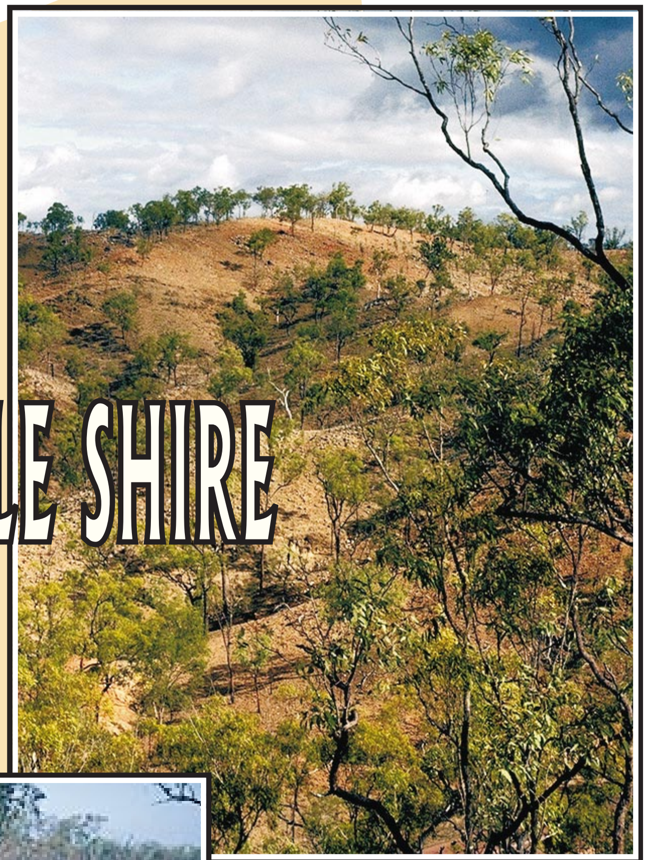
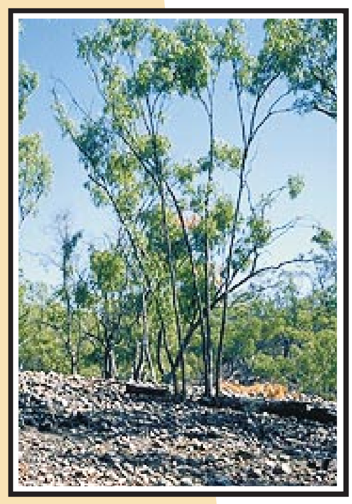
DNRQ980090

LAND RESOURCES OF THE DALRYMPLE SHIRE

VOLUME 1





Authors
L.G. Rogers
M.G. Cannon
E.V. Barry

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CSIRO LAND and WATER

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LAND RESOURCES OF THE DALRYMPLE SHIRE

VOLUME ONE

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This is a joint publication by the Department of Natural Resources (DNR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and presents data on the soil, land and vegetation resources of the Dalrymple Shire. It may be distributed to other interested individuals or organisations. Funds provided under National Landcare Program to partly fund this project are gratefully acknowledged.

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Contents

	Page
Preface	iv
List of Tables	v
List of Figures	v
List of Photographs	vi
Appendices	vi
Accompanying Maps	vi
Mapping unit index	vii
Summary	viii
Acknowledgments	ix
Introduction	**1**
Previous studies	2
Description of study area	**3**
Climate	3
Vegetation	3
Geology	4
Landform	9
Land Use	13
European history	13
Recent developments	14
Water resources	15
Methods	**17**
Data collection and site database	17
Vegetation data	17
Soil erosion data	17
Chemical and physical analyses	17
Dispersion score	18
Infiltration and plant available water	18
UMA-unique mapping area database	19
Map preparation	19
Geological landscapes	**21**
Alluvial landscapes	21
Basalt landscapes	24
Cainozoic landscapes	27
Granodiorite landscapes	30
Igneous landscapes	33
Metamorphic landscapes	36
Sedimentary landscapes	38
Mapping units	**41**
Data summaries	**89**
Degradation	89
Infiltration	91
Dispersion data	95
Grass and tree basal area	96
Native weeds	99
Exotic weeds	102
Salinity	104
References	**109**
Glossary	**115**

Preface

This report presents the data from a land resource survey of the Dalrymple Shire, North Queensland. Preliminary findings from the survey have been published in *'Land Degradation in the Dalrymple Shire: A Preliminary Assessment, Methods and Results'* (De Corte *et al*., 1994). This report presents the background and methods of the survey and a description of the landscapes, soils and land degradation recorded during the survey.

To accompany this report are six 1: 250 000 scale soil association maps.

List of Tables

Table 1	Area of elevation classes and major land use limits for Dalrymple Shire	9
Table 2	Value of primary industry in Dalrymple Shire, 1992–1993	13
Table 3	Annual discharges (megalitres) of major rivers in Dalrymple Shire	15
Table 4	Degradation categories recorded for Alluvial landscapes	23
Table 5	Degradation categories recorded for Basalt landscapes	26
Table 6	Degradation categories recorded for Cainozoic landscapes	29
Table 7	Degradation categories recorded for Granodiorite landscapes	32
Table 8	Degradation categories recorded for Igneous landscapes	35
Table 9	Degradation categories recorded for Metamorphic landscapes	37
Table 10	Degradation categories recorded for Sedimentary landscapes	39
Table 11	Soil types grouped on classification (Order of Australian Classification) and geological landscape	43
Table 12	Estimated plant available water content and profile saturation of soil types assessed over 1 metre of profile unless constrained by soil depth	44
Table 13	Generalised degradation rank for the geological landscapes	89
Table 14	Generalised degradation rank for the Orders of Australian Classification	89
Table 15	Percentage of sites were degradation occurs for various degradation categories across soil types	89
Table 16	Cumulative infiltration for 15 soil types	91
Table 17	Average dispersion score for A and B horizons of soil types	95
Table 18	Average grass and tree basal area for the soil types	97
Table 19	Percentage distribution of grass cover classes	99
Table 20	Percentage occurrence of dominant grasses for mid-dense to dense cover class and as percentage occurrence in the site database	99
Table 21	Ground cover classes for currant bush and mimosa bush	100
Table 22	Number and percentage of survey sites with exotic weeds	102
Table 23	Number of sites for various electrical conductivity (EC) classes	106

List of Figures

Figure 1	Location of study area	1
Figure 2	Average monthly rainfall and estimated evaporation for Charters Towers	5
Figure 3	Monthly rainfall Charters Towers, long term average (dark grey) and monthly totals 1987 to September 1994 (light grey)	5
Figure 4	Short and long term monthly average rainfall for selected centres in Dalrymple Shire	6
Figure 5	Rainfall isohyet map (mm) for Dalrymple Shire	7
Figure 6	Geological landscapes of Dalrymple Shire	8
Figure 7	Slope classes of map units	10
Figure 8	Elevation classes (AMSL) for Dalrymple Shire	11
Figure 9	Major land use limits for extensive grazing	12
Figure 10	Beef cattle numbers in the Dalrymple Shire, 1960–1993	14
Figure 11	Location of survey sites in the Dalrymple Shire	16
Figure 12	Map of Dalrymple Shire showing Orders of the Australian Soil Classification	42
Figure 13	Survey sites where soil erosion was recorded	94
Figure 14	Dispersion score vs exchangeable sodium percentage for two classification Orders (Chromosols and Sodosols)	96
Figure 15	Grass basal area vs Tree basal area for all sites	98

Figure 16	Grass basal area vs Tree basal area for two selected soil types	98
Figure 17	Grass basal area for all sites showing cases of poor, marginal and good pasture condition	99
Figure 18	Survey sites with currant bush (*Carissa* spp.)	101
Figure 19	Survey sites with exotic weeds	103
Figure 20	Average electrical conductivity (EC) for A and B horizons grouped by Orders of the Australian Soil Classification	104
Figure 21	Salinity risks for catchments in the Dalrymple Shire	105

