72	68	66	79	56	91	76
January	38	30	98	17	62	123	13	127	101	115	54	51	72	141	56	51	73
February	60	46	30	45	32	81	46	47	61	45	31	159	93	96	51	42	56
Summer	186	148	251	182	216	281	105	240	292	272	157	278	231	316	163	184	205
March	76	9	34	32	57	81	71	39	107	144	32	95	171	26	74	14	61
April	26	28	63	95	67	89	53	52	103	30	17	28	29	31	29	54	71
May	33	72	151	75	93	55	15	98	160	71	34	80	122	67	48	50	81
Autumn	135	109	248	202	217	225	139	189	370	245	83	203	322	124	151	118	213
Year	725	597	871	791	1,097	831	848	907	1,076	948	604	742	991	765	548	649	775

TABLE 5 - Mean number of grazings per year (1974-1979) in each replicate and tree density, Invermay

	Stems per hectare			
	0	**400**	**750**	**Mean**
Replicate 1	4.3	4.2	3.8	4.1
2	3.8	2.3	2.3	2.8
3	4.0	2.7	2.5	3.1
Mean	4.0	3.1	2.9	3.3
Relative	100	78	73	

TABLE 5a — Comparison of grazing days and herbage dry matter yields. Means for 1983 to 1986

Sph	**Treatment grazing Days**	**Herbage yield (kg DM/ha)**	**Relative grazing days**
0	8260	10640	4.0*
185→80 (400)	7490	11600	3.6
230→105 (750)	6680	10560	3.2
Trees + Slash	7060	10890	3.4
Trees - Slash	7100	11270	3.4

* 8260 has an assumed Relative Grazing Day value of 4 to give some compatability with Table 5.

TABLE 6 — Mean stock days June 1983 to November 1986

	Stock grazing days					SED		CV
Stems/ha	**0**	**185+S**	**230+S**	**185-S**	**230-S**	**0**	**±S**	**%**
1983/84								
Winter 1983	440	240	240	270	280	109	126	48.8
Spring 1983	1,070	1,040	940	990	950	120	139	16.8
Summer 1983-84	1,060	1,110	710	790	670	139	161	21.8
Autumn 1984	730	660	830	550	610	135	155	27.8
Total 1983-84	3,300	3,050	2,720	2,600	2,510			
+Slash (+S)	2,890		185	(400) sph 2,830				
-Slash (-S)	2,560		230	(750) sph 2,620				
1984/85								
Winter 1984	390	300	240	350	260	129	139	53.4
Spring 1984	690	780	640	720	740	69	80	13.8
Summer 1984-85	990	470	510	710	560	244	282	49.0
Autumn 1985	300	320	230	350	390	85	98	38.5
Total 1984-85	2,370	1,870	1,620	2,130	1,950			
+Slash (+S)	1,750		185	(400) sph 2,000				
-Slash (-S)	2,040		230	(750) sph 1,790				
1985-86								
Winter 1985	160	160	160	160	160	0	0	-
Spring 1985	310	440	370	470	410	86	99	31.4
Summer 1985-86	510	510	310	400	380	109	126	35.5
Autumn 1986	660	810	420	620	620	166	191	37.1
Total 1985-86	1,640	1,920	1,260	1,650	1,570			
+Slash (+S)	1,590		185	(400) sph 1,790				
-Slash (-S)	1,610		230	(750) sph 1,420				
Part 1986-87								
Winter 1986	300	250	410	350	310	83	95	36.3
Spring 1986	650	540	460	590	520	148	171	36.8
Part Total 1986-87	950	790	870	940	830			
+Slash (+S)	830		80	(400) sph 870				
-Slash (-S)	890		105	(750) sph 850				

* Note thinning regime Initial 400 SPH → 215 Dec 77 → 185 March 81 → 80 Jan 84
750 SPH → 305 Dec 77 → 230 March 81 → 105 Jan 84

TABLE 7— Tree damage Invermay

Sph	Sep 1974 Planted Aug 1974	Tree survival %		Jan 1976 % browsed	July 1980 % barked
		May 1975*	May 1976*		
400	79.2	78.0	85.3	3.3	29.7
750	77.1	85.0	93.0	4.7	19.0

* Includes blanked trees

TABLE 8 — Thinning and pruning sequence and pasture availability 1977 to 1995

Observation	Stems per ha (sph)	Tree Age (yrs)	% Available Pasture
1st Thin Dec 1977	400 to 215	3.3	
	750 to 305		
2nd Thin March 1981	(400) 215 to 200	6.6	84.6
+ 1st prune to 2 metres	(750) 305 to 200		78.8
October 1981	(400/215) 200	7.1	90.2
	(750/305) 200		85.2
April 1982	(400/215) 200	7.7	94.5
	(750/305) 200		91.8
+ 2nd prune January 1983 (to 2 metres)	(400/215) 200	8.4	
	(750/305) 200		
23 March 1983		8.6	95.2
NB Slash removed to give slash and no slash treatments for 1983/84			
13 October 1983	(400/215) 200	9.1	95.3
	(750/305) 200		91.0
3rd Thin	(400/215) 200 to 80	9.4	-
+ 3rd prune 10 January 1984	(750/305) 200 to 105		-
18 April 1984	(400/215/200) 80	9.7	85.0
	(400/305/200) 105		83.5
+ 4th prune to 3 top whorls December 1984	(400/215/200) 80	10.3	77.3
11 December 1984	(750/305/200) 105		72.5
14 November 1985	(400) 80	11.2	82.0
	(750) 105		80.3
June 1986	(400) 80	11.9	83.8*
	(750) 105		82.0*
June 1987	(400) 80	12.9	87.6*
	(750) 105		85.5*
9 June 1988	(400) 80	13.9	91.3
	(750) 105		89.0
14 May 1990	(400) 80	15.7	90.3
	(750) 105		91.2
11 August 1995	(400) 80	21.0	99.0
	(750) 105	21.0	99.0

* Estimated

TABLE 9 — Tree density by time 1974-1995* (stems per hectare)

1974	400	750
1975	400	750
1976	400	750
1977	400	750
1978	215	305
1979	215	305
1980	215	305
1981	200	200
1982	200	200
1983	200	200
1984	80	105
1985	80	105
1986	80	105
1987	80	105
1988	80	105
1989	80	105
1990	80	105
1991 to 1995	80	105

* For date of actual thinning see Table 8.

TABLE 10 - Tree measurements at Invermay

Tree age (years)	Year	Height (m)		Dbh (cms)		Green crown length	
		400*	**750***	**400***	**750***		
0.8	1975	0.4	0.4			0.4	
1.8	1976	0.7	0.7			0.7	
2.8	1977	1.2	1.2			1.2	
3.3	1978 Thin	(215)	(305)				
4.9	1979	2.4	2.3			2.4	
6.6	1981 Thin	(200)	(200)				
6.6	1981	5.3	5.4	11.5	11.6	3.3	
7.0	1981	6.0	6.0			4.0	
8.5	1983	7.7	7.9			5.8	
9.0	1983	8.8	8.9			6.9	
9.4	1984 Thin	(80)	(105)				
10.0	1984	9.5	9.6		22.3	3.8	
11.0	1985	10.9	10.8	23.4	23.8	5.2*	5.0*
12.0	1986	11.8	11.7	25.9	26.4	6.0	5.9
13.0	1987	13.3	13.4	29.9	30.2	7.6	7.6
14.0	1988	-	-	-	-	-	
15.0	1989	-	-	-	-	-	
16.0	1990	16.3	16.0	40.7	39.7	10.6	10.2
21.1	1995	22.6	21.9	56.9	55.2	-	

