CHAPTER 13

A GRAZING MANAGEMENT SYSTEM DESIGNED TO INCREASE THE ABUNDANCE OF D. LINKII

Experiment 11. The effects of grazing with sheep on the herbage mass and abundance of *Danthonia linkii*

The grazing management system outlined in Chapter 11 (Fig. 11.1) to increase the abundance of the desirable native perennial grass *D. linkii* was tested over a three year period at a field site (Study area 5) near Tamworth, New South Wales.

A. Materials and Methods

The experimental site (Study area 5) was a 2.43 ha area of fertilized natural pasture, at the Agricultural Research Centre, Tamworth (Fig. 3.1). The site which had received 125 kg ha^{-1} of superphosphate per annum since 1966, had a northerly aspect and was located on a red-brown earth soil type (Dr 2.23) (Northcote 1971).

The experiment consisted of three replicates of two grazing treatments in six 0.40 ha paddocks. Plots were grazed with dry Merino ewes and stocking commenced in January 1980. The two grazing treatments were to either continuously graze at 7.5 sheep per ha/year or rest-rotationally graze at an equivalent annual stocking rate. In the rest-rotational grazing plan stocking generally commenced in December or early January of each year (Fig. 13.1) after flowering and seedfall of *D. linkii* plants, and sheep were removed from the plots in April before *D. linkii* seedling germination commenced. In late September 1980 plots were grazed at a rate of 5 sheep/ha for two weeks to control the growth of annual legumes and grasses. In all other years rainfall was low and the growth of annual species was limited.

Each plot was divided into four strata of equal area (1000 m^2). Herbage mass was estimated every eight weeks from December 15, 1979 by harvesting to ground level two randomly located 0.16 m^2 quadrats from each strata using the rank set method of MacIntyre (1952). Within each quadrat all *D. linkii* plants were counted and harvested separately, dried for 48 hours at $80^{o}C$ in a forced draught dehydrator and weighed. Data collection of other herbage in the sampled quadrats and the measurement of plant basal area were as described in Experiment 9.

The percentage basal cover of the native perennial grasses and of bare ground was estimated in May and November of each year using a single wheel-point apparatus. Within each paddock 1000 wheel-point estimates were collected; 250 in each of the four strata (Lodge and Gleeson 1979).

All data were examined by analysis of variance and an examination of the residuals again showed that no transformation of the data was necessary.

B. Results and Discussion

The results of this study and those of Experiment 10 indicate that grazing of natural pastures in summer and early autumn, and the resting of these pastures from grazing in late autumn, winter and spring, increases the abundance of yearlong green grasses such as *D. linkii*.

At the start of this experiment the herbage mass of *D. linkii* was around 125 kg ha^{-1} in both grazing treatments (Fig. 13.1b). Within 12 months continuously grazing at 7.5 sheep/ha/year reduced the herbage mass and density of *D. linkii* to a very low level in the pasture (Fig. 13.1b and 13.1c). In contrast the rest-rotational grazing management system increased the herbage mass of *D. linkii* up to 400 kg ha^{-1} in September 1981 and increased plant density of *D. linkii* to around 50 plants m^{-2} by the end of the experiment. These substantial increases in *D. linkii* herbage mass and plant density occurred despite below average rainfall during the experiment (Fig. 13.1a), which would have adversely affected the flowering and seedling establishment of this species. After November 1981 the herbage mass and density of *D. linkii* in the rest-rotation grazing treatments was always significantly higher ($P < 0.05$) than in the continuously grazed plots. This result confirms the findings of Experiment 10.

In both grazing treatments the dead grass component of the herbage other than *D. linkii* contributed most to the pasture herbage mass of the other species throughout the experiment (Fig. 13.2). From February 1981 until July 1982 this component of the pasture was significantly higher ($P < 0.05$)