List of Photographs

Photo 1	Erosion gully in levee bank showing that gullies can advance rapidly into alluvial plains	22
Photo 2	Open woodland of narrow-leaved ironbark trees on a Red Ferrosol (Hillgrove soil)	25
Photo 3	An exposure of ferricrete with shallow sandy'Barkla' soils in the foreground	28
Photo 4	Rubber vine has invaded many streams and adjacent landforms throughout the Granodiorite landscapes	31
Photo 5	Granite outcrop is common in hilly Igneous landscapes shown here in the background with sandy soil type Carse O' Gowrie in the foreground	34
Photo 6	This photo shows naturally dissected terrain in metamorphic landscapes which often have quartizite gravels on the surface	37
Photo 7	Surface rock is a feature of many Sedimentary landscapes as shown here with grey box *(Eucalyptus normantonensis)*	40
Photo 8	Infiltration on surface soil under grass cover	92
Photo 9	Infiltration on bare topsoil	92
Photo 10	Infiltration on top of B horizon	92
Photo 11	Infiltration on soil surface under tree canopy	93
Photo 12	Currant bush (*Carissa* spp.) under box trees in a Cainozoic landscape	100
Photo 13	Chinee apple infestation on a black clay in the Granodiorite landscape	102

Appendices

The appendix sections are in *'Land Resources of the Dalrymple Shire - Volume 2. Appendices'*

Appendix I	Vegetation codes, scientific and common names
Appendix II	Codes used in site description database
Appendix III	List of analytical methods/ reference soil profiles
Appendix IV	Codes used in Unique Mapping Area (UMA) database
Appendix V	Listing of UMA data
Appendix VI	Map legend
Appendix VII	Area of soil types and representation in database

Accompanying Maps

(in plastic folder)

1. Soil Associations of the Dalrymple Shire - Sheet 1 1:250 000 (Ref No. 96-DLR-I-P3171)
2. Soil Associations of the Dalrymple Shire - Sheet 2 1:250 000 (Ref No. 96-DLR-I-P3172)
3. Soil Associations of the Dalrymple Shire - Sheet 3 1:250 000 (Ref No. 96-DLR-I-P3173)
4. Soil Associations of the Dalrymple Shire - Sheet 4 1:250 000 (Ref No. 96-DLR-I-P3174)
5. Soil Associations of the Dalrymple Shire - Sheet 5 1:250 000 (Ref No. 96-DLR-I-P3175)
6. Soil Associations of the Dalrymple Shire - Sheet 6 1:250 000 (Ref No. 96-DLR-I-P3176)

Mapping unit index

Mapping unit	Map symbol	Map unit page Vol 1	Soil reference profile page,Vol 2
Amity	AT	46	34
Argentine	AR	46	35
Barkla	BA	47	36
Basalt Rock	BS	47	
Bluff	BL	48	37
Boston	BO	48	38
Bulliwallah	BW	49	39
Burdekin	BU	50	40
Burra	BR	50	41
Cape	CP	51	42
Carse O'Gowrie	CG	51	43
Ceaser	CE	52	44
Charters Towers	CT	53	45
Conjuboy	CB	53	46
Conolly	CO	54	47
Corea	CR	54	48
Creek	CK	55	49
Dalrymple	DA	56	50
Dotswood	DO	56	51
Egera	EG	57	52
Ewan	EW	58	53
Fanning River	FR	58	54
Featherby	FE	59	
Felspar	FS	59	55
Flagstone	FL	60	56
Gainsford	GA	60	57
Galmara	GL	61	58
Glencoe	GC	61	59
Greenvale	GR	62	60
Hillgrove	HG	62	61
Hillview	HV	63	62
Lime View	LI	63	63
Liontown	LT	64	64
Lolworth	LL	65	65
Manoa	MN	65	66
Maryvale	MA	66	67
Mingela	ML	67	68
Miscellaneous Basalt	MB	67	69
Miscellaneous Carbonate	MK	68	
Miscellaneous Disturbed	MD	68	
Miscellaneous Flooded	MF	68	
Miscellaneous Terrain	MT	68	70
Mount Ravenswood	MR	69	71
Miscellaneous Granodiorite	MG	69	
Miscellaneous Igneous	MI	70	
Miscellaneous Metamorphic	MM	70	
Miscellaneous Sedimentary	MS	71	
Myrtlevale	MY	71	72
Nial	NI	72	73
Nosnillor	NS	72	74
Nulla	NU	73	75
Pallamana	PL	74	76
Pandanus	PA	74	77
Paynes	PN	75	78
Pentland	PE	75	79
Pin Gin	PG	76	80
Pinnacle	PI	76	81
Powlathanga	PO	77	82
Rangeside	RS	78	83
Rangeview	RA	78	84
Rishton	RI	79	85
Rolston	RL	80	86
Scartwater	SC	80	87
Severin	SV	81	88
Star	ST	81	89
Thorpe	TH	82	90
Tuckers	TU	82	91
Two Creek	TC	83	92
Umala	UM	83	93
Utchee	UT	84	94
Victoria Downs	VD	84	95
Wairuna	WR	85	96
Wambiana	WB	85	97
Warrawee	WA	86	98
Wattle Vale	WV	87	99
Worsley	WO	87	100
Yarraman	YA	88	101

Summary

A study of the land resources of the Dalrymple Shire, situated in the upper Burdekin River catchment was conducted by the Department of Natural Resources (DNR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Funding for the collaborative project was provided by the National Landcare Program (NLP). The study is one of a number of government initiatives designed to provide information for property planning and pasture management to achieve sustainable beef cattle production within the Shire. This publication presents the findings of the survey. Preliminary results have been published in 'Land Degradation in the Dalrymple Shire: A Preliminary Assessment, Methods and results' (DeCorte *et al.*, 1994).

The Dalrymple Shire covers 6.8 million hectares in the upper Burdekin River catchment of north Queensland and is centred on the town of Charters Towers. The main industries of the Shire are beef cattle production and the mining of gold and base metals. The survey was undertaken from January 1990 to December 1994. Data were obtained from 2559 study sites at which vegetation (species, structure and form, tree basal area, grass basal area, exotic and native weeds), landform, erosion (sheet, rill, gully and scalds), and soil profile description data were recorded. The data were grouped into seven broad geological units and then into 72 soil types. A combination of remote sensing techniques using 1:100 000 scale satellite images and 1:80 000 scale black and white aerial photography were used to delineate the mapping units (Soil Associations) which were mapped onto six 1:250 000 maps.

Soils

Sandy surfaced soils (sands to sandy loams) cover 45% of the Shire, with uniform sandy soils covering 21%, gradational sandy soils 6% and texture contrast soils occurring over 18% of the Shire. Loamy surfaced soils (sandy clay loams to clay loams) cover 44% of the Shire, with uniform loamy soils covering 1%, gradational loamy soils 22% and texture contrast soils occurring on 21% of the Shire. Clay soils cover 9% of the Shire, with massive surface soils covering 1%, structured (blocky) 2.5% and self-mulching clays occurring on 5.5% of the Shire. Rock outcrop (Basalt flow lines and sandstone outcrop) occupies 1% while less than 1% of the Shire is flooded by natural or man-made lakes.

Weeds

Currant bush (*Carissa* spp.) was the dominant native weed and was recorded at 53% of assessed sites. Ground cover of *Carissa* spp. exceeded 80% in places and restricted pasture growth at many sites. False sandlewood (*Eremophila mitchellii*) was locally dominant and found mainly on shallow texture contrast soils (Sodosols) and was recorded at 12% of assessed sites. The other native weed recorded was mimosa bush (*Acacia farnesiana*) which occurred mainly on clay soils at 2.3% of assessed sites.

Eleven species of exotic weeds were recorded at 16% of sites with rubber vine (*Cryptostegia grandiflora*) occurring at 7.5% of sites and chinee apple (*Ziziphus mauritiana*) at 5% of sites. These weeds were found mainly in the disturbed granodiorite landscapes around Charters Towers with rubber vine extending to alluvial systems of surrounding landscapes.

Erosion

Sheet erosion was the dominant form of erosion occurring at 34% of assessed sites. Scalds occurred at 26% of sites, gully erosion at 12% and rill erosion at 8% of sites. No erosion was recorded at 31% of sites.