*400 and 750 sph

TABLE 11 — Mean pasture yield (DM kg/ha) at Invermay during haying and non-haying periods

	s.p.h.	**0**	**400**	**750**	**Mean**	**SED**	**CV%**
Haying	1974/78	7,870	8,470	8,830	8,390	412	6.9
Non Haying	1979/86	9,820	10,240	9,300	9,300	413	7.2

TABLE 11a — Method of Yield Estimations and Number of Observations 1974-95

Year	No of Cuts	Method	Period of Cuts	Notes
1974/75	3	Pasture Cages	4/11; 22/2; 6/6	2 of these were "hay" cuts
75/76	2	Pasture Cages	13/11; 8/3	Both "hay" cuts
76/77	5	Pasture Cages	9/11 to 19/7	"Rate of Growth"
77/78	7	Pasture Cages	28/9 to 29/5	"Rate of Growth"
78/79	6	Pasture Cages	27/9 to 3/5	"Rate of Growth"
79/80	9	Pasture Cages	3/9 to 8/7	"Rate of Growth"
1980/81	9	Pasture Cages	9/7 to 3/7	"Rate of Growth"
81/82	9	Pasture Cages	25/9 to 6/5	"Rate of Growth"
82/83	8	Pasture Cages	15/9 to 9/5	"Rate of Growth"
83/84	10	Pasture Cages	23/9 to 11/6	"Rate of Growth"
84/85	10	Pasture Cages	18/9 to 20/5	"Rate of Growth"
85/86	9	Pasture Cages	24/9 to 20/5	"Rate of Growth"
86/87	Nil	_	-	No cuts - financial constraints
87/88	Nil	-	-	No cuts - financial constraints
88/89	Nil	-	-	No cuts - financial constraints
89/90	Nil	-	-	No cuts - financial constraints
1990/91	4	Pasture Probe	1/6 to 8/5	Electronic Pasture Probe
91/92	Nil	-	-	No Cuts Financial Constraints
92/93	5	Pasture Probe	5/10 to 24/5	Electronic Pasture Probe
93/94	Nil	-	-	No Cuts Financial Constraints
94/95	Nil	-	-	No Cuts Financial Constraints

TABLE 12 — Slash effect on annual pasture availability. 400 to 80 Stems per hectare
Proportion of open pasture availability

1981/82			**1986/87***		
June 81 - Sept 81	0.846 x 4 =	3.384	June 86 - Nov 86	0.838 x 6 =	5.028
Oct 81 - Mar 82	0.902 x 6 =	5.412	Dec 86 - May 87	0.838 x 6 =	5.028
April 82 - May 82	0.945 x 2 =	1.890	Weighted Total		10.056
Weighted Total		10.686	Mean DM avail 1986/87 =		0.84
Mean DM Avail for 1981/82 =		0.89			
1982/83			**1987/88**		
June 82 - Mar 83	0.945 x 10 =	9.450	June 87 - Nov 87	0.876 x 6 =	5.256
April 83 - May 83	0.952 x 2 =	1.904	Dec 87 - May 88	0.876 x 6 =	5.256
Weighted Total		11.354	Weighted Total		10.512
Mean DM Avail for 1982/83 =		0.95	Mean DM Avail for 1987/88		0.88
1983/84			**1988/89**		
June 83 - Oct 83	0.952 x 5 =	4.760	June 88 - Nov 88	0.913 x 6 =	5.478
Nov 83 - April 84	0.953 x 6 =	5.718	Dec 88 - May 89	0.908 x 6 =	5.448
April 84 - May 84	0.850 x 1 =	0.850	Weighted Total		10.926
Weighted Total		11.328	Mean DM Avail for 1988/89 =		0.91
Mean DM Avail for 1983/84		0.944			
1984/85			**1989/90**		
June 84 - Nov 84	0.850 x 6 =	5.100	June 89 - Nov 89	0.908 x 6 =	5.448
Dec 84 - May 85	0.773 x 6 =	4.638	Dec 80 - May 90	0.903 x 6 =	5.418
Weighted Total		9.738	Weighted Total		10.866
Mean DM Avail for 1985/86 =		0.81	Mean DM Avail for 1989/90		0.91
1985/86					
June 85 - Nov 85	0.773 x 6 =	4.638			
Dec 85 - May 86	0.820 x 6 =	4.920			
Weighted Total		9.558			
Mean DM Avail for 1985/86 =		0.79			

*Data for 1986/87 lost. Estimated from period Nov 19845 and June 1988

TABLE 13 — Slash effect on annual pasture availability. 750 to 105 Stems per hectare
Proportion of open pasture availability

1981/82			**1986/87***		
June 81 - Sept 81	0.788 x 4 =	3.152	June 86 - Nov 86	0.82 x 6 =	4.920
Oct 81 - Mar 82	0.852 x 6 =	5.112	Dec 86 - May 87	0.82 x 6 =	<u>4.920</u>
April 82 - May 82	0.918 x 2 =	<u>1.836</u>	Weighted Total		9.84
Weighted Total		10.100	Mean DM Avail 1986/87 =		0.82
Mean DM Avail for 1981/82 =		0.84			
1982/83			**1987/88**		
June 82 - Mar 83	0.918 x 10 =	9.180	June 87 - Nov 87	0.855 x 6 =	5.13
April 83 - May 83	0.937 x 2 =	<u>1.874</u>	Dec 87 - May 88	0.855 x 6 =	<u>5.13</u>
Weighted Total		11.054	Weighted Total		10.26
Mean DM Avail for 1982/83 =		0.92	Mean DM Avail for 1987/88		0.86
1983/84			**1988/89**		
June 83 - Oct 83	0.937 x 5 =	4.685	June 88 - Nov 88	0.89 x 6 =	5.34
Nov 83 - April 84	0.910 x 6 =	5.460	Dec 88 - May 89	0.90 x 6 =	<u>5.40</u>
April 84 - May 84	0.835 x 1 =	<u>0.835</u>	Weighted Total		10.74
Weighted Total		10.980	Mean DM Avail for 1988/89 =	0.90	
Mean DM Avail for 1983/84		0.92			
1984/85			**1989/90**		
June 84 - Nov 84	0.835 x 6 =	5.010	June 89 - Nov 89	0.901 x 6 =	5.406
Dec 84 - May 85	0.725 x 6 =	<u>4.350</u>	Dec 89 - May 90	0.912 x 6 =	<u>5.472</u>
Weighted Total		9.36	Weighted Total		10.878
Mean DM Avail for 1984/85 =		0.78	Mean DM Avail for 1989/90 =	0.91	
1985/86					
June 85 - Nov 85	0.725 x 6 =	4.350			
Dec 85 - May 86	0.803 x 6 =	<u>4.818</u>			
Weighted Total		9.168			
Mean DM Avail for 1985/86 =		0.76			

*Data for 1986/87 lost. Estimated from period Nov 1985 and June 1988.

