



*The role of grazing management in the
functioning of pasture ecosystems*

Judith Megan Earl, BRSc (Hons I) UNE

A thesis submitted for the degree of Doctor of Philosophy of the
University of New England

February, 1998

Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

A solid black rectangular box used to redact the signature of the author.

Judi Earl

February 1998

Acknowledgments

I wish to express my sincere thanks to my supervisor Dr. Christine Jones (Division of Botany, UNE) for constant guidance, support, encouragement and friendship over the duration of this project. I am thankful to Christine for providing the chance to undertake this research project and for the opportunities which have been created for me as a result. The enduring patience which Christine has displayed, particularly over the last few months is sincerely appreciated.

Thanks to John and Helen McKemey (Green Hills), David and Anne Mitchell (Strathroy) and Tim and Karen Wright (Lana) for providing their time, land and livestock to enable this project to proceed. Their enthusiasm for the project, their cooperation and assistance in holding field days, maintaining stocking rates and appropriate records was very much appreciated.

Sincere thanks to those who have provided technical assistance with various aspects of the project; Dorothy Bell, John Steer, Jo Newley, Greg Jones, Mark Clayton, Michelle Murphy, Barb Blenman, Olive Bourke, Jim Charley, Doug Clarke, Kerry Greenwood, Janelle Douglas, Holly Ainslie, Ann White and Kate McGregor.

For typing of notes, drafts and references in preparation of this manuscript thanks to Gwen Earl.

Thanks to Raelee Kerrigan, Martin Witchard, Dorothy Bell, Margaret Brock and Mark Gardener for helpful comments and criticism on various aspects of this thesis.

Thanks to Jill Parker and Thea Harris from Research Services for their help and support with administrative issues.

The financial support provided by the Meat Research Corporation is gratefully acknowledged as well as assistance received from the A.S. Nivison Memorial Scholarship.

Particular thanks must go to my postgraduate cohorts in the Division of Botany, Mark Gardener and Dorothy Bell for provision of frequent procrastination sessions, lunches and occasional scientifically related discussion. To other members of the Division of Botany, many thanks for providing such a enjoyable work environment for the past four years.

To the participants of the soils-plant (latterly bugs weeds and worms) postgrad group particularly, Marie-Louise Johnson, Mark Gardener, Kerry Greenwood, Holly Ainslie, Suzanne Boschma, Janelle Douglas, Anthony Casanova, Malem McLeod for many interesting and enjoyable sessions.

I am also extremely grateful to Raelee Kerrigan with whom I have shared space for most of the past three years. Raelee has been primarily responsible for the maintenance of my physical condition via extraordinary culinary skills, providing constant entertainment through expression of her vast musical talents with both stringed and wind instruments, maintenance of some semblance of sanity with her good humour and being a great friend.

Special mention must go to my boys Jason and Terry, the most loyal of friends and excellent study partners.

Finally, thanks to my Mum and Dad, Gwen and Ray Earl, who have been a constant source of encouragement and support in every possible way.

I have been extremely fortunate in having developed an association with the greatest group of people over the duration of this project and wish to express my sincere thanks to each of them.

Abstract

This thesis reports what is thought to be the first scientific analysis of the comparative effects of cell grazing and continuous grazing on botanical composition and soil physical properties undertaken in Australia. Vegetation change in grasslands is a dynamic process and involves both the recruitment of individuals from the seed bank and the loss of individuals and species from the community through mortality. Recruitment from the seed bank at two of the sites studied far exceeded most previous reports. At both sites small-seeded species dominated the seed bank, and there was a poor relationship between the composition of the seed bank and the existing vegetation. The findings indicated that there was a high potential for regression of the botanical composition to rushes and annual dicots if inappropriate management practices were imposed or extended periods of stress were experienced. Perennial grasses comprised only 26% and 16% of the seedling recruitment from soil cores collected from the two sites respectively.

The frequency of defoliation is one of the main factors affecting the productivity and persistence of perennial grasses. A pot experiment was undertaken over a 13 month period to determine the effect of defoliation at 2, 4 and 8 week intervals, or no defoliation, on the production of key indicator species from each site. As the defoliation interval was increased from 2 to 8 weeks above and below-ground biomass of the native grasses *Eragrostis leptostachya*, *Stipa scabra*, *Bothriochloa macra*, *Poa sieberiana* and *Sporobolus creber* increased to a greater extent than the biomass of the introduced species *Phalaris aquatica*. Defoliation at 2 week intervals had significant negative effects on both the herbage production and root biomass of all species tested. A vigorous root system is not only important for the survival of perennial grasses but also has implications for soil structure, providing an important source of below-ground organic matter.