Pasture condition

Condition of the pasture was determined by measuring the grass basal area. Grass basal area (GBA) is the percentage area of growing points of a perennial tussock or hummock grass per unit area. Using this method the condition of the pasture could be assessed independent of grazing pressure or occurrence of fire. Sites with a GBA less than or equal to 1.5% were considered to be in a degraded state and accounted for 43% of sites. Some 26% of sites had a GBA between 1.5 and 2.0% and were in marginal condition, while the remainder of sites (31%) had a GBA greater than or equal to 2.0% and were considered to be in good condition. Sites in good condition were observed to provide adequate ground cover to significantly reduce soil erosion.

Acknowledgments

The authors wish to thank the following people for their assistance and involvement with this study:

Diane Bray and Charlie Ellis, Land Resources Publications for final editing and production of the report.

Gavin Clarke for assistance with field work and advice on geology and identifying rocks.

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INTRODUCTION

A study of the land resources of the Dalrymple Shire was conducted by the Department of Natural Resources (DNR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Funding for the collaborative project was provided by the National Landcare Program (NLP). The aim of the project was to identify the land resources (soils, vegetation and land degradation status) of the Shire. Issues of pasture condition decline, exotic weed invasion, regrowth, soil erosion and salinity hazard were also addressed after being identified as problems by the Dalrymple Landcare Committee and staff from the Queensland Department of Primary Industries (DPI) office based at Charters Towers.

The Dalrymple Shire occupies approximately 6.8 million hectares. (67 670 km^2) in the upper Burdekin River catchment of north Queensland and is centred on the town of Charters Towers (Figure 1). The Shire boundary follows the Seaview and Leichhardt Ranges in the east, the Great Divide in the west, and the Suttor and Belyando Rivers in the south-east. The northern boundary lies at about latitude 18° 30'S and the southern at latitude 22° 10'S, the western at longitude 144° 15’E and the eastern boundary at 147° 25’E.

Figure 1. Location of study area

Previous studies

Soil information is available for the Shire at a scale of 1: 2 000 000 by Isbell *et al.* (1967, 1968). Vegetation maps have been compiled by Isbell and Murtha (1972) using the base maps of previous soil mapping and additional data. Geological data (1:250 000 scale) is available through a series of maps and explanatory notes by the Geological Survey of Queensland.

A previous erosion study of the upper Burdekin River catchment conducted for the Burdekin Project Committee (1976) concluded that land use and land management practices (grazing, burning), although subordinate factors, were major contributors to erosion. Approximately 12% of the upper Burdekin River catchment was affected by erosion with one third of the affected area having severe sheet and gully erosion. The report made qualitative aerial assessment of three classes of sheet erosion only. No quantitative measure was made of scalds, rill or gully erosion, nor of pasture condition or woody weed occurrence. Kent and Shields (1984) published a 1:1 000 000 land capability study of most of the area using the soil mapping units from Isbell and Murtha (1970). They examined photo patterns and made field traverses to derive capability ratings for grazing use. Approximately 8% of the Shire was found suitable for intensive pastoral activities, this area consisting of mainly moderately deep to deep clays. Areas unsuitable for grazing covered 12% and were characterised by steep slopes, shallow soils, and the presence of heart-leaf poison bush (*Gastrolobium grandiflorum*). The remaining area was suitable for extensive grazing of mainly native pastures. The Bradfield Study Consortium (1984) mapped land units at 1:100 000 scale around Greenvale, Hillgrove and riparian areas along the Burdekin River between these two areas. Irrigated land capability was assessed and 48 500 ha were found with slight to moderate limitations for irrigated land use. Resource data for areas abutting the Dalrymple Shire are found in turner *et al*. (1993), Wilson and Baker (1990), Grundy and Bryde (1989), Pedley (1967), Perry(1964), Perry and Lazarides (1964).

This report builds on previous work and provides resource information at a more appropriate scale for regional use. The soil and landforms of the Dalrymple Shire are mapped at a scale of 1:250 000. The soil and vegetation are described for the mapping units and an assessment is made of land degradation. The framework for the soil type descriptions has been established to allow for use in more detail mapping should it be required.

DESCRIPTION OF STUDY AREA

Climate

The Dalrymple Shire lies within the seasonally wet-dry tropics and has a warm, subhumid climate with a distinct hot-wet summer and a warm-dry winter. Average annual rainfall ranges from approximately 500 mm in the south-west of the Shire, to 1600 mm in the Seaview Ranges to the north-east, with 3200 mm per annum at Mt. Spec. However, the majority of grazing land in the north-east receives less than 700 mm (Figure 5). The rainfall is highly seasonal with more than 80% of the total rainfall occurring between November and April. Both monthly and yearly totals are highly variable and rainfall events are often intense. The rainfall pattern and intensity is due to summer storms, together with occasional cyclonic influences.

The average monthly rainfall (Bureau of Meteorology) and estimated evaporation (Hutchinson, 1989) patterns at Charters Towers are shown in Figure 2. Recorded annual rainfall at Charters Towers ranges from 108 to 1631mm with a mean yearly rainfall of 658 mm. More than half of the recorded yearly totals are less than the mean due to periodic high rainfall years. Figure 2 shows clearly the high evaporation rates throughout the year such that water deficits occur in most soils during the year. Finlay and Lloyd (1983) have more detailed information.

The mean monthly temperatures at Charters Towers are relatively high in summer (mean December maximum of 34.3°C and minimum of 23.3°C) with daily maximum temperatures exceeding 30°C in 84% to 91% of days in the months of October to January. Winter months have moderate temperatures with July mean maximum temperatures of 24.4°C and mean minimum temperatures of 10.5°C. Frosts are usually light and average 2 to 3 per year. More elevated regions in the north and north-west of the Shire are likely to show cooler winter temperatures with more frequent and heavier frosts. The survey was conducted following three reasonable wet years and then below average rainfall through to the end of the survey. Rainfall distribution from January 1987 until the end of the survey is compared with the long term monthly average for Charters Towers in Figure 3. Long term monthly average, versus monthly average from October 1989–94 (survey period April 90–Sept. 94) for selected rainfall centres is presented in Figure 4.

Vegetation

Vegetation types in the Dalrymple Shire range from rainforest to open woodland and spinifex, however, eucalypt open woodland is the dominant vegetation community. The vegetation for most of the Shire has been mapped and described by Isbell and Murtha (1972) at a scale of 1:1 000 000.

Tree clearing has occurred throughout the Shire, although predominantly in the southern half. Areas of clay soils that supported gidgee, blackwood and brigalow have traditionally been cleared. Minor areas of the more valuable agricultural country associated with alluvial soils and to a larger extent vegetation on the red and yellow earths of the Cainozoic landscapes have been cleared in recent times. However, much of the Shire retains its original vegetation. Between 1991 and 1995 the average annual clearing rate for the Shire was 38 km^2 which is 0.06% per year (SLATS, 1997).

The 1:250 000 topographic sheets of Charters Towers, Hughenden, Buchanan, Galilee and Jericho have been mapped by Thompson and Turpin (in prep).

A list of scientific and common names for vegetation species and the dominant 95% of upper, mid and lower stratum species for the Shire (as recorded in site database) is given in Appendix I. Common names are used to describe species throughout the report and are supplemented with scientific names where several species have the same common name. Unless otherwise stated the following common names have been used; narrow-leaved ironbark (*Eucalyptus crebra*) and silver-leaved ironbark (*E. shirleyi*).