TABLE 12 & 13 (cont'd

1990/91			**1991/92**		
May 90	0.91		June 91	0.95	
June 91	0.95				
Mean DM Avail 1990/91 =		0.93			
1992/93			**1993/94**		
Assumed	0.95		No Observations		
1994/95					
June 95	0.99				

* Slash effect is the same at both tree densities (i.e. 80 and 105 sph) from 1990 to 1995

TABLE 14 - Livestock carrying capacity (LCC) as a percentage of open pasture 400 sph Initial to 80 Final — Annual Means

						LCC [3]		cf 0-400-750	
Tree age	Year	Slash effect	Pasture 0 sph	DM kg/ha "x" sph	Tree effect	Actual	Potential	SED	CV%
1	74/75	ND	8,900	9,200	1.00	0.00	1.00	1,200	22.7
2	75/76	ND	7,930	8,080	1.00	0.02	1.00	485	10.0
3	76/77	ND	9,120	9,200	1.00	0.21	1.00	849	16.9
4	77/78[1]	ND	7,280	7,340	1.00	0.55	1.00	429	10.7
5	78/79	ND	11,670	11,300	1.00	0.78	1.00	1,217	17.0
6	79/80[2]	ND	8,710	9,920	1.00	0.85	1.00	668	12.6
7	80/81[2]	ND	8,130	8,890	1.00	0.85	1.00	565	11.8
8	81/82	0.89	9,400	9,070	1.00	NA	0.89	584	11.8
9	82/83	0.95	10,570	8,970	1.00	NA	0.95	545	12.0
10	83/84	0.94	11,820	11,240	1.00	0.86	0.94	1,189	18.2
11	84/85	0.81	9,620	13,020	1.00	0.84	0.81	1,680	25.6
12	85/86	0.74	10,470	10,540	1.00	1.09	0.79	521	9.0
13	86/87	0.84	ND	ND	0.92*	NA	0.77	-	-
14	87/88	0.88	ND	ND	0.84*	NA	0.74	-	-
15	88/89	0.91	ND	ND	0.76*	NA	0.69	-	-
16	89/90	0.91	ND	ND	0.68*	NA	0.62	-	-
17	90/91	0.93	9,400	5,570	0.59	NA	0.55	438	10.6
18	91/92	-	ND	ND	ND	NA	-	-	-
19	92/93	0.95	7990	4810	0.60	NA	0.57	557	16.0
20	93/94	0.99	ND	ND	ND	NA	-	-	-
21	94/95	0.99	ND	ND	ND	NA	-	-	-

1. Rep 1 omitted in means as it was intensively grazed. Rep 1 = 9,200; Rep 2 + 3 = 7,400.
2. 79/80, 80/81 represent yields from above and below mower height measurements.
3. LCC = Livestock carrying capacity as a fraction of open pasture (=1.00) = Slash effect x tree effect.
4. Actual LCC from 1974 to 1980/81 and 1983 to 86 based on farm records of stock movement on and off the trial block.
5. ND = not determined. NA = not available

* Estimated

TABLE 15 — Livestock carrying capacity (LCC) as a percentage of open pasture 750 sph initial to 105 final — Annual means

						LCC[3]		cf 0-400-750	
Tree age	**Year**	**Slash effect**	**Pasture 0 sph**	**DM kg/ha "x" sph**	**Tree effect**	**Actual**	**Potential**	**SED**	**CV%**
1	74/75	ND	8,900	9,350	1.00	0.00	0.9	1,200	22.7
2	75/76	ND	7,930	9,060	1.00	0.20	0.9	485	10.0
3	76/77	ND	9,120	9,070	1.00	0.21	0.9	849	16.9
4	77/78[1]	ND	7,280	7,860	1.00	0.55	0.9	429	10.7
5	78/79	ND	11,670	12,930	1.00	0.78	0.9	1,217	17.0
6	79/80[2]	ND	8,710	8,950	1.00	0.77	0.9	668	12.6
7	80/81[2]	ND	8,130	7,880	1.00	0.79	0.9	565	11.8
8	81/82	0.84	9,400	8,160	1.00	NA	0.84	584	11.8
9	82/83	0.92	10,570	8,620	1.00	NA	0.92	545	12.0
10	83/84	0.92	11,820	10,910	1.00	0.79	0.92	1,189	18.2
11	84/85	0.78	9,620	11,330	1.00	0.76	0.78	1,680	25.6
12	85/86	0.77	10,470	9,250	1.00	0.87	0.77	521	9.0
13	86/87	0.82	ND	ND	0.92*	NA	0.75	-	-
14	87/88	0.86	ND	ND	0.84*	NA	0.72	-	-
15	88/89	0.90	ND	ND	0.76*	NA	0.68	-	-
16	89/90	0.91	ND	ND	0.68*	NA	0.62	-	-
17	90/91	0.93	9,400	5,990	0.64	NA	0.59	438	10.6
18	91/92	ND	ND	ND	ND	NA	-	-	-
19	92/93	0.95	7,990	5,330	0.67	NA	0.63	557	16.0
20	93/94	0.99	ND	ND	ND	NA	-	-	-
21	94/95	0.99	ND	ND	ND	NA	-	-	-

1. Rep 1 omitted in means as it was intensively grazed. Rep 1 = 9,200; Rep 2 + 3 = 7,400.
2. 79/80, 80/81 represent yields from above and below mower height measurements.
3. LCC = Livestock carrying capacity as a fraction of open pasture (=1.00) = Slash effect x tree effect.
4. Actual LCC from 1974 to 1980/81 and 1983 to 1986 based on farm records of stock movement on and off the trial block.
5. ND = not determined. NA = not available

* Estimated

TABLE 16 — Gross and net forest pasture herbage yield (DM kg/ha) and actual carrying capacity in stock units per hectare (su/ha) 1983 — 1986

			+ Slash				- Slash			
	0		**185 → 80**		**230 → 105**		**185 → 80**		**230 → 105**	
1983/84	**DM**	**SU/ha**	**DM**	**SU/ha**	**DM**	**SU/ha**	**DM**	**SU/ha**	**DM**	**SU/ha**
Gross pasture	11,820	22.5	11,250	20.8	10,940	18.6	11,230	17.8	10,970	17.1
Available pasture	1.00		0.904		0.885		0.904		0.885	
Net pasture	11,820		10,110		9,680		10,150		9,710	
km DM/SU/ha/yr (net)	525		440		461		515		503	
Net area (ha)			1.08		1.06		1.08		1.06	
1984/85										
Gross pasture	9,620	16.2	13,150	12.8	10,960	11.1	12,900	14.5	11,970	13.4
Available pasture	1.00		0.81		0.78		0.81		0.78	
Net pasture	9,620		10,650		8,550		10,450		9,340	
kg DM/SU/ha/yr (net)	594		832		770		720		697	
1985/86										
Gross pasture	10,470	11.2	9,710	13.1	9,340	8.6	11,370	11.3	9,160	10.8
Available pasture	1.00		0.74		0.76		0.74		0.76	
Net pasture	10,470		7,190		7,100		8,410		6,960	
kg DM/SU/ha/yr	934		548		825		744		644	

(1) Net Pasture = Gross pasture x available pasture

TABLE 17 — Contribution of components to total production (kg DM/ha) Invermay 1981/82

	Slash			No slash				
S	**0**	**185**	**230**	**0**	**185**	**230**	**Mean**	**SEM**
Tophtal	10,730	9,780	9,070	9,570	10,070	9,530	9,790	(688)
Below MH*	550	750	700	940	970	1,580	920	(478)
Above MH	10,170	9,030	8,370	8,630	9,100	7,950	8,870	(424)
Dead (AMH)	970	550	200	730	500	600	590	(145)
Live (AMH)	9,200	8,480	8,210	7,900	8,560	7,320	8,280	(471)
Ryegrass	4,240	3,130	3,080	3,330	3,860	2,640	2,940	(496)
(LAMH)								
Cocksfoot	640	920	1,080	720	1,290	740	900	(320)
(LAMH)**								
Other grasses	2,690	3,380	2,850	2,400	2,270	2,900	2,750	(357)
(LAMH)								
Clover (LAMH)	1,410	970	1,120	1,320	1,080	980	1,150	(86)

* MH = mower height (approx 2.5 cm)

** In the absence of species dissection on post-grazing material, component production values rely on the assumption that the proportion of each species on the post-grazing mown material is the same as that in the following pre-grazing sample.