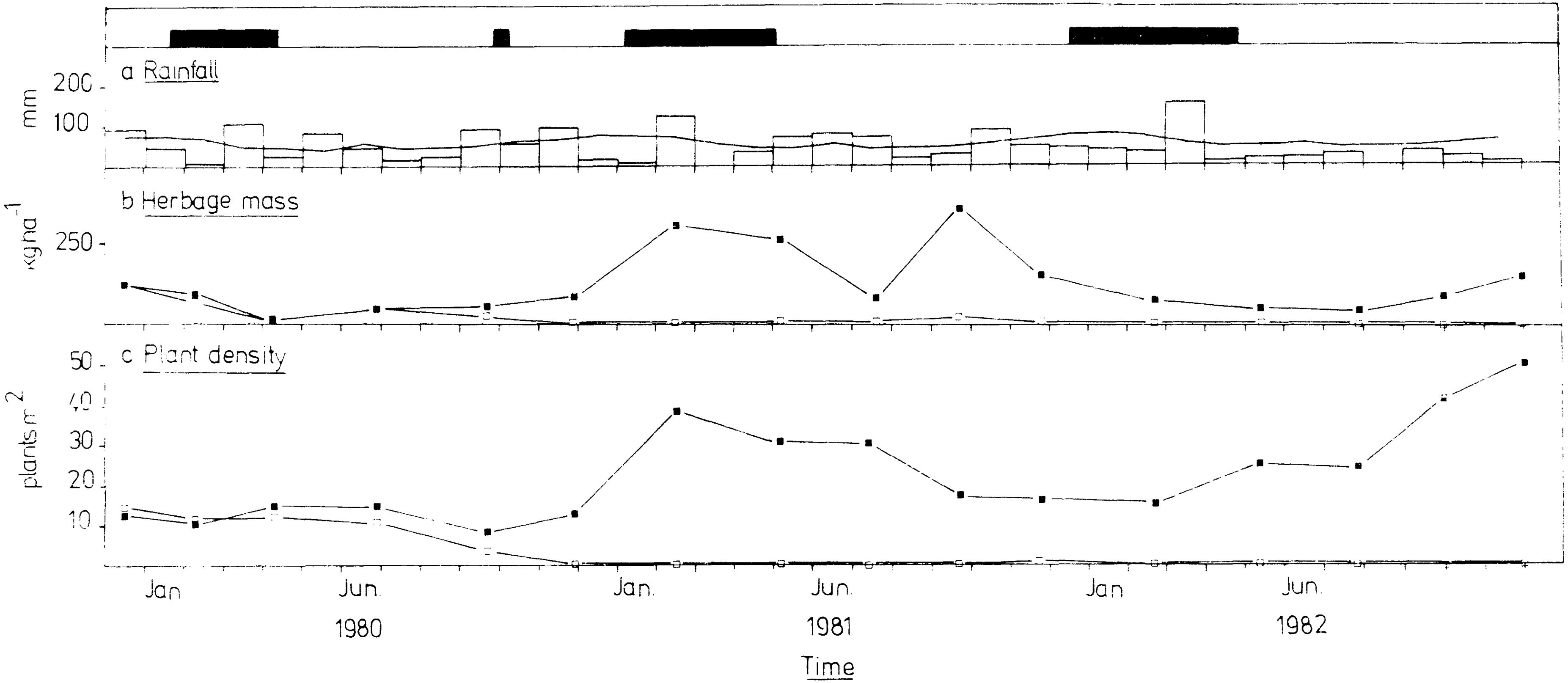

Figure 13.1 (a) The monthly rainfall (mm) at Study area 5 together with the long term average at Tamworth and (b) the herbage mass (kgha^{-1}) and (c) density (plant m^{-2}) of D. linkii in the continuously grazed (□) and rest-rotationally grazed (■) treatments. Grazing periods for the rest-rotationally grazed plots are indicated by ■ .