Geology

The geology of the Dalrymple Shire is varied and complex, resulting in the development of a large number of soil types. A comprehensive description of the geology can be found in a series of 1:250 000 maps and explanatory notes by the Geological Survey of Queensland; Buchanan (Olgers, 1970), Charters Towers (Clarke and Paine, 1970), Clarke River (White, 1963a), Einasleigh (White, 1963b), Hughenden (Casey, 1969a), Ingham (Fardon, 1973), Tangorin (Casey, 1969b), and Townsville (Wyatt, 1968). A summary of the geology is found in Paine and Cameron (1972). Geological units are aggregated into seven broad groups (adapted from Paine and Cameron, 1972). These include the following geological landscapes which have been derived from the soil map database, Figure 6;

1) Alluvial
2) Basalt
3) Cainozoic (includes Tertiary landscapes)
4) Granodiorite
5) Igneous (other than Granodiorite and Basalt)
6) Metamorphic
7) Sedimentary

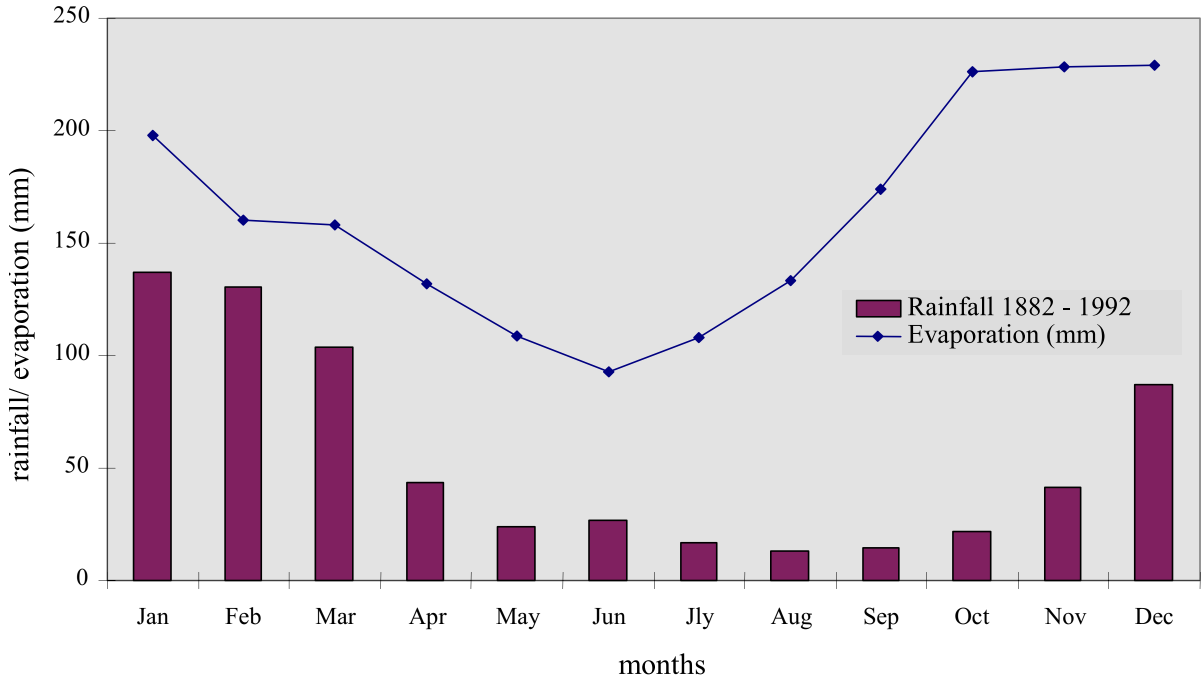


Figure 2. Average monthly rainfall and estimated evaporation for Charters Towers

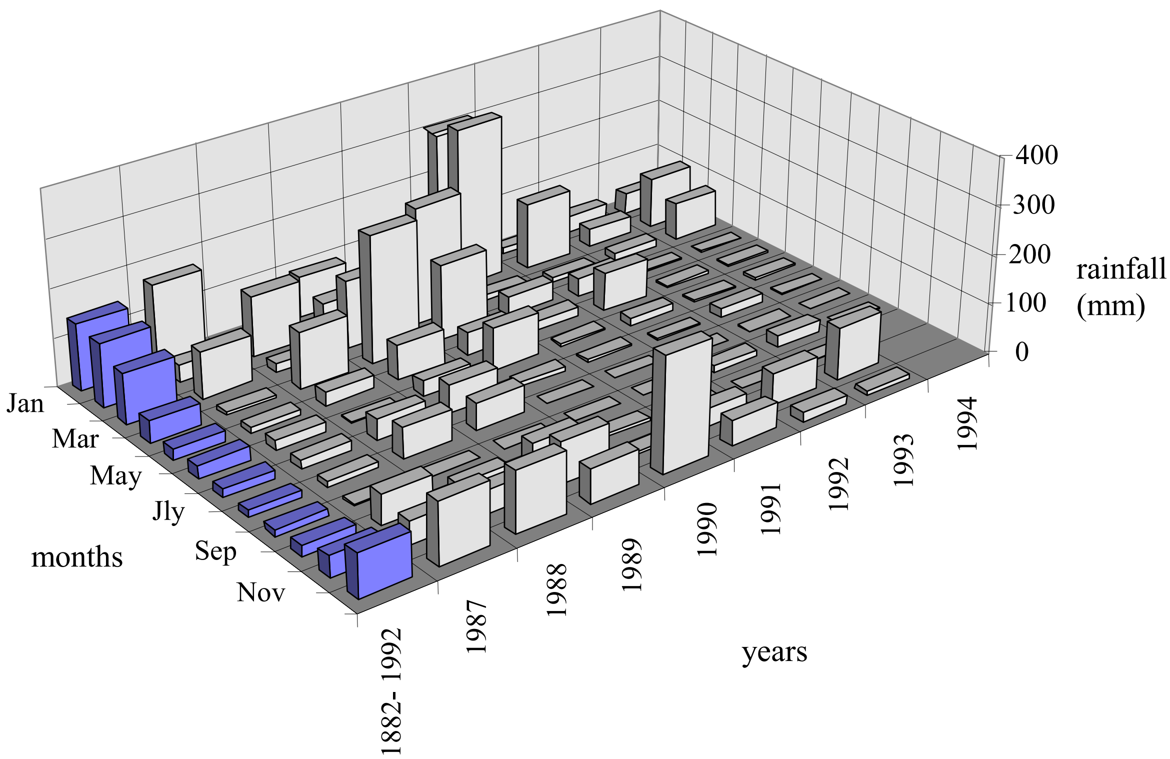
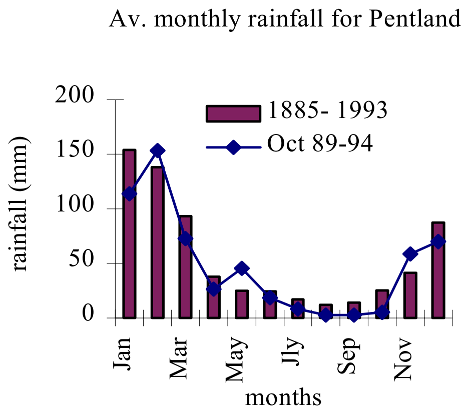
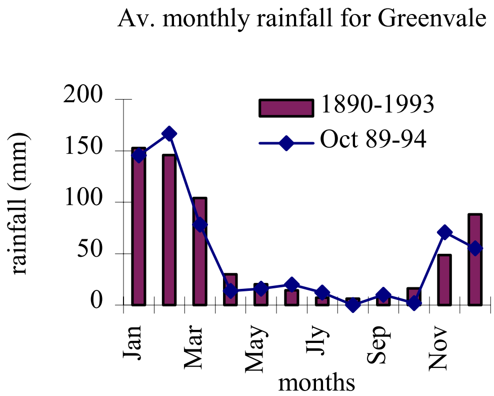
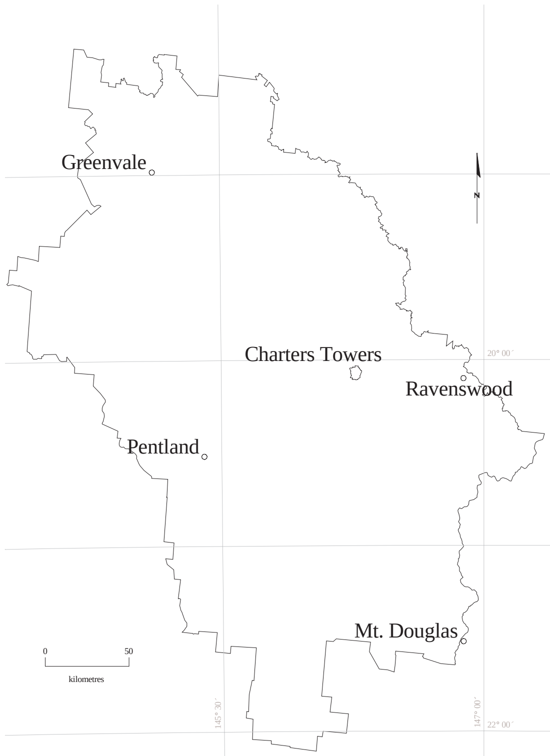
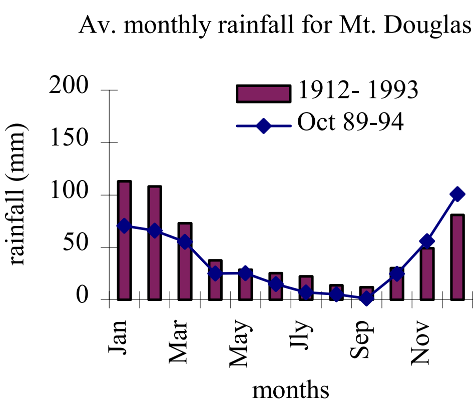