TABLE 18 — Pasture composition 1974-1995, % Species of total yield

		Ryegrass			Cocksfoot			Other grasses			Clovers			Dead matter			Weeds		
Date	**Year**	**0**	**400**	**750**	**0**	**400**	**750**	**0**	**400**	**750**	**0**	**400**	**750**	**0**	**400**	**750**	**0**	**400**	**750**
1974-75	1	29.5	29.3	23.3	14.0	15.0	11.0	28.3	36.0	39.7	11.6	8.3	7.5	11.0	12.0	14.5	2.0	0.2	0.8
1975-76	2	23.0	25.3	10.0	14.5	23.7	25.0	36.0	38.2	53.7	23.3	12.5	7.0	2.8	3.8	4.3	0.2	0.5	0.5
1976-77	3	12.8	16.0	11.0	36.5	31.5	21.5	47.0	49.3	58.3	2.8	2.8	4.5	0.7	0.3	1.0	0.0	0.2	0.0
1977-78	4	11.3	9.5	8.0	12.0	25.7	12.7	49.8	48.3	53.5	20.3	5.0	6.5	4.0	10.6	21.0	2.0	1.0	0.5
1978-79	5	27.2	13.7	19.2	7.5	10.0	6.8	43.8	62.7	58.5	11.0	5.7	6.5	9.0	9.7	7.3	1.3	0.2	1.0
1979-80	6	30.0	24.5	25.0	6.8	14.8	7.5	44.8	45.8	47.9	15.3	13.9	14.4	1.0	9.3	9.4	-	-	-
1980-81	7	33.3	32.6	27.0	3.9	12.6	10.4	44.5	39.0	44.7	16.3	14.7	17.1	8.8	2.4	4.2	-	-	-
1981-82	8	44.3	41.0	36.8	8.0	13.0	5.7	29.8	33.2	37.0	16.0	12.0	13.5	10.5	6.2	5.2	-	-	-
1982-83	9	43.0	42.5	37.0	6.0	10.0	7.5	22.5	24.0	32.3	15.0	12.0	14.5	-	-	-	-	-	-
1983-84	10	39.5	43.8	35.8	6.0	7.9	7.0	35.1	28.9	38.3	13.7	14.2	12.1	3.3	2.7	2.8	2.4	3.2.	4.5
1984-85	11	38.5	45.6	35.7	3.2	6.2	5.6	37.4	28.1	38.4	8.8	6.3	7.3	9.7	10.2	10.4	2.0	0.9	1.6
1985-86	12	43.0	47.5	42.8	3.5	9.0	8.7	26.1	26.2	29.3	16.4	9.3	9.6	8.9	7.2	8.3	2.0	2.0	1.1
1986-87	13	Not Determined																	
1987-88	14	Not Determined																	
1988-89	15	Not Determined																	
1989-90	16	Not Determined																	
1990-91	17	40	23	25	6	16	18	32	38	32	17	5	8	3	13	11	2	5	6
1991-92	18	Not Determined																	
1992-93	19	31	9	15	3	11	7	41	32	37	8	2	4	15*	44*	35*	2	2	2
1993-94	20	Not Determined																	
1994-95	21	Not Determined																	

* Largely Pine Needles - Some needles blown into control treatments.

TABLE 19 - Mean Seasonal in vitro digestible organic matter (%), Invermay 1979-1981

Season		**Stems per hectare**		
	0	**400**	**750**	**SEM**
Spring	78.7	77.3	78.2	0.8
Summer	73.6	73.7	73.0	0.7
Autumn	71.8	70.6	71.8	1.6

TABLE 20 — Historical time sequence, Forest grazing site, Soil Quick Test Analysis 1953 to 1974 control treatments

	Depth (cm)	pH	Ca	K	PTruog	SO_4 -S	Mo		
1950									
1951									
1952									
1953	7.5	6.4	11	6	7		0.9		Soil tests from paddocks
1954		6.3	8	8	5				originally numbered 45a,
1955		6.1	10	8	10				45b, 46a, 46b, 46c (i.e.
1956									45 and 46) later (after
1957		5.6	7	5	6				1984) becoming paddock 109.
1958		6.0	9	5	5				
1959		6.1	7	5	6				
1960		5.9	7	5	6				
Trial I9/0		**pH**			**Ca**	**K**	**P**		
Trial	kg/ha	125		375			125	375	I9/0 rates of super by rates
1961	7.5	5.7		5.8	7	7	4.4	4.8	of stocking trial ran from
1962	"	5.8		5.7	7	7	3.7	4.7	October 1960 to 1971.
1963	"	5.6		5.6	6	7	3.9	5.2	
1964	"	5.5		5.5	8	6	3.1	6.0	
1965	-	-		-	-	-	-	-	1,149 kg/ha Super applied to 375
									kg/ha treatment.
1966	"	5.9		5.8	8	5	6.0	14.5	
1967	"	-		-	-	-	-	-	
1968	"	6.2		6.2	7	9	5.0	13.0	
1969	"	6.0		6.0	6	9	4.1	10.5	
1970	"	5.9		5.8	6	9	3.8	10.9	
		pH	**Ca**	**K**	**P Truog**				
1971		-	-	-	-				
1972		-	-	-	-				
1973	"	5.8	7	2	6				Some haying in 1973.
1974	"	5.6	8	6	9				Trial I313 commences.

TABLE 21 - Historical sequence, Forest grazing site, soil Quick test analyses by tree density 1974-1995

	pH			Ca			K			P*			Mg			SO_4 -S		
8.74	0	400	750	0	400	750	0	400	750	0	400	750	0	400	750	0	400	750SPh
1974	5.6	5.5	5.5	8	8	8	6	4	5	9	9	10	-	-	-	-	-	-
1975	5.6	5.5	5.5	7	7	7	5	7	7	8	9	10	-	-	-	-	-	-
27.5.76*	5.5	5.4	5.5	8	8	8	6	6	6	17*	22*	19*	23	26	23	-	-	-
19.7.77	5.5	5.6	5.6	9	9	9	6	7	7	15	20	19	32	31	31			
7.78	0	215	305	0	215	305	0	215	305	0	215	305	0	215	305	0	215	305SPh
22.8.78	5.7	5.7	5.8	11	11	11	6	8	7	33	32	33	17	29	26	8	6	7
1979	5.9	5.8	5.9	8	8	9	4	8	6	7	13	13	27	30	29	-	-	-
1980	5.6	5.6	5.6	9	9	9	5	6	5	7	9	12	32	33	33	-	-	-
3.81	0	185	230	0	185	230	0	185	230	0	185	230	0	185	230	0	185	230SPh
24.6.81	5.7	5.8	5.8	8	8	9	4	5	4	12	13	15	29	29	30	9	8	6
7.82	5.7	5.7	5.7	9	8	9	9	9	6	16	19	26	37	30	31	12	8	9
1.6.83	5.6	5.6	5.5	8	8	8	7	8	6	18	21	22	28	29	22	-	-	-
1.84	0	80	105	0	80	105	0	80	105	0	80	105	0	80	105	0	80	105SPh
16.8.84	5.6	5.5	5.4	10	10	10	7	10	8	19	27	34	34	35	36	-	-	-
22.7.85	5.5	5.5	5.6	8	8	9	6	7	6	14	20	19	32	33	34	17	16	16
1986	Not Determined					-	-	-	-	-	-	-	-	-	-	-	-	
1987	5.5	5.4	5.5	9	8	9	7	7	7	15	18	20	35	33	35	13	14	17
1988	Not Determined					-	-	-	-	-	-	-	-	-	-	-	-	
1989	Not Determined					-	-	-	-	-	-	-	-	-	-	-	-	
22.6.90	5.5	5.4	5.5	8	8	8	6	9	6	12	16	22	32	33	35	10	11	11
3.8.92	5.5	5.4	5.3	8	8	8	9	8	8	19	24	31	37	36	40	13	22	19
11.8.95	5.5	5.3	5.3		-	-	-	-	-	19	52	46	-	-	-	-	-	-

* P values are "Truog P" until March 1976; after March 1976 P values are "Olsen P".