Field trials were undertaken on three predominantly native pasture sites located on properties on the Northern Tablelands of NSW where cell grazing had recently been implemented by skilled managers. The Strathroy and Lana experimental sites were located on soils of granitic parent material and the pastures were dominated by warm season native perennial grasses. The Green Hills site was located on soils derived from basaltic parent material. The area had been sown with introduced pasture species in the past but was dominated by native species when the field studies were initiated. The continuously grazed and cell grazed paddocks selected at each property were originally part of a single larger paddock.

Under the cell grazing regime, pastures are rested from grazing for at least 95% of the time. Cell grazing was found to result in an improvement in the vegetation resource in comparison with continuous grazing. The basal diameters, relative frequency and contribution to dry weight of the most desirable pasture components either increased or remained constant under cell grazing, while declining significantly under continuous grazing. The converse was true for the least palatable components of the pasture, which declined significantly under cell grazing but changed little under continuous grazing. Percentage ground cover was significantly higher after two years of cell grazing than under continuous grazing. Possible mechanisms which operate in grazed pastures to influence these responses are discussed. The short-term changes recorded in pasture composition may have long-term benefits with respect to erosion control, nutrient cycling, hydrological function and the stability of animal production at the cell grazed sites.

The high stock densities associated with the cell grazing process were found to have no detrimental effects on a range of soil properties in comparison to continuous low density stocking. At two sites unsaturated hydraulic conductivity, soil strength and bulk density data were influenced to a greater degree by spatial variation than by grazing treatment. At the third site where cell grazing had been implemented for 18 months longer than the other sites the changes in soil physical properties were positive in comparison to the continuously grazed treatment.

Table of Contents

	Page
Title	
Declaration	ii
Acknowledgements	iii
Abstract	v
Table of Contents	vii
List of Tables	xi
List of Figures	xiii
List of Plates	xv
Chapter 1	
Review of the literature	1
1.1 A brief history of grazing management and pasture decline	1
1.2 The grazing ecosystem	2
1.2.1 The producers	3
1.2.2 The consumers	6
1.2.3 The decomposers	7
1.3 The process of vegetation change	9
1.3.1 Theories of vegetation change	9
1.3.2 Competition	10
1.3.3 Influence of grazing on plant competition	11
1.4 Plant response to defoliation	12
1.4.1 Evolved mutualism?	12
1.4.2 Grazing resistance	13
1.4.3 Physiological response	14
1.4.4 Morphological response	17
1.4.5 Timing of defoliation	17
1.5 Selective grazing	18
1.5.1 Factors associated with diet selection	18
1.5.2 Grazing systems: attempting to control the grazing process	19
1.6 Cell grazing	21
1.6.1 Origins	21
1.6.2 Theory	22
1.6.3 Practice	23
1.7 Conclusions from the literature	24

Chapter 2

Introduction	26
2.1 Background to the study	26
2.2 Approach	28
2.3 Aim of the study	29

Chapter 3

Site descriptions, general materials and methods	30
3.1 Site descriptions	30
3.1.1 Strathroy	31
3.1.2 Lana	33
3.1.3 Green Hills	35
3.2 Sampling plots	39
3.3 Experimental design and statistical analyses	40
3.4 Botanical nomenclature	40
3.5 Terminology	40

Chapter 4

The soil seed bank	41
4.1 Introduction	41
4.2 Methods	42
4.2.1 Extant vegetation	42
4.2.2 Soil sampling	42
4.2.3 Seed germination	42
4.2.4 Statistical analysis	43
4.3 Results	45
4.3.1 Extant vegetation	45
4.3.2 Total germination	45
4.3.3 Relationship between the seed bank composition and the extant vegetation	51
4.4 Discussion	53

Chapter 5

The effects of defoliation interval on the productivity of grasses	59
5.1 Introduction	59
5.2 Methods	60
5.2.1 Statistical analyses	61
5.3 Results	63
5.3.1 Climatic data	63
5.3.2 Cumulative dry weight	63
5.3.3 Root biomass	65
5.3.4 Root:shoot ratio	70
5.3.5 Basal diameter	72
5.3.6 Crown weight	73
5.3.7 Correlations with total yield	73
5.3.8 Reproductive tiller production	74
5.3.9 Seasonal variation	76
5.3.10 Protein content	79
5.4 Discussion	83

Chapter 6

Vegetation change in response to grazing regime	89
6.1 Introduction	89
6.2 Methods	90
6.2.1 Basal diameter	90
6.2.2 Percentage plant basal cover	90
6.2.3 Relative species frequency	91
6.2.4 Percentage contribution to dry weight	91
6.2.5 Diversity	93
6.2.6 Statistical analyses	93
6.3 Results	94
6.3.1 Basal diameter	94
6.3.2 Percentage plant basal cover	100
6.3.3 Relative species frequency	101
6.3.4 Diversity indices	103
6.3.5 Percentage contribution to dry weight	105
6.4 Discussion	109