Figure 3. Monthly rainfall at Charters Towers, long term average (dark grey) and monthly totals for 1987 to September 1994 (light grey)


Av. monthly rainfall for Pentland
1885- 1993
Oct 89-94
rainfall (mm)
200
150
100
50
0
Jan
Mar
May
Jly
Sep
Nov
months


Av. monthly rainfall for Greenvale
1890-1993
Oct 89-94
rainfall (mm)
200
150
100
50
0
Jan
Mar
May
Jly
Sep
Nov
months


Greenvale
Charters Towers
Ravenswood
Pentland
Mt. Douglas
0
50
kilometres


Av. monthly rainfall for Mt. Douglas
1912- 1993
Oct 89-94
rainfall (mm)
200
150
100
50
0
Jan
Mar
May
Jly
Sep
Nov
months

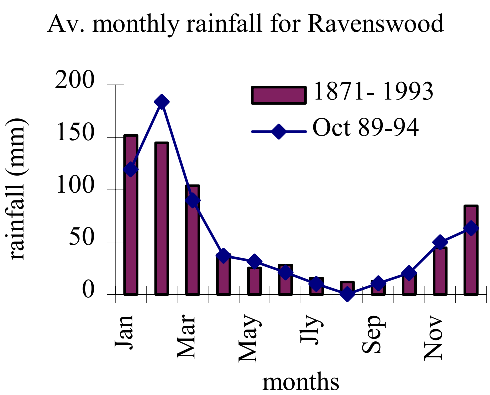

Av. monthly rainfall for Ravenswood
1871- 1993
Oct 89-94
rainfall (mm)
200
150
100
50
0
Jan
Mar
May
Jly
Sep
Nov
months

Figure 4. Short and long term monthly average rainfall for selected centres in Dalrymple Shire