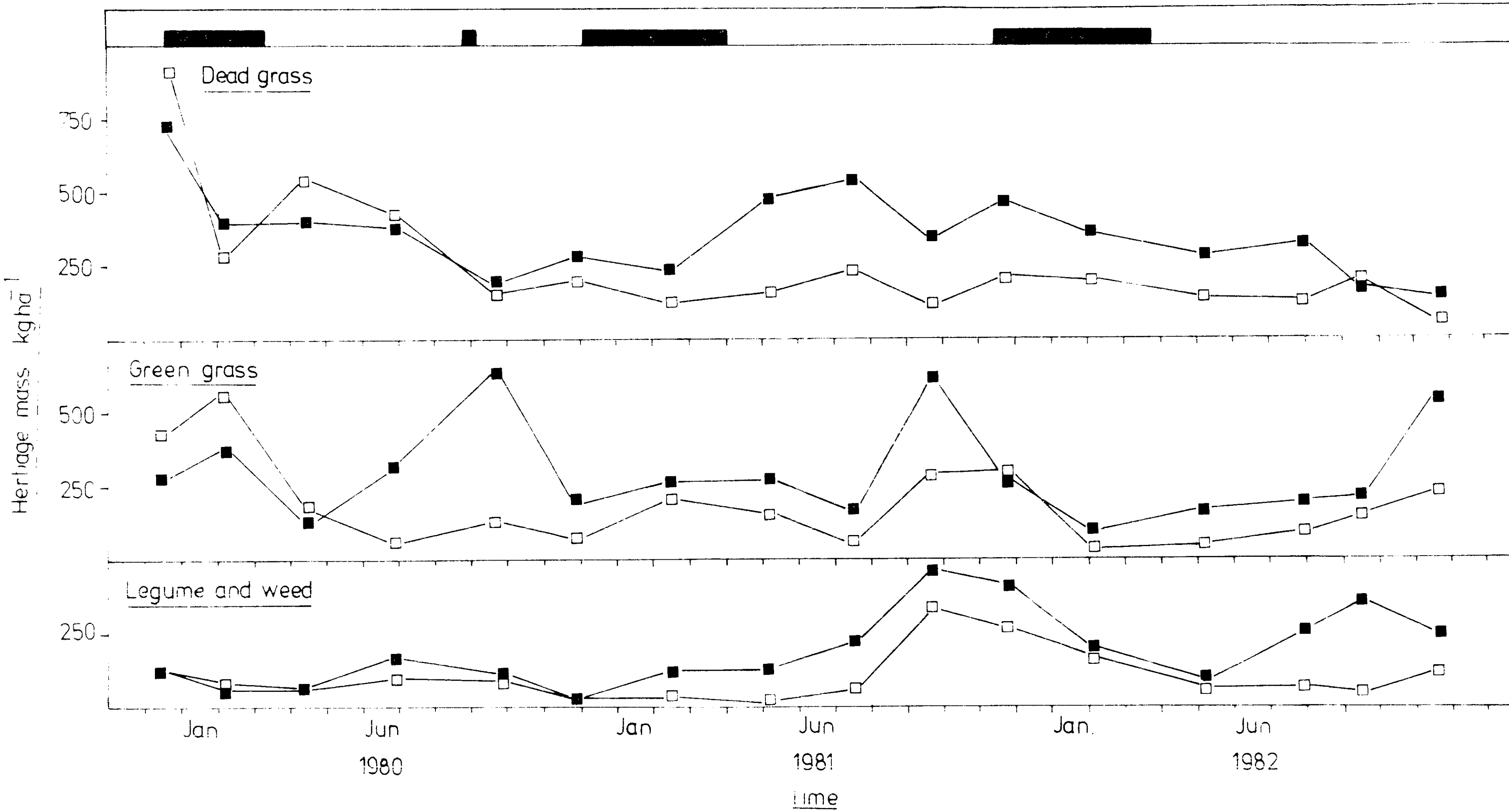

Figure 13.2 The herbage mass (kgha^{-1}) of dead and green grass other than D. linkii and legume and weed in the continuously grazed (□) and rest-rotationally grazed (■) treatments. Grazing periods for the rest-rotationally grazed plots are indicated by ▬ .

in the rest-rotation grazing treatments than in the continuously grazed plots. The green grass portion of the rest-rotationally grazed plots was significantly higher ($P < 0.05$) than that of the continuously grazed plots in winter and spring 1980, and spring 1981 and 1982 when these plots were spelled from grazing. The increase in the green grass component of these plots was associated with the higher abundance of D. linkii in the rest-rotation plots and the ability of cool season annuals such as Bromus molliformis, Hordeum leporinum and Vulpia myuros to establish and grow in the absence of grazing in late-autumn, winter and spring.

Continuous grazing over the period of the experiment appeared to completely eliminate Danthonia from these treatments (Table 13.1). However, after good rainfall in autumn 1983 some Danthonia plants were observed in these treatments in winter 1983. Rest-rotational grazing decreased the mean plant mass, and mean basal area per plant of D. linkii, but increased its mean plant density five-fold. A Henderson and Hayman (1960) analysis of these data at the start and end of the experiment indicated that at these times plant density and mass per unit basal area were significant ($P < 0.05$) components of the herbage mass of D. linkii.

In the first year after grazing the amount of legume and weed species in both grazing treatments was less than 200 kg ha^{-1} (Fig. 13.2) and not significantly different between treatments. However, after the second grazing period the amount of legume and weed in the rest-rotationally grazed plots was often significantly higher ($P < 0.05$) than that in the continuously grazed plots, particularly in spring 1981 and 1982. The increased herbage masses at these times were associated with the growth of cool season annual forbs, such as, Trifolium glomeratum, Trifolium campestre, Medicago polymorpha and Erodium cicutarium. The higher herbage mass of forbs in the rest-rotation plots in summer 1981 was associated with the appearance of Silene gallica and Carthamus lanatus in these treatments. The main yearlong green perennial forbs common in both grazing treatments were Dichondra repens and Boehavia diffusa.

In December 1979 the basal cover of D. linkii was 0.4% in both the continuously grazed and rest-rotationally grazed treatments (Table 13.2). Over the period of the experiment, however, the Danthonia basal cover in the continuously grazed plots declined to 0.1%, while that in the rest-rotation treatments increased to 2.0% and after May 1980 these values were always

Table 13.1 The mean plant mass (g $plant^{-1}$), mean basal area (cm^2 $plant^{-1}$), mean mass per unit basal area (g cm^{-2}), and mean density (plants m^{-2}) of D. linkii in the continuously and rest-rotationally grazed plots at the start (December 1979) and end (November 1982) of the experiment