TABLE 22 - Soil chemical analyses (0-7.5 cms) for the years 1983 to 1995

	Element			**Tree density**			
		0	**400+S**	**750+S**	**400-S**	**750-S**	***SED**
1.6.83	pH	5.6	5.5	5.5	5.6	5.5	0.15
	Ca	8.3	7.0	8.0	8.0	7.0	0.97
	K	7.2	10.0	6.0	5.7	5.3	3.32
	P	18.2	22.7	23.3	20.0	20.7	2.88
	Mg	28.3	27.7	29.7	30.0	27.0	0.79
16.8.84	pH	5.6	5.5	5.4	5.4	5.4	0.31
	Ca	9.5	10.0	9.3	9.0	9.7	1.03
	K	7.7	9.7	8.3	9.3	7.0	2.71
	P	18.7	21.0	30.3	17.0	23.7	2.93
	Mg	34.2	34.7	36.0	35.7	35.3	0.76
22.7.85	pH	5.5	5.5	5.5	5.4	5.5	0.12
	Ca	8.0	7.3	8.7	8.3	8.3	0.93
	K	5.5	7.3	5.0	6.7	6.7	1.87
	P	14.1	22.0	21.3	17.0	18.0	2.34
	Mg	32.3	32.0	34.7	34.0	33.7	0.43
1986	No samples taken						
27.4.87	pH	5.5	5.4	5.4	5.4	5.5	0.04
	Ca	8.7	8.0	8.,7	7.7	8.3	0.56
	K	6.7	7.0	6.3	6.0	7.3	2.38
	P	14.5	21.7	22.7	15.0	17.7	2.42
	Mg	34.8	35.3	35.7	31.3	34.0	1.79
	S	13.0	12.7	14.3	16.0	20.0	4.04
1988 and 1989	No samples taken						
1990	Ph	5.5	5.4	5.4	5.4	5.5	0.05
	Ca	7.7	7.0	8.7	7.7	7.7	0.50
	K	7.5	10.7	6.7	6.0	7.0	1.39
	P	12.0	18.0	25.0	13.3	17.7	2.75
	Mg	31.5	34.0	36.3	31.3	32.7	1.74
	S	9.5	12.7	10.3	9.7	11.7	2.48
3.8.92	Treatment reps bulked sample						
11.8.95	pH	5.5	5.3	5.3	5.2	5.4	0.05
	P	18.5	56.3	43.3	47.0	48.3	3.12

* Comparison applies only between control and trees, not between trees and trees

TABLE 23 — Soil chemical analysis: Organic carbon and nitrogen (0-7.5cms)
From Trial I 9/0 (1963,1967) and I313 (1978,1990)

	0	**400+S**	**750+S**	**400-S**	**750+S**	**SED**	**CV%**
23.3.63							
%C	5.32						
%N	0.36						
C/N	14.8						
3.3.67							
%C	5.37						
%/N	0.38						
C/N	14.4						
SED	3.63 to 3.67						
% C	0.46						
%N	0.02						
C/N	1.7						
22.8.78							
%N	0.19	0.23	0.22	0.23	0.23	-	-
23.6.90							
%C	4.7	4.9	5.2	5.6	5.2	0.33	3.3
%N	0.37	0.39	0.38	0.38	0.38	0.12	16.5

Figure 1. **Site Location, Invermay Agricultural Centre and Agroforestry Trial Project I313. Scale 1:50,000, Part Sheet NZMS 260 I44**