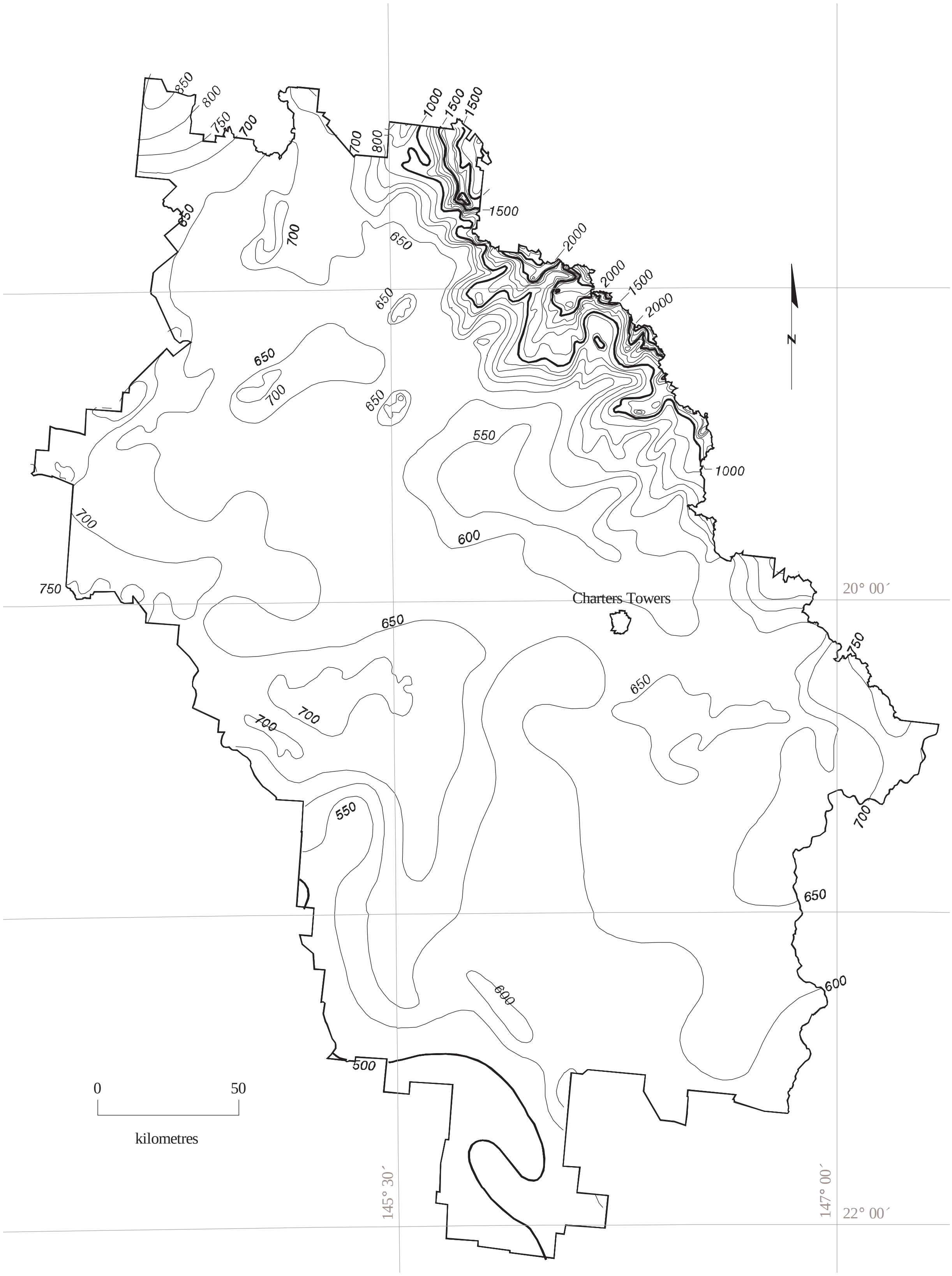


Figure 5. Rainfall isohyet map (mm) for Dalrymple Shire

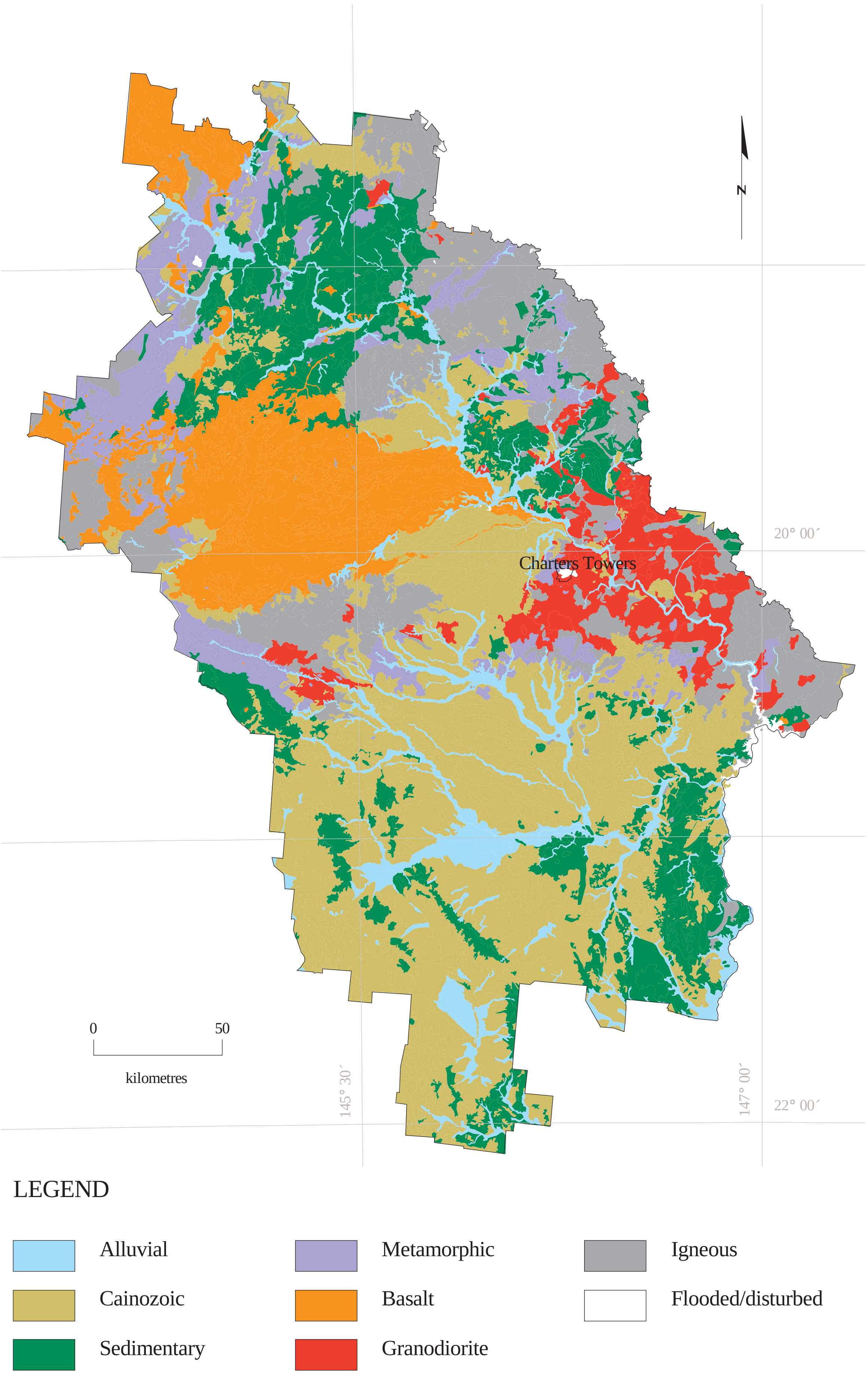


Figure 6. Geological landscapes of Dalrymple Shire

Landform

The Shire is drained by the Burdekin River and its tributaries, this area is 50% of the Burdekin Basin catchment. An area of 2000 km^2 is a centripetal (internal) drainage system that feeds into Lake Buchanan. The eastern edge of the Shire is bounded by a series of ranges rising to over 900 metres, however most of the area is flat to gently undulating with decreasing relief and elevation to the south and east. The elevation of the Shire is mostly 200–650 metres with the Burdekin River dissecting the area and breaching the Leichhardt ranges before flowing to the coastal plains. Figure 7 shows the average slope classes for the mapping units and Figure 8 shows the elevation classes of the Shire in 100 m steps derived from 9 second (250 m grid) digital elevation data. Table 1 lists the area of slope classes and major land use limits (for land use of extensive grazing). Figure 9 shows extent of land use limits listed in Table 1.

Table 1. Area of elevation classes and major land use limits for Dalrymple Shire

Slope class	Area (ha)	% of Shire
Level (0-1%)	1 562 000	23
Very gently inclined (1-3%)	2 024 000	30
Gently inclined (3-10%)	1 959 000	29
Moderately inclined (10-32%)	686 110	10
Steep to very steep (32-100%)	535 690	8

Major land use limit	Area (ha)	% of Shire
Short slopes/ dissected	2 113 700	31
Access difficulties	100 700	1.5
Gilgai (>20 cm)	41 000	0.6
Wetness (wet > 3 months/yr.)	30 600	0.5
Flooding	85 800	1.3
Badlands	60 000	0.9
Human influence - disturbed	19 000	0.3
Shallow soil depth (<50cm)	245 400	3.6
Stony (>20%)	1 128 100	16.7
Rock outcrop (>10%)	505 100	7.5
No major land use limit apparent	2 437 400	36