Grazing	Mean plant mass (g $plant^{-1}$)		Mean basal area (cm^2 $plant^{-1}$)		Mean mass/unit basal area (g cm^{-2})		Mean density (plants m^{-2})	
	Dec. 1979	Nov. 1982	Dec. 1979	Nov. 1982	Dec. 1979	Nov. 1982	Dec. 1979	Nov. 1982
Continuous	1.08	0	22.6	0	0.048	0	12.21	0
Rest-rotation	1.16	0.28	24.8	5.7	0.047	0.049	11.37	50.8

Table 13.2 The percentage basal cover of D. linkii, A. ramosa, B. macra and of bare ground in the continuously and rest-rotationally grazed treatments

	Basal Cover						
	Dec. 1979	May 1980	Nov. 1980	May 1981	Nov. 1981	May 1982	Nov. 1982
				%			
Continuously grazed							
D. linkii	0.4	0.2	0.0	0.0	0.0	0.1	0.1
A. ramosa	1.3	0.9	1.0	0.7	0.8	1.0	0.7
B. macra	2.3	2.2	1.6	1.5	1.3	1.0	3.4
Bare ground	93.2	94.4	95.5	97.1	97.1	97.1	97.7
Rest-rotationally grazed							
D. linkii	0.4	1.4	1.8	1.9	1.5	1.1	2.0
A. ramosa	1.1	0.8	0.6	1.4	1.2	1.1	1.1
B. macra	1.5	1.4	1.6	1.6	1.2	0.8	1.4
Bare ground	93.6	95.8	94.5	94.2	95.7	96.6	95.9

significantly different ($P < 0.05$) between the two grazing treatments. The basal cover of A. ramosa was around 1% in both treatments and not significantly different between grazings (Table 13.2). B. macra basal cover and the percentage of bare ground were generally higher in the continuously grazed plots.

Detailed animal production measurements were not taken, although sheep bodyweights were monitored. In each year of the experiment sheep continuously grazing at a rate of 7.5 sheep ha^{-1} either maintained or lost up to 10% of their bodyweight and produced around 3.0-3.5 kg greasy wool $head^{-1}$. Despite drought conditions sheep on the rest-rotationally grazed treatments increased bodyweight by 15-20% over summer, indicating the beneficial effect of late-autumn, winter and spring deferment of grazing in dry years.

In this experiment, as in Experiments 9 and 10, the matching of grazing to species phenology resulted in the alteration of botanical composition in a desired direction. However, the reported increases in D. linkii herbage mass and abundance occurred during a period of severe drought; conditions which probably enhanced the decrease in A. ramosa herbage mass and abundance in Experiments 9 and 10. These changes in natural pasture species composition on the Northern Slopes of New South Wales indicate that grazing can be used to manipulate the abundance of individual species and species groups. Further studies have commenced to investigate the feasibility of integrating these grazing management systems into commercial whole farm systems. Cost/benefit economic analyses will be used to assess the overall effectiveness of these grazing management systems on animal production and returns to producers.

CHAPTER 14

GENERAL DISCUSSION AND CONCLUSIONS

Studies of the seasonal growth, crude protein and in-vitro digestibility of eight native perennial grasses on the Northern Slopes of New South Wales indicated that the yearlong green species Danthonia linkii had a potentially higher grazing value than any of the six warm season grasses examined. The warm season native perennial grass Aristida ramosa is composed mainly of coarse, green stems which have crude protein contents less than 5% and digestibilities lower than 55% and so it is an undesirable pasture species. Of the other warm season grasses Chloris truncata, and Eragrostis leptostachya may produce some green forage in autumn and winter, when low temperatures severely limit the green forage production of A. ramosa, Bothriochloa macra, Dichanthium sericeum and Sporobolus elongatus restricting their potential usefulness.

Further studies indicated that the use of a grazing management system, in which the time and intensity of grazing was matched to the reproductive biology of D. linkii and A. ramosa, could manipulate the species composition of natural pasture in a desired direction. A grazing management system was constructed and used to decrease the abundance of A. ramosa, and increase D. linkii abundance at two separate sites and at another decrease A. ramosa and increase D. linkii abundance in the same pasture. These successful manipulations of botanical composition towards pastures with more desirable species assemblages are the first to be reported for temperate rangelands in Australia. While these results are encouraging for researchers and graziers on the Northern Slopes, further studies are required to investigate methods of successfully incorporating the grazing management system into the whole farm situation and examining its effects on animal production.

The effects of superphosphate application on the above grazing management system were not investigated, however, there were substantial differences between the herbage mass responses to fertility of the different native perennial grasses. For example, superphosphate application did not greatly affect the herbage mass of A. ramosa, although it increased D. linkii herbage mass. Hence, in natural pastures in which the abundance of D. linkii has been increased and A. ramosa reduced by grazing management, superphosphate applications either alone or in association with the sowing of a responsive legume may lead to further increases in pasture and animal production.