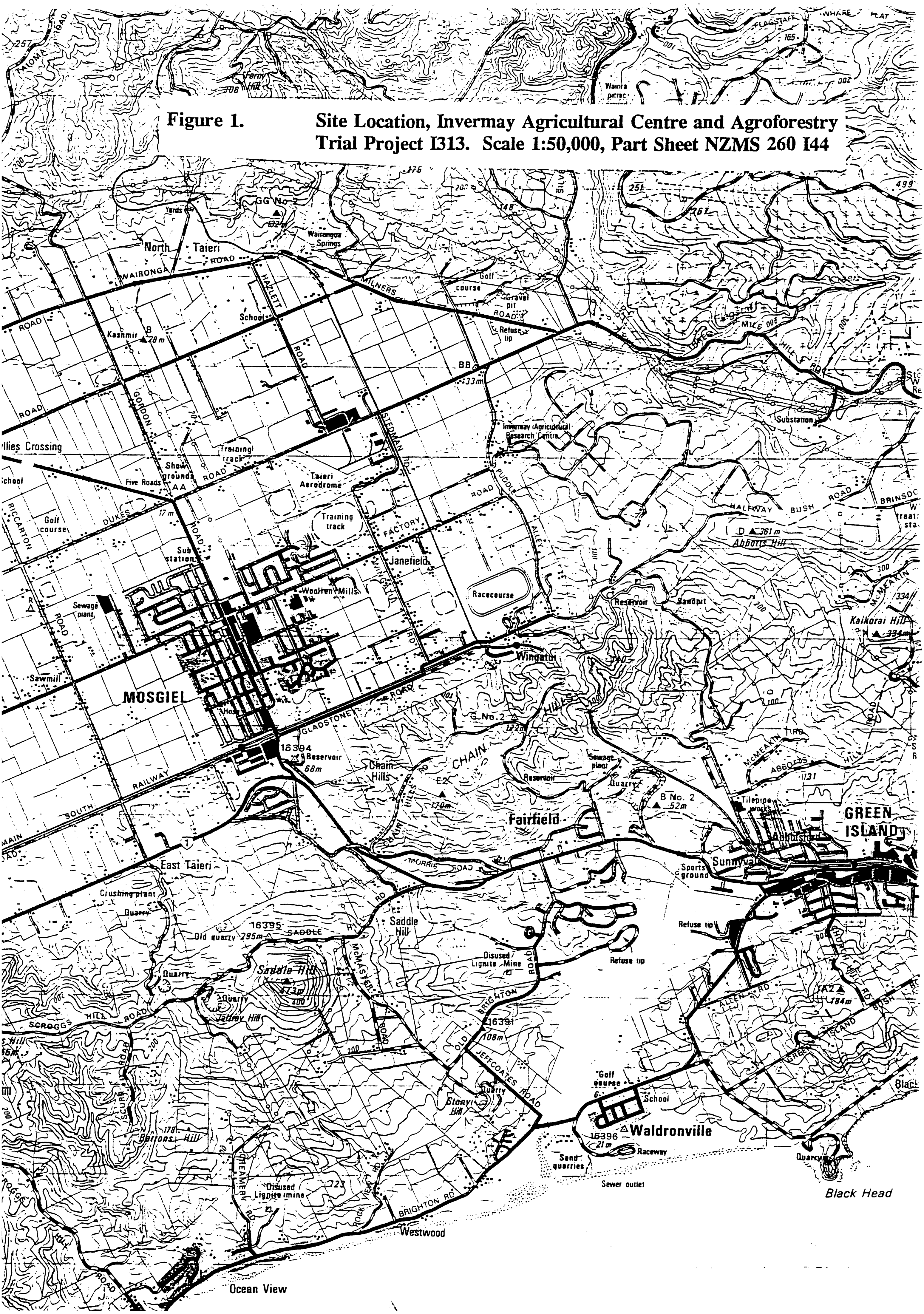


Figure 2. **Agroforestry Trial Location, Invermay Farm Project I313**