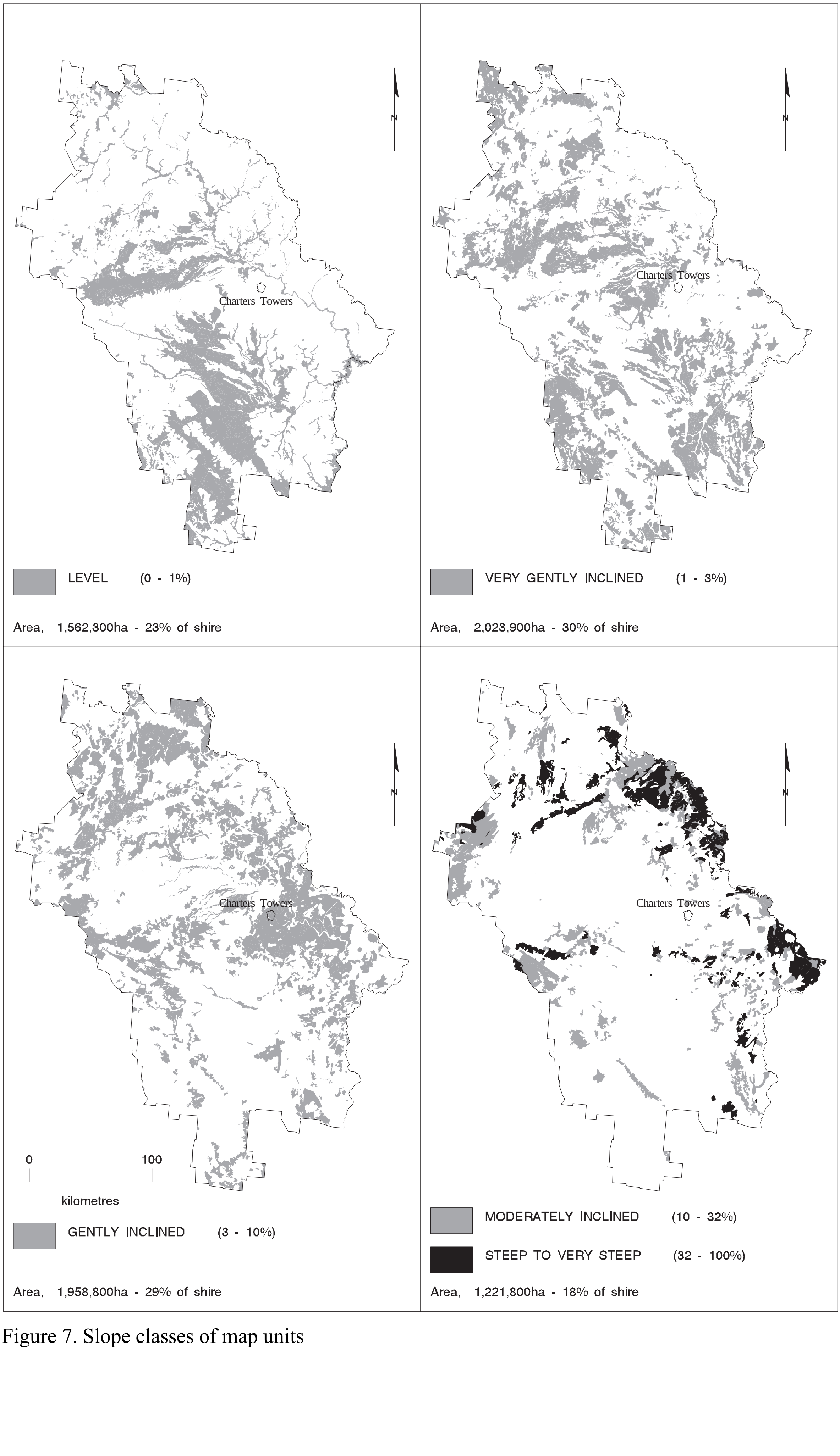


Figure 7. Slope classes of map units

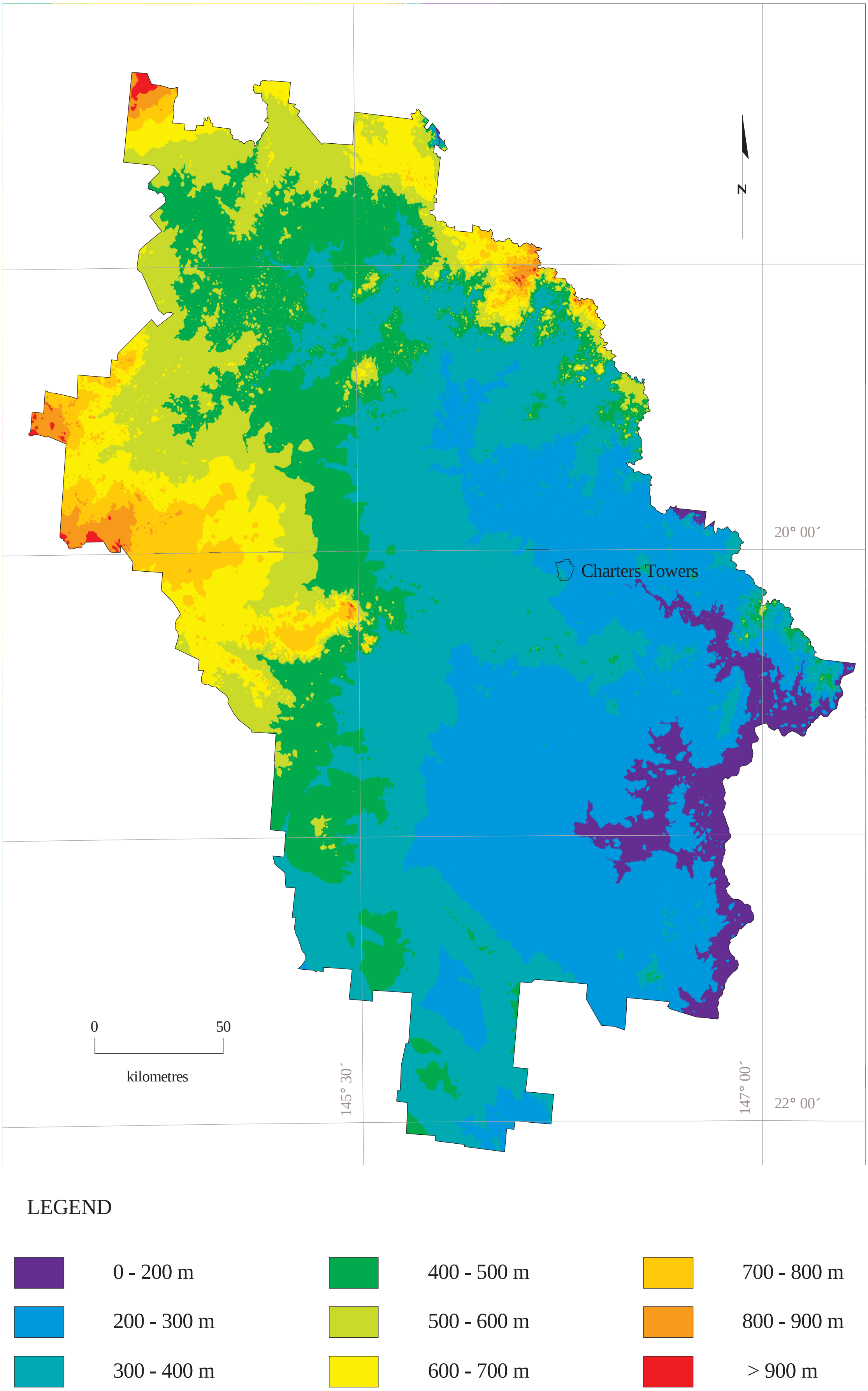


Figure 8. Elevation classes (metres AMSL) for Dalrymple Shire

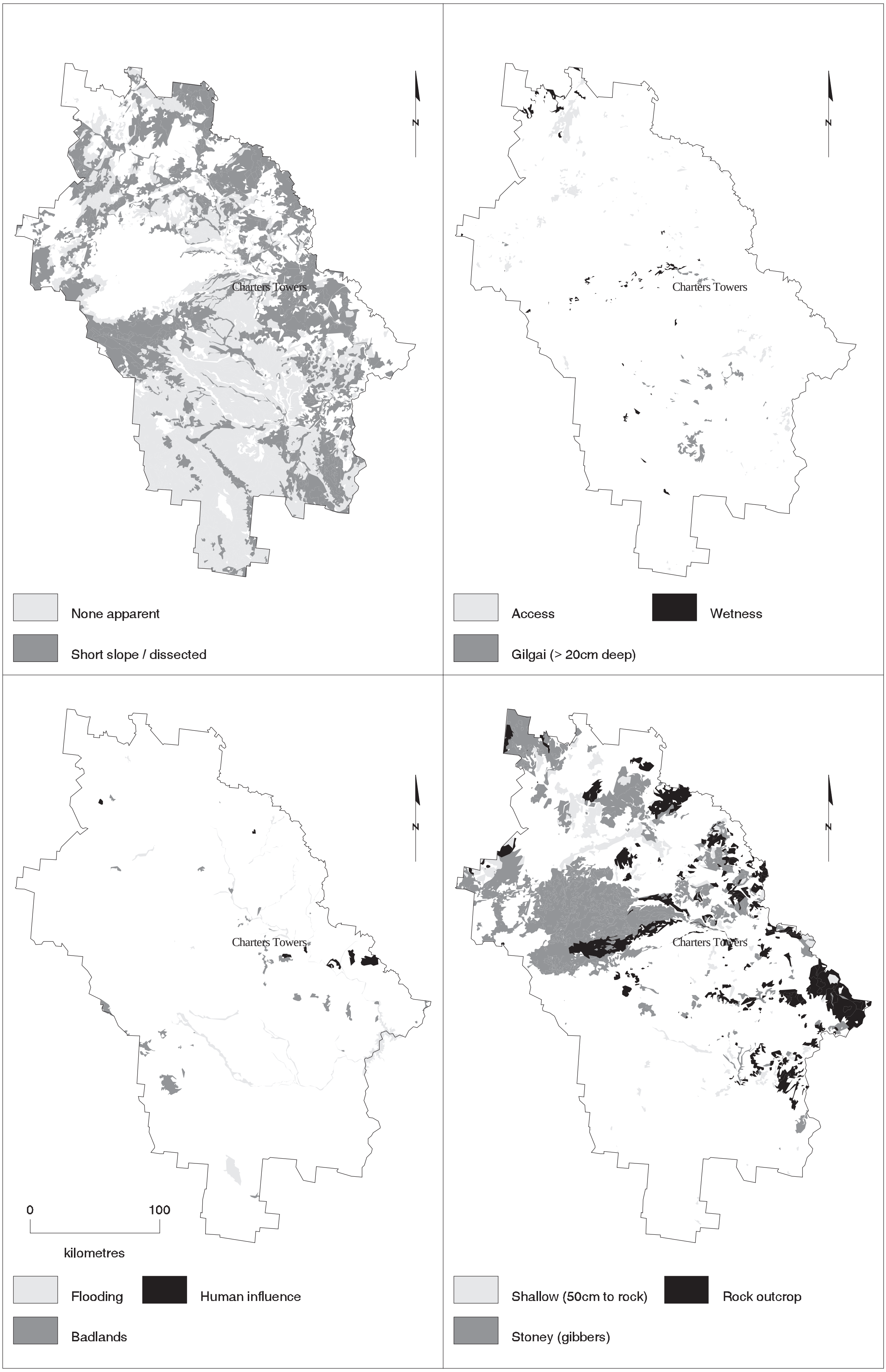


Figure 9. Major land use limits for extensive grazing

Land use

More than 90% of the Shire is used for extensive beef production from 271 grazing properties. Hinton (1993) examined commercial properties in the Shire (>1000 ha), amalgamated properties with the same ownership and excluded those with significant income derived from outside the Shire to arrive at 196 business entities. Most properties in the Shire are between 10 000 and 50 000 ha and run 2000 to 5000 head of cattle. The Australian Defence Force manages the former properties of Star and Dotswood, 217 890 ha on the eastern edge of the Shire and a facility at Macrossan (388 ha). National Parks in the Shire total 92 488 ha (1.37%) and include the Blackwood National Park (1648 ha), Great Basalt Wall National Park (32 500 ha), Dalrymple National Park (1640 ha) and White Mountains National Park (108 000 ha, of which half is in the Shire). Environmental reserves occupy 12 056 ha.