In the present project only two yearlong green grasses, D. linkii and S. scabra were studied. The reported studies were all conducted on red-brown earth soils (Dr 2.23 Northcote (1971)) on which both D. linkii and A. ramosa occur on the Northern Slopes (Williams 1979). A. ramosa occurs across a wide range of soil types (Harradine 1976; Williams 1979) but, D. linkii does not occur on sandy textured soils of granitic origin (Williams 1979; Scott and Whalley 1982). However, on such soils Danthonia species, such as D. racemosa, D. pilosa and D. laevis, do occur (Scott and Whalley 1982) and grazing management systems could be constructed to increase their abundance. The responses of D. racemosa to grazing and fertility are similar to that of D. linkii in that it also responds to increased fertility (Robinson 1976) and persists under heavy grazing (Robinson and Dowling 1976). The occurrence of D. laevis is, however, not associated with either high fertility or stocking (Scott and Whalley 1982). Little information is available on the response to fertility and grazing of other yearlong green native perennial grasses on the Northern Slopes such as Dichelachne micrantha and Enneapogon nigricans. The frequency of the yearlong green species Microleana stipoides, increase with fertility and grazing on the Northern Tablelands (Taylor 1980) and grazing management systems could well be constructed to increase the abundance of this species and D. racemosa (Robinson and Dowling 1976) in that region.

Although the preliminary rankings of grazing value determined in this study need to be confirmed by diet selection and animal production experiments in this environment, these rankings are consistent with the subjective assessment of the value of Aristida and Danthonia spp. in other environments. Species of Danthonia are among the more highly regarded species of natural pastures (Breakwell 1923; Christian and Donald 1960; Moore 1970; Whalley et al. 1978) whilst Aristida species are undesirable pasture species (Moodie 1934a; Harradine 1976). With the widespread occurrence of Aristida and Danthonia species in other areas of New South Wales e.g., the south-western Slopes (Moore 1953a and 1953b); the western districts (Beadle 1948); the Macquarie region (Biddiscombe 1963), and the northern Tablelands (Whalley et al. 1978) the grazing management system devised in the present study may be widely applicable, provided that the time of grazing is matched to the species phenology in each of the different regions.

The introduction of white clover (Trifolium repens) on the northern Tablelands, together with the application of superphosphate and associated higher stocking rates, have been reported to control Aristida (Moodie 1934a; Berman 1954) and increase the abundance of Danthonia (Robinson and Dowling 1976). On the Northern Slopes, however, legume introduction into natural pastures has only been evaluated at higher elevations (Archer 1981); at lower elevations oversown legumes generally do not persist, because of either establishment failure or selective grazing before seeding. A grazing management system, which includes heavy grazing over summer to reduce the cover of the warm season perennial grasses may enhance the establishment of autumn sown legumes, and resting from grazing until after seed set in spring could ensure successful seed set in introduced cool season annual legumes. An increase in the abundance of Danthonia species at the same time would further increase the carrying capacity of these natural pastures as they are both responsive to applied fertilizer (Robinson 1976) and increase with increased stocking rate (Robinson and Dowling 1976; Whalley et al. 1978). Such increases in stocking rate and fertility and the provision of a vigorous, competing pasture association would also prevent the re-invasion of A. ramosa into the pastures.

The grazing management system outlined in this study could be best conducted on a whole farm basis using a four or five paddock rotation, similar to that proposed by Hormay (1970); the exact number and size of the paddocks would depend on the numbers of stock available to heavily graze over summer. Only one paddock would be treated each year and when the treated paddock was rested from grazing, in late autumn, winter and spring, stock would have to be moved to untreated paddocks. The success of such a grazing management system will depend on favourable seasonal conditions for the regeneration of desirable species in the pasture, the key to Aristida control being the continued defoliation of the species, associated with increased interspecific competition (Harradine 1976).

In the short-term some livestock liveweight losses may occur, although these may not be reflected in wool production and could be offset by a reduction in the grass seed content of wool and carcases. Management systems aimed at decreasing the amount of A. ramosa and increasing the abundance of D. linkii (initially either with or without a companion legume) would increase returns to producers on the Northern Slopes by: (i) reducing grass seed penalty in wool, hides and carcases; (ii) increasing stocking rates with the potential for fattening enterprises; and, (iii) increased land values.

A survey of export abattoirs in northern New South Wales (Hamilton 1978) indicated that 40% of sheep slaughtered were contaminated by grass seed resulting in a downgrading of carcase quality. Also a lowering of the grass seed content of wool from 5% to 2% would increase returns from wool by 30 to 50 cents per kg. This together with an increase in the abundance of D. linkii in natural pastures could lead potentially to higher pasture and livestock productivity. For example, if the abundance of D. linkii plants growing in unfertilized natural pasture could be increased tenfold then the green leaf content of these pastures would increase from about 220 and 350 kg ha^{-1} respectively in winter and spring to over 600 kg ha^{-1} in both seasons. An increase of this magnitude is not unrealistic. Despite severe drought conditions the grazing management system outlined increased D. linkii herbage mass and plant density by fourfold. The application of fertilizer alone to such pastures (Experiments 1 and 3A) also increased the green leaf weight of D. linkii plants four to fivefold. Such increases in green leaf availability in winter and spring would also increase the availability of forage high in crude-protein and digestibility, enabling substantial increases in stocking rate.