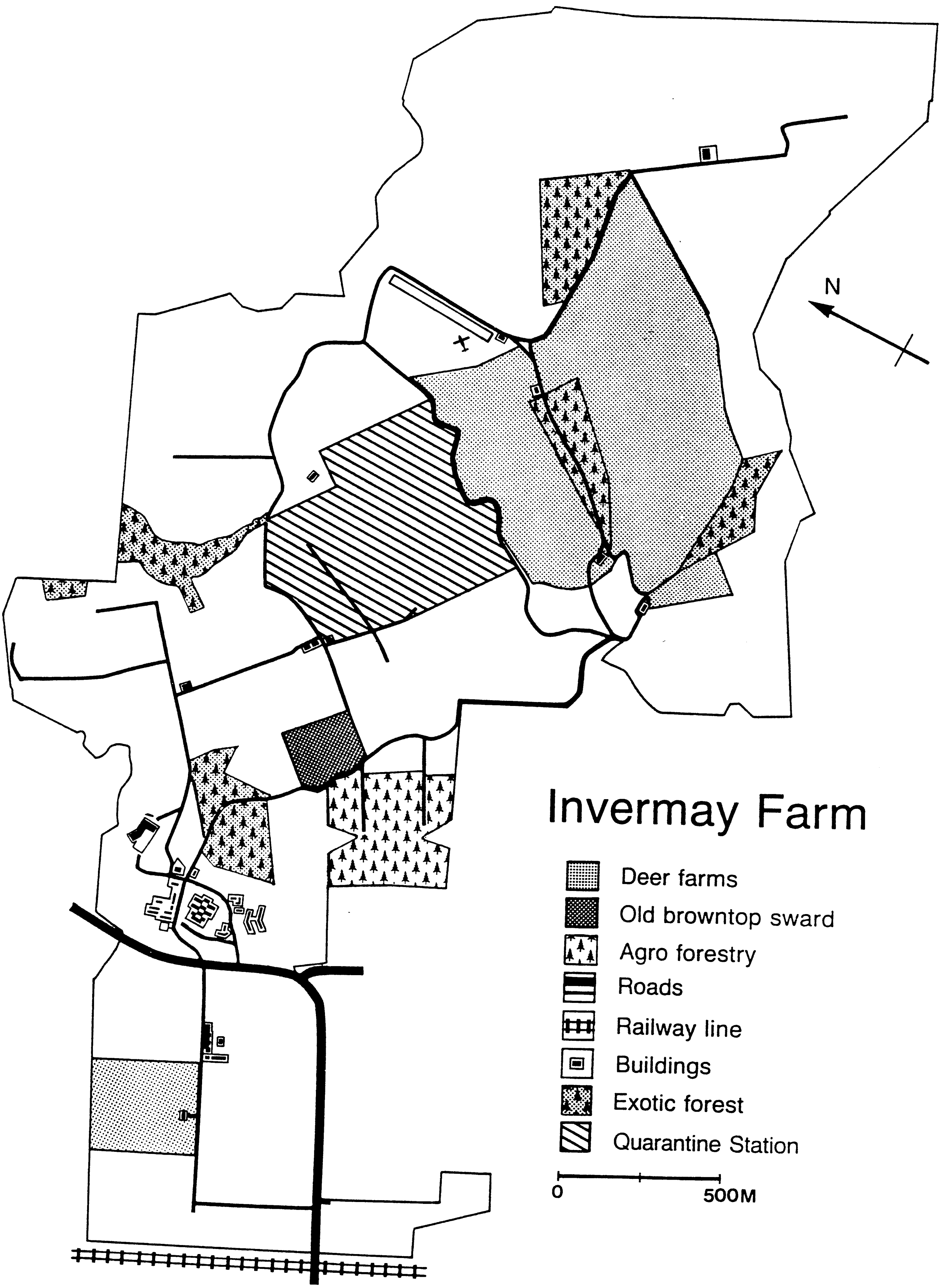
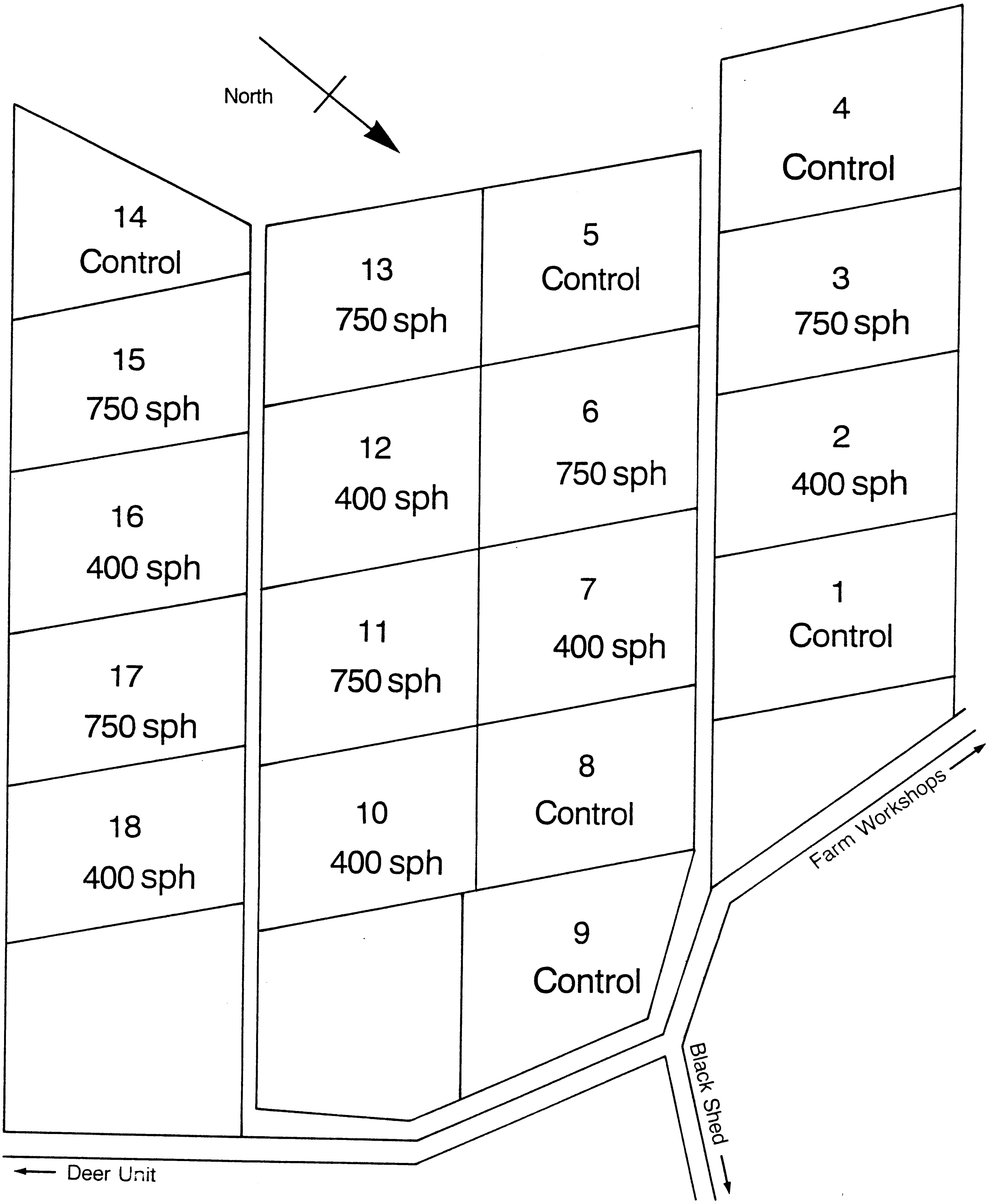
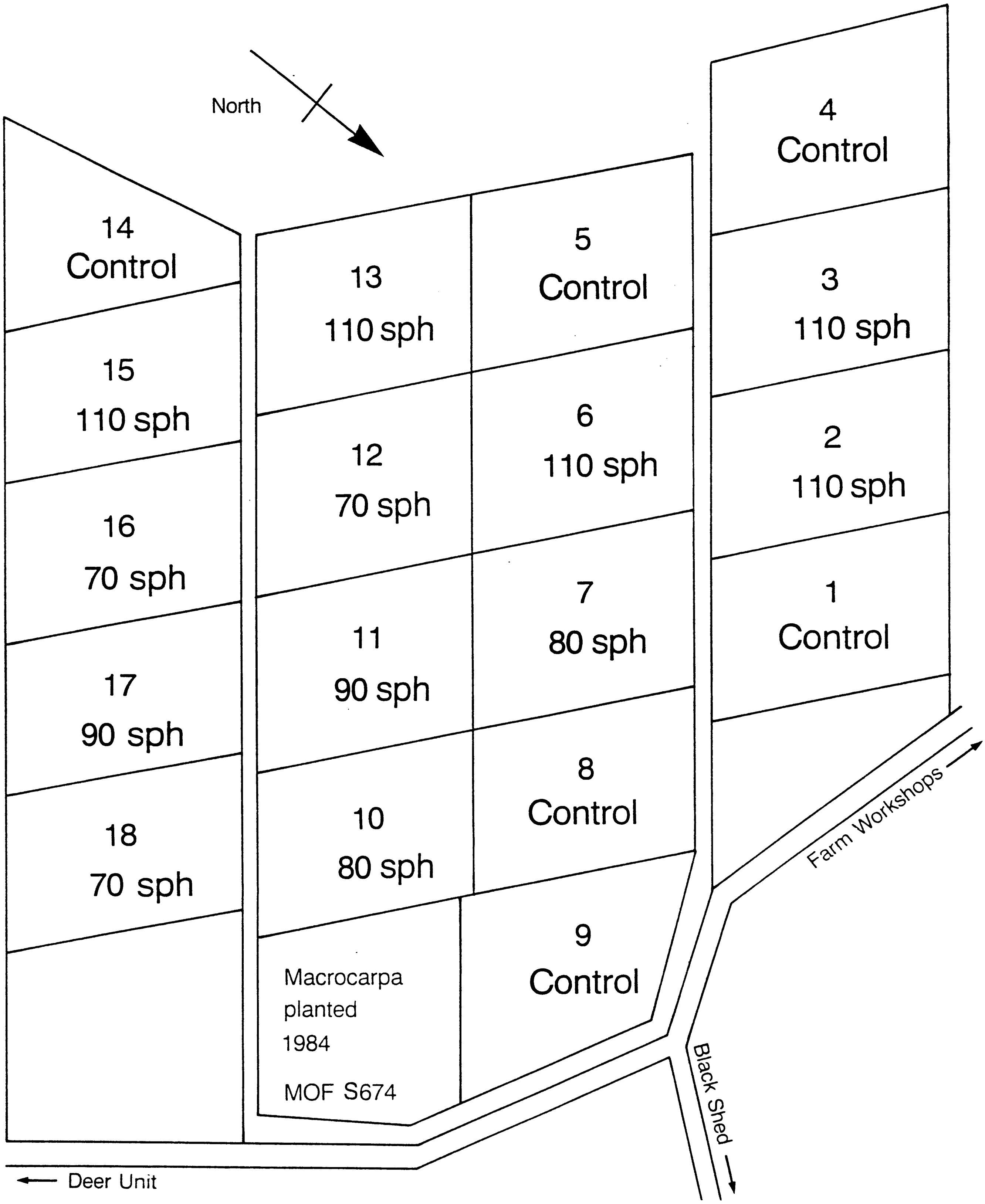