Chapter 7

Soil characteristics	114
7.1 Introduction	114
7.2 Methods	115
7.2.1 Experimental sites	115
7.2.2 Unsaturated hydraulic conductivity	116
7.2.3 Soil strength and moisture content	118
7.2.4 Bulk density and total porosity	118
7.2.5 Soil chemical analyses	118
7.2.6 Statistical analyses	119
7.3 Results	120
7.3.1 Unsaturated hydraulic conductivity	120
7.3.2 Soil strength and moisture content	125
7.3.3 Bulk density and total porosity	131
7.3.4 Soil chemical analyses	134
7.4 Discussion	137

Chapter 8

Integrating discussion	143
------------------------	-----

Literature cited	151
-------------------------	-----

Appendix 1. Photographic supplement	171
--	-----

Appendix 2. Species to recruit from the seed bank	179
--	-----

Appendix 3. Publications arising from this thesis	185
--	-----

List of Tables

		Page
Table 1.1	Energy content and conversion efficiencies for primary and secondary production in relation to total and photosynthetically active solar radiation.	3
Table 1.2	Grazing resistance strategies of perennial grasses.	14
Table 3.1	Description of the property sites on which the study was conducted.	30
Table 4.1	Number and type of seedlings to emerge from the soil seed bank at each site.	46
Table 4.2	The most abundant taxa to recruit from the seed bank at the Strathroy site.	49
Table 4.3	The most abundant taxa to recruit from the seed bank at the Green Hills site.	49
Table 4.4	Recruitment of annual and perennial grass seedlings from soil cores collected from the Strathroy site.	50
Table 4.5	Recruitment of annual and perennial grass seedlings from soil cores collected from the Green Hills site.	51
Table 4.6	Pearson's correlation coefficient for the relationship between the composition of the seed bank and the extant vegetation at the Strathroy and Green Hills sites at the time of collection of soil cores (August 1994).	52
Table 4.7	Pearson's correlation coefficient for the relationship between the composition of the seed bank and the vegetation at the Strathroy and Green Hills sites fourteen months after collection of soil cores (October 1995).	52
Table 5.1	Root:shoot ratios of plants cut at 2, 4 and 8 weekly intervals and uncut.	71
Table 5.2	Regression parameters for the influence of crown weight, basal diameter and root biomass on final yield of plants.	74
Table 5.3	Total protein yield of plants cut at 2, 4 and 8 week intervals for the 8 week period 15 November 1995 to 10 January 1996.	82
Table 5.4	Total protein yield of plants cut at 2, 4 and 8 week intervals for the 8 week period 6 March to 1 May 1996.	82
Table 6.1	Percentage plant basal cover at each site.	100
Table 6.2	Changes in the proportions of the main species components of pastures at three sites determined by percentage basal cover, relative species frequency and contribution to dry weight.	102

Table 6.3	Shannon diversity indices over time under cell grazing and continuous grazing at three sites calculated using percentage basal cover and pasture dry weight.	105
Table 7.1	Bulk density of surface 40 mm soil at the Strathroy site under cell grazing and high density cell grazing.	132
Table 7.2	Bulk density of surface 40 mm soil at the Strathroy site under cell grazing and continuous grazing.	132
Table 7.3	Bulk density of surface 40 mm soil at the Green Hills site under cell grazing and continuous grazing.	132
Table 7.4	Bulk density of surface 40 mm soil at the two Lana sites under cell grazing and continuous grazing.	132
Table 7.5	Total porosity of surface 40 mm soil at the Strathroy site under cell grazing and high density cell grazing.	133
Table 7.6	Total porosity of surface 40 mm soil at the Strathroy site under cell grazing and continuous grazing.	133
Table 7.7	Total porosity of surface 40 mm soil at the Green Hills site under cell grazing and continuous grazing.	133
Table 7.8	Total porosity of surface 40 mm soil at the two Lana sites under cell grazing and continuous grazing.	133
Table 7.9	Changes in soil chemical composition over time at the Strathroy site.	135
Table 7.10	Changes in soil chemical composition over time at the Green Hills site.	136
Table 7.11	Changes in soil chemical composition over time at the Lana site.	136