The yearlong carrying capacities of natural pastures dominated by Danthonia and Stipa species in southern New South Wales range from 4.6 to 6.8 dry sheep equivalents per ha (Moore 1970). Unfertilized natural pastures dominated by warm season native perennial grasses in northern New South Wales have carrying capacities of only about 3 dry sheep equivalents/ha.

The experimental evidence from these studies strongly indicates that strategic grazing management can be used to manipulate species composition. For this practice to be widely used and adopted by graziers similar changes in species composition in paddock situations, together with a system of implementing these grazing systems on a whole farm basis, will need to be demonstrated. Future research should aim to further increase natural pasture productivity by the introduction of legumes into these pastures and to investigate the management inputs required to maintain pasture stability.

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APPENDIX 1

SOME CHEMICAL AND PHYSICAL PROPERTIES OF THE SOILS AT THE FERTILIZED (STUDY AREA 1) AND UNFERTILIZED (STUDY AREA 2) SITES

	Soil analysis		
	Study area 1 (fertilized)		Study area 2 (unfertilized)
	Site 1 (Sheep camp)	Site 2 (Non-sheep camp)	
Available P (ppm)	96.9	57.8	61.2
Total nitrate N (ppm)	9.8	1.3	4.1
Sulphate S (ppm)	4.2	5.9	3.9
pH	6.3	6.3	6.9
Organic carbon (%)	3.01	1.93	1.21
Soil texture:			
0-10 cm Slit (%)	25.1	25.9	22.0
Clay (%)	28.5	15.1	15.5
Sand (%)	40.2	59.2	55.6
10-20 cm Slit (%)	21.0	21.2	25.3
Clay (%)	38.8	19.6	19.1
Sand (%)	46.4	59.0	62.5

Two hundred soil samples were collected in 5 cm diameter cores to a depth of 10 cm at Study area 1 in February 1976 and at Study area 2 in February 1977. At 50 of the soil sampling sites additional samples were collected at a depth of 10-20 cm. The 0-10 cm depth soil samples were analysed for available phosphorus by the method of Olsen et al. (1954), soil sulphate by that of Barrow (1967) and soil-nitrate-nitrogen by that of Henzell et al. (1968). These samples were also analysed for organic carbon content and soil pH using the methods described in Appendices 2 and 3 respectively. Soil texture was also determined by the method described in Appendix 4 on the 50 samples taken at both soil depths.

APPENDIX 2

SOIL ORGANIC CARBON CONTENT. METHOD.*

1. Weigh out duplicate samples of 1.00 g of air dried soil ground to pass through a 0.5 mm sieve into a 500 ml conical flask.

2. Add 10 ml N Potassium dichromate.

3. Add 20 ml conc. sulphuric acid (A.R. grade).

4. Shake gently (using flask shaker) for 1 minute, allow to stand for 30 minutes.

5. Add about 200 ml distilled water and 10 ml phosphoric acid.

6. Add 10 ml diphenylamine indicator[A].

7. Titrate against N ferrous sulphate until colour changes green.

8. Add further 0.5 ml potassium dichromate, titrate drop by drop until purple or blue colour changes to green.

[A]If a green colour developed at this stage the sample was rejected and a smaller quantity of soil (0.5 g) was used for analysis.

*After Walkley and Black (1934).

Reagents

Normal potassium dichromate: Dissolve exactly 49.04 g $K_2Cr_2O_7$ in distilled water and dilute to 1 litre.

Phosphoric acid: 85 percent.

Diphenylamine indicator: Dissolve 0.5 g diphenylamine in 20 ml of distilled water and 100 ml conc. sulphuric acid.

Normal ferrous sulphate: Dissolve 278.0 g $FeSo_4 7H_2O$ in distilled water containing 15 ml conc. sulphuric acid. Dilute to one litre, avoid heating.

APPENDIX 3

SOIL pH. METHOD.*

1. Weigh out duplicate samples of 4.00 g of air dried soil ground to pass through a 2 mm sieve and place in a bottle.

2. Add 10 ml of distilled water, stopper bottle and shake for one hour on a reciprocating shaker.

3. Take pH reading on a Pye pH meter.

*After the method of Reed and Cummings (1945).