Figure 3. **Trial Layout Initial Density**
Project I313, Invermay



Invermay Grazing Trial
Agroforestry Project I313
MOF Project S489

Figure 4. **Trial Layout Final Density Project I313, Invermay**



Invermay Grazing Trial
Agroforestry Project I313
MOF Project S489

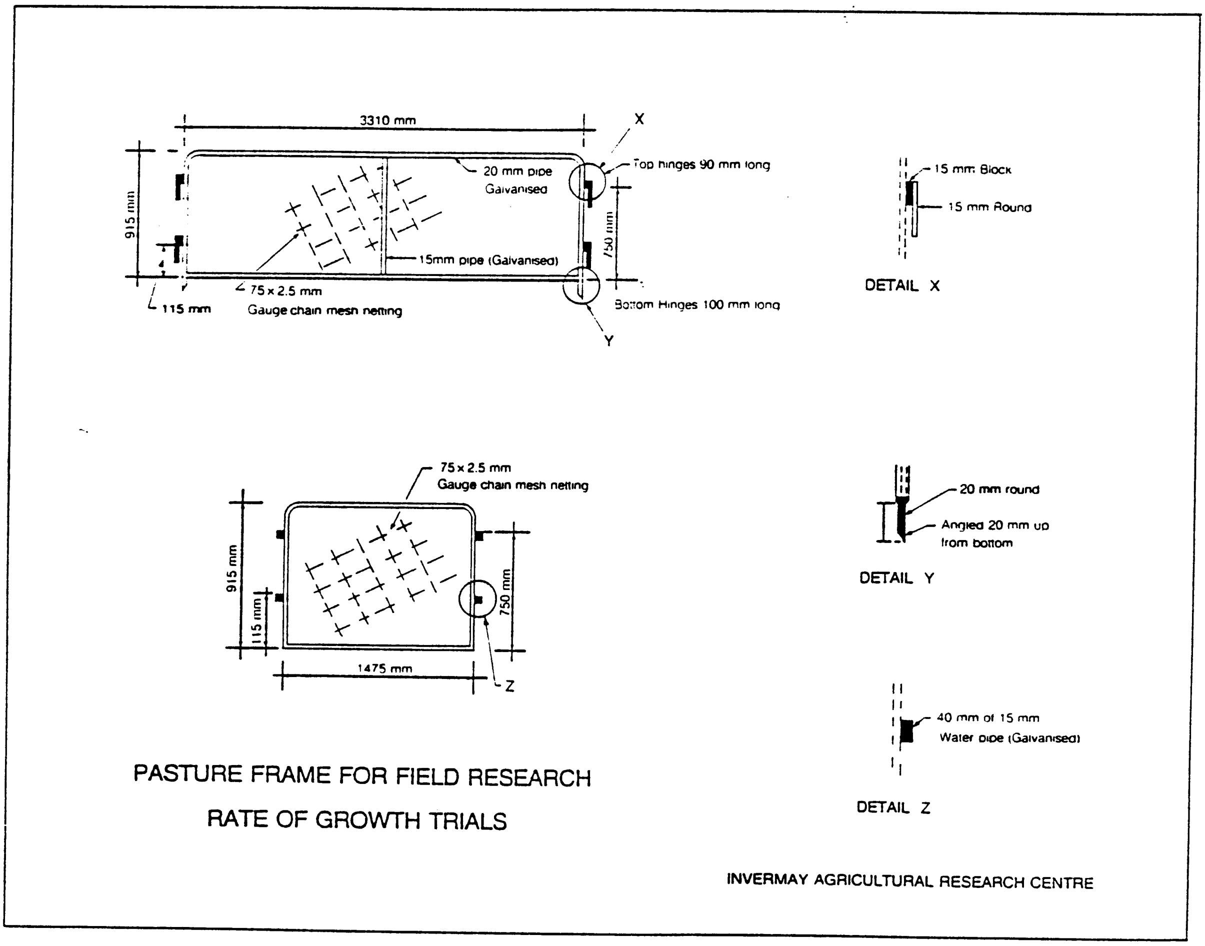


Figure 6. Construction details of pasture frame used for rate of growth trials.

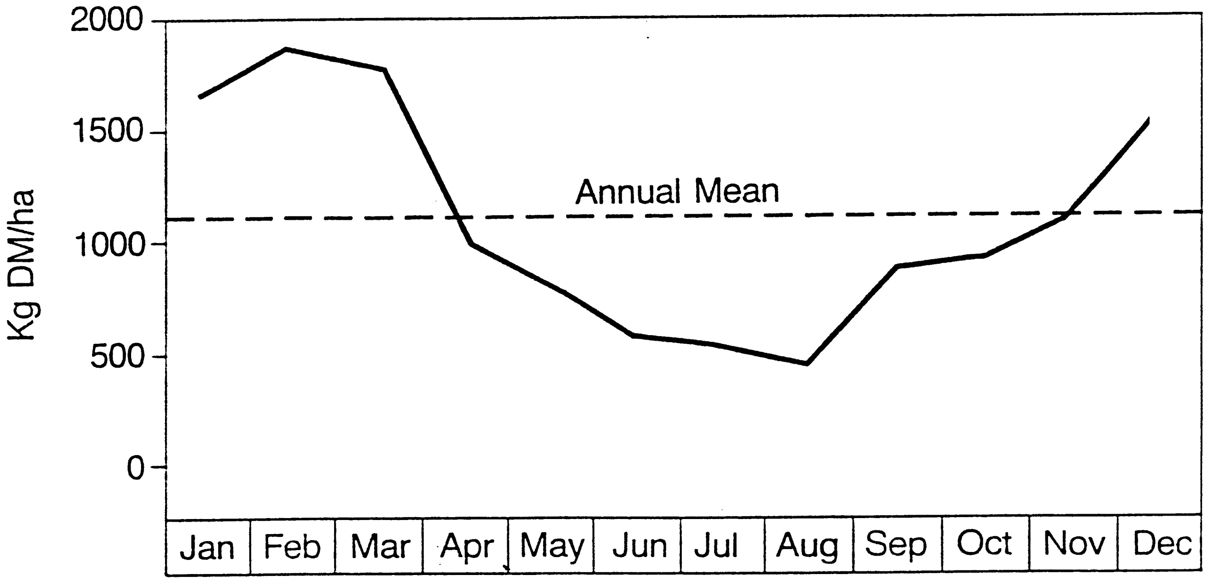


Figure 7. Mean annual herbage yields below mower height (1974 - 1982)

Figure 8. **Pasture Species Composition 1974-1990**

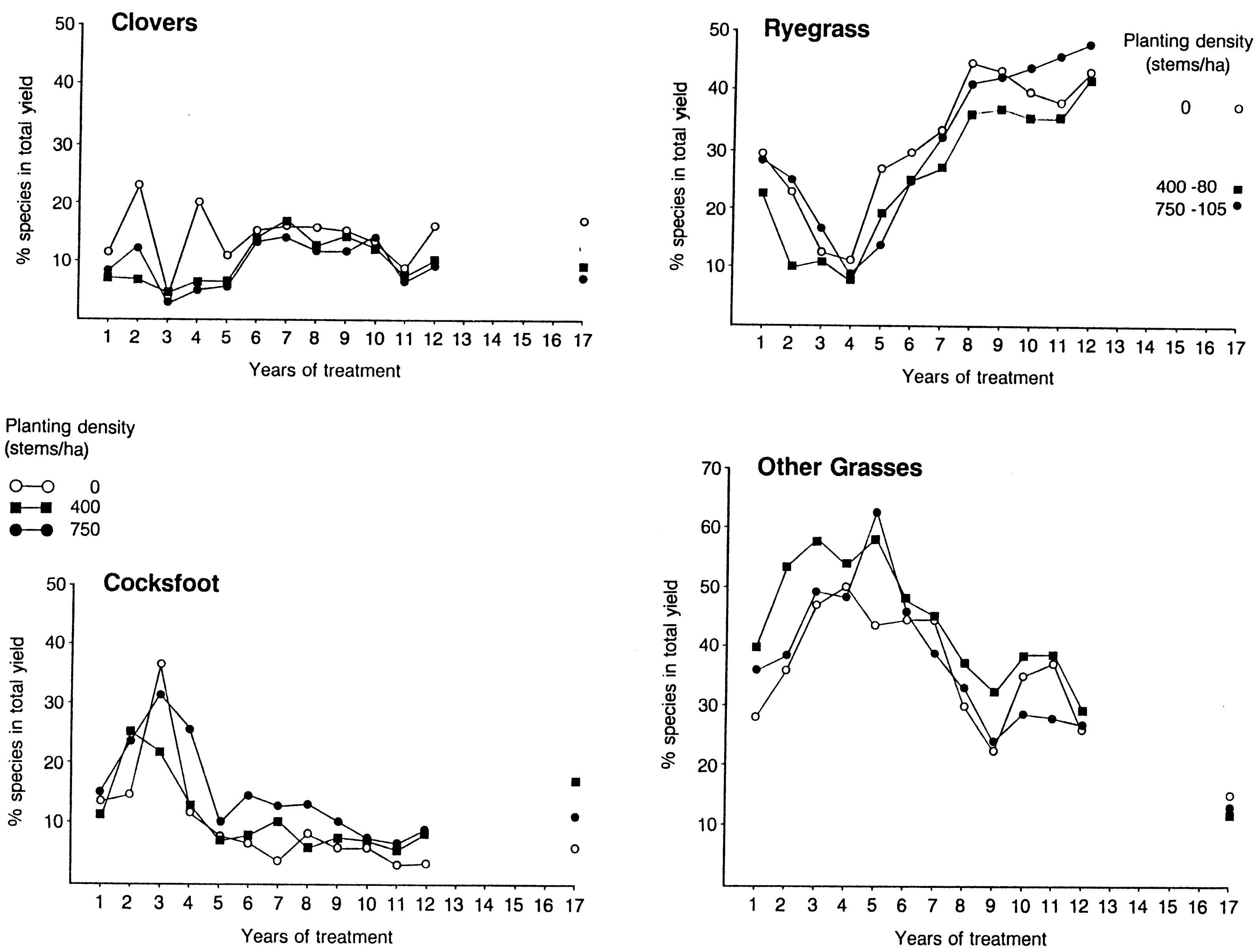


Figure 9. **Changes in Soil pH, 1953-1995** Control