List of Figures

Fig. 3.1	Contour map of the Strathroy site showing the position of the experimental plots.	32
Fig. 3.2	Contour map of the Lana site showing the position of the experimental plots.	34
Fig. 3.3	Contour map of the Green Hills site showing the position of the experimental plots.	36
Fig. 3.4	DSE days/ha/month in cell grazed and continuously grazed paddocks from the initiation of monitoring at each site to the end of June 1996.	37
Fig. 3.5	Total monthly rainfall recorded at each site and long term average district monthly rainfall.	38
Fig. 4.1	Seedling recruitment as a percentage of the total germinable seed bank in soil cores collected from each site during each period of wetting.	47
Fig. 4.2	Percentage contribution of each plant type to the total germinable seed bank at the Strathroy site.	48
Fig. 4.3	Percentage contribution of each plant type to the total germinable seed bank at the Green Hills site.	48
Fig. 5.1	Mean weekly maximum and minimum temperatures experienced at the Clarks Farm experimental site.	63
Fig. 5.2	Mean clipped biomass production of species cut at 2, 4 or 8 week defoliation intervals or uncut.	64
Fig. 5.3	Dry weight of shoot and root material at the final harvest of accessions originating from the Strathroy site.	66
Fig. 5.4	Dry weight of shoot and root material at the final harvest of accessions originating from the Green Hills site.	67
Fig. 5.5	Percentage of total root biomass present in the top 50 cm of soil. Plants were cut at 2, 4 or 8 week intervals or uncut.	70
Fig. 5.6	Mean basal diameter of plants cut at 2, 4 or 8 week intervals or uncut.	72
Fig. 5.7	Mean crown weight of plants cut at 2, 4 or 8 week intervals or uncut.	73
Fig. 5.8	Mean number of reproductive tillers per plant produced by plants cut at 2, 4 or 8 week intervals or uncut plants.	75
Fig. 5.9	Mean weight of reproductive tillers per plant produced by plants cut at 2, 4 or 8 week intervals or uncut plants.	75
Fig. 5.10	Clipped biomass production for each 8 week period of species from Strathroy cut at 2, 4 week and 8 week intervals.	77

Fig. 5.11	Clipped biomass production for each 8 week period of species from Green Hills cut at 2, 4 week and 8 week intervals.	78
Fig. 5.12	Crude protein content for each 8 week period of species from Strathroy cut at 2, 4 week and 8 week intervals.	80
Fig. 5.13	Crude protein content for each 8 week period of species from Green Hills cut at 2, 4 week and 8 week intervals.	81
Fig. 6.1	Relative change in basal diameter over time in the selected indicator species at the Strathroy site under cell grazing and continuous grazing.	96
Fig. 6.2	Relative change in basal diameter over time in the selected indicator species at the Strathroy site under regular density cell grazing and high density cell grazing.	97
Fig. 6.3	Relative change in basal diameter over time in in the selected indicator species at the Lana site under cell grazing and continuous grazing.	98
Fig. 6.4	Relative change in basal diameter over time in in the selected indicator species at the Green Hills site under cell grazing and continuous grazing.	99
Fig. 6.5	Number of species per quadrat recorded over time at each site under cell grazing and continuous grazing.	104
Fig. 6.6	Changes in pasture biomass over time at each site under cell grazing and continuous grazing.	108
Fig. 7.1	Unsaturated hydraulic conductivity at Strathroy under high density cell grazing and regular density cell grazing during December 1994 and 1996.	121
Fig. 7.2	Unsaturated hydraulic conductivity at the Strathroy site under cell grazing and continuous grazing during December 1994 and 1996.	122
Fig. 7.3	Unsaturated hydraulic conductivity at the Green Hills site under cell grazing and continuous grazing during December 1994 and 1996.	123
Fig. 7.4	Unsaturated hydraulic conductivity at Site 1 and Site 2 at Lana under cell grazing and continuous grazing during December 1993, 1994 and 1996.	124
Fig. 7.5	Soil strength at the Strathroy site under high density cell grazing and regular density cell grazing in December 1994 and 1996.	127
Fig. 7.6	Soil strength at the Strathroy site under cell grazing and continuous grazing in December 1994 and 1996.	128
Fig. 7.7	Soil strength at the Green Hills site under cell grazing and continuous grazing in December 1994 and 1996.	129
Fig. 7.8	Soil strength at Site 1 and Site 2 at Lana under cell grazing and continuous grazing during December 1993, 1994 and 1996.	130

List of Plates

Plate 3.1	The Strathroy site.	31
Plate 3.2	The Lana site.	33
Plate 3.3	The Green Hills site.	35
Plate 4.1	Arrangement of trays in the glasshouse.	44
Plate 4.2	Seedlings at the stage of growth where they were removed identified and counted.	44
Plate 5.1	Arrangement of the experimental plants in PVC pipes set up outdoors at Clarks Farm UNE.	62
Plate 5.2	Defoliated plant cut to 3 cm height.	62
Plate 5.3	Root systems of species originating from the Strathroy site cut at 2, 4 and 8 week intervals and uncut.	68
Plate 5.4	Root systems of species originating from the Green Hills site cut at 2, 4 and 8 week intervals and uncut.	69
Plate 6.1	The line intercept method used to determine plant basal diameter.	92
Plate 6.2	The 100 point quadrat used to determine percentage plant basal cover.	92
Plate 7.1	The disc permeameters used to determine unsaturated hydraulic conductivity of soils under four tensions.	117