APPENDIX 4

PARTICLE SIZE ANALYSIS OF SOIL SAMPLES. METHOD.*

1. Weigh out 20 g of air dried soil ground to pass through a 2 mm sieve.

2. Add 50 ml 10 percent Calgon solution and 200 ml distilled water.

3. Place in a metal container and agitate for 10 minutes.

4. Transfer with washing to a 1000 ml graduated cylinder and make up to 1000 ml with distilled water.

5. Stir thoroughly.

6. Take solution density readings with a Bouycous hydrometer at time intervals of one, five, ten and 30 minutes, and one, two, four, seven and 18 hours from the commencement of settling.

7. After each reading calibrate the hydrometer in a 1000 ml measuring cylinder containing Calgcn solution. Note temperature.

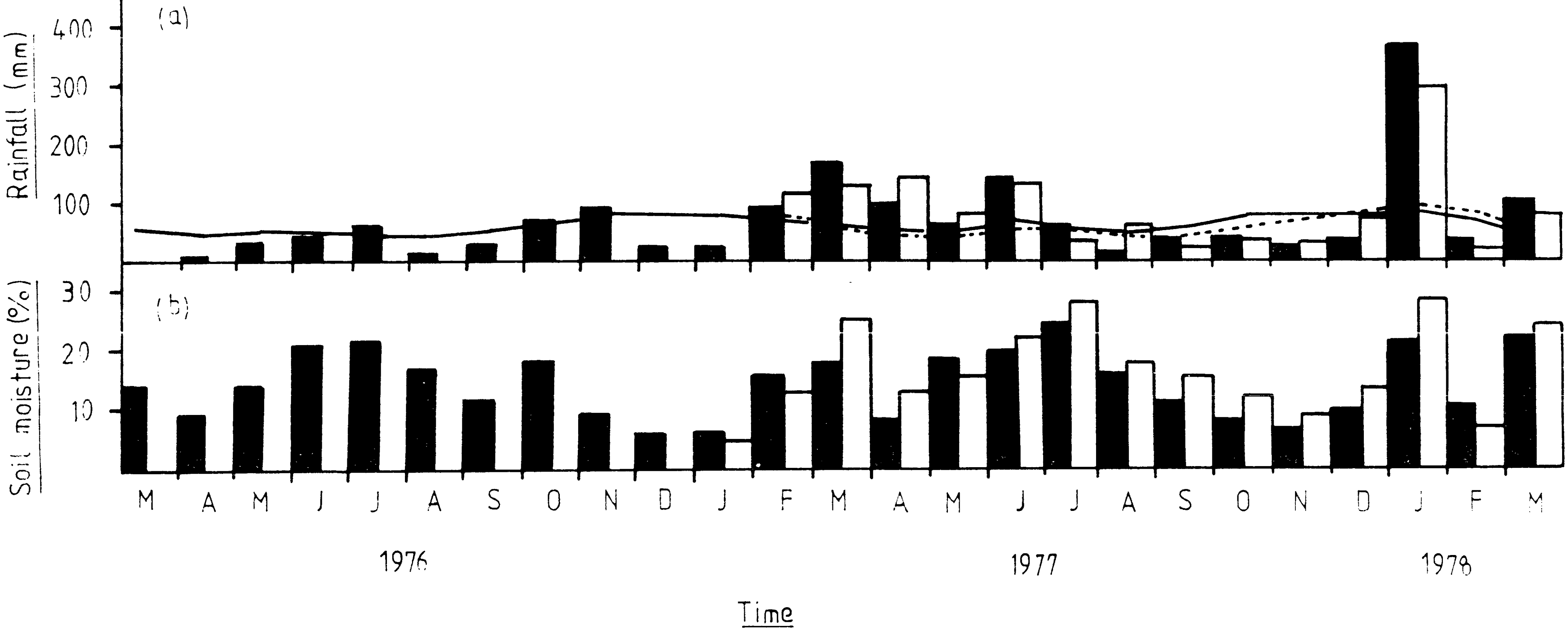
8. To determine the percent silt and clay calculate the concentration suspension (g/litre), corrected for temperature at each time of measurement and the particle diameter.

9. Percent sand was determined by washing through a 70 mesh sieve. The dry weight of the sieve residue was recorded as coarse sand. Fine sand was determined by pouring off the supernatant from the measuring cylinder and transferring the sediment to a 500 ml beaker. The beaker was filled with water to a depth of 10 cm, stirred, and the supernatant poured off after 5 minutes settling; the residue was dried and weighed.

*After the procedures outlined by Russel (1950).

APPENDIX 5A

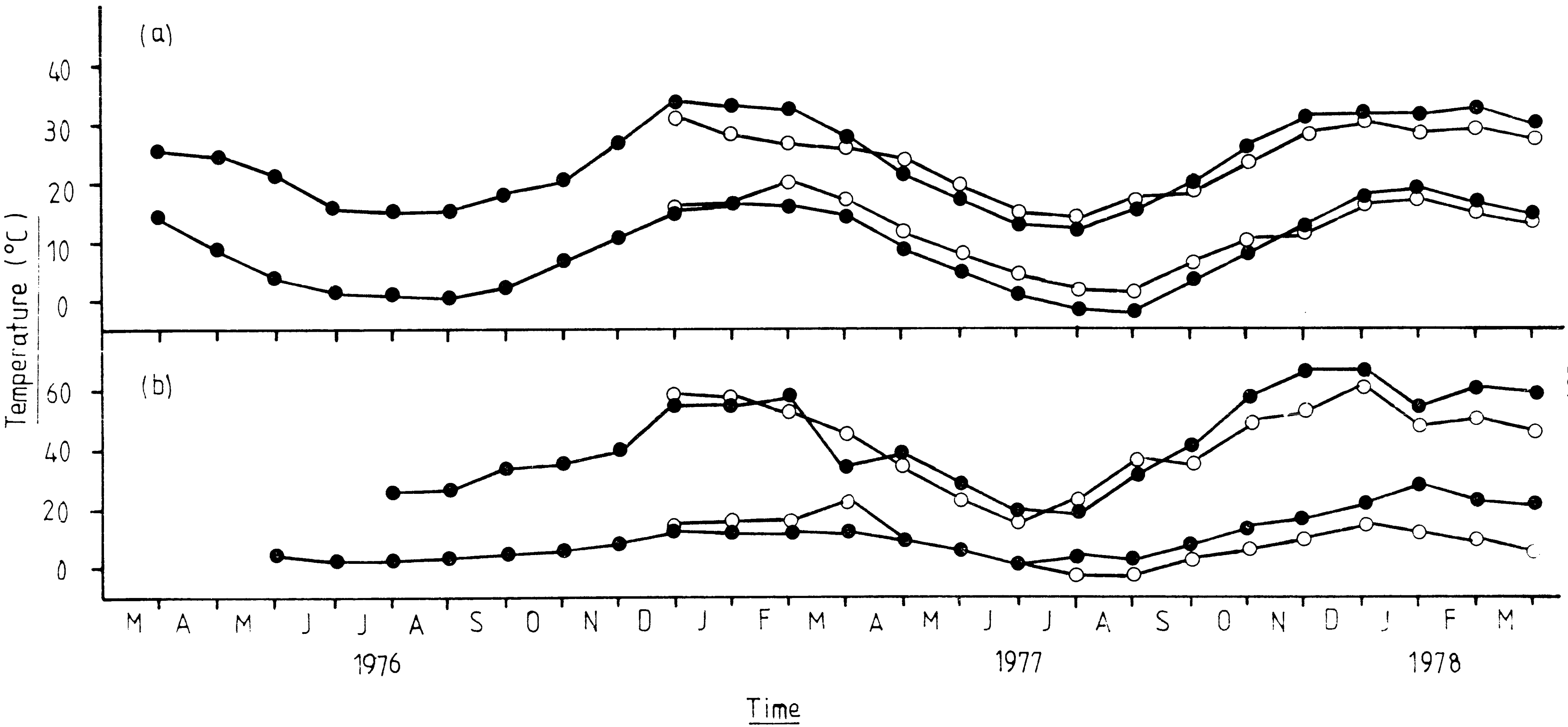
RAINFALL AND SOIL MOISTURE DATA FOR STUDY AREAS 1 AND 2



(a) Monthly rainfall at Study area 1 (■) and Study area 2 (□) and the long-term average monthly rainfall at Barraba (—) and Manilla (---), together with (b) the average soil moisture content in the top 10 cm. Soil moisture was estimated gravimetrically from ten 5 cm diameter cores sampled monthly.

APPENDIX 5B

AMBIENT AND SOIL TEMPERATURE DATA FOR STUDY AREAS 1 AND 2



(a) Mean maximum and minimum ambient temperatures (°C) at Study area 1 (●) and Study area 2 (○). Data were collected in a standard Stevenson screen using continuously recording thermographs, and (b) the soil surface temperatures at the two field sites.

APPENDIX 6

PUBLICATIONS ARISING FROM THE STUDIES REPORTED IN THIS THESIS

1. Lodge, G.M. (1979) Effect of fertility level on the yield of some native perennial grasses on the North-West Slopes of New South Wales. Aust. Rangel. J. 1, 327-333.

2. Lodge, G.M., and Whalley, R.D.B. (1981) Establishment of warm-and cool-season native perennial grasses on the north-west Slopes of New South Wales. I. Dormancy and germination. Aust. J. Bot. 29, 111-119.

3. Lodge, G.M. (1981) Establishment of warm-and-cool-season native perennial grasses on the north-west Slopes of New South Wales. II. Establishment and seedling survival in the field. Aust. J. Bot. 29, 121-133.

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