Other land use in the Shire includes small rural residential and non-commercial grazing blocks around Charters Towers and between Charters Towers and Mingela, approximating 30 000 ha. Mining activities occupy a small area with the extraction of gold, base metals and dolomite. There are a small number of horticultural enterprises occurring mainly on alluvial soils that grow oranges, grapes and vegetables. In 1992 an area of 2800 ha was licensed to be irrigated from the Burdekin River with 75% of the area for pasture and fodder crops and the remainder for vegetables. A list of commodity values for 1992–93 is listed in Table 2.

Table 2. Value of primary industry in Dalrymple Shire, 1992–1993

Commodity	Value as at 1994
Crops and horticulture #	$3 078 000
Cattle disposals #	$51 110 000
Mining*	$232 300 000

[1] (Source: ABS, 1994#. Dept. of Minerals and Energy, Queensland*)

European history

The area was first visited by Europeans in 1845 when Dr. Ludwig Leichhardt led a party of five men and two aboriginal boys into the Dalrymple area. It was on the journey that Leichhardt named the Burdekin river after Mrs Burdekin of Sydney who helped to outfit the expedition. The area was visited again in 1856 by Augustus Charles Gregory who, like Leichhardt, returned with favourable reports of the area. Land was first taken up on an expedition led by George Elphinstone Dalrymple which left Rockhampton in August 1859. Pioneers entered the area during the 1860’s and overlanded sheep from the south, so that by 1863 most of the area was taken up for sheep raising. Sheep numbers declined due to the poor quality of flocks, losses to dingoes, footrot and the spear grass which damaged the wool and caused high animal mortality.

Beef cattle were introduced into the area, with numbers increasing to 17 000 by 1861 and 123 000 by 1868. The increase in cattle numbers was due to the discovery of gold in the region (Star River in 1865, Cape River, 1867, Ravenswood, 1869, and Charters Towers in 1872) which provided a significant local market. A rail link to assist transport of stock was completed from Townsville to Mingela in 1880, extended to Charters Towers in 1882, to Ravenswood in 1884 and to Hughenden in 1887. Meat processing and freezing plants were built on the coast in the early 1890’s with excess cattle driven overland to New South Wales and Victoria. The cattle tick *Boophilus microplus* entered the area in 1895 and together with the 1902 drought, caused cattle numbers to be reduced to half that of the 1895 herd by 1905. Except for a period between World War I and World War II cattle prices were economic and herd numbers increased.

Recent developments

A number of management changes have occurred since 1970 which have had a significant negative impact on the condition of rangelands in the Shire.

- An increase in cattle numbers over the past two decades, primarily during the early 1970's, brought about by a combination of good seasons and reduced sales in response to low cattle prices from 1974 to 1977. (See Figure 10)
- The replacement of *Bos taurus* strains of cattle with *Bos indicus*, which are more adapted to grazing in tropical environments, are more resistant to cattle tick and less inclined to die in drought.
- The use of supplementary feeding allowing the use of country previously deemed marginal or unsuitable.
- Below average rainfall for the last 10 years (1985–1995).
- Financial burdens on graziers from cost-price pressures and increasing interest rates.
- A reluctance by most graziers to use fire on a regular basis as a management tool to control woody weeds and regrowth.
- An improvement in road infrastructure and the capacity of road transport operations to move stock, allowing rapid build-up in stock numbers after periods of drought.

In the mid 1980's widespread drought conditions combined with increased cattle numbers resulted in serious degradation of land resources through soil erosion, pasture deterioration and woody weed invasion. Above average wet seasons occurred in 1974/5, 1981 and 1989.

Mortiss (1995) reports that based on local observations, cattle numbers may have increased to around one million by the late 1970's and fallen to around 300 000 by late 1994. The area of sown pasture in the Shire varied between 96 000 and 168 000 ha between the years 1990–1994 (ABS). Further information on factors affecting land use in the cattle industry in the Shire can be found in Mortiss (1995), Hinton (1993, 1995), Mims and Reid (1992), Frank (1988), and Finlay and Lloyd (1983).

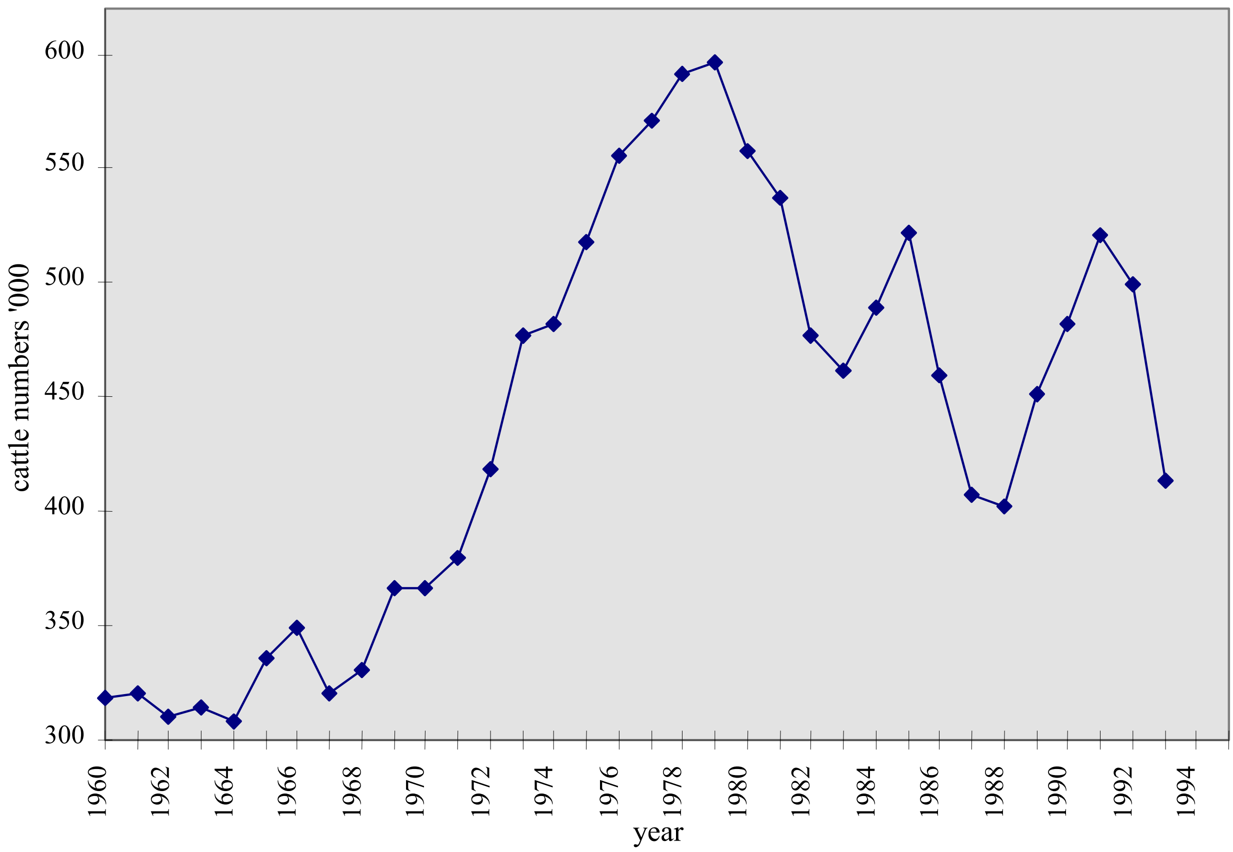


Figure 10. Beef cattle numbers in the Dalrymple Shire, 1960-1993

Water resources

Surface water is the main water resource in the Shire. The main rivers in the Shire are the Burdekin, Cape, Campaspe, Clarke, Running and Suttor. Annual discharges for three of these rivers is presented in Table 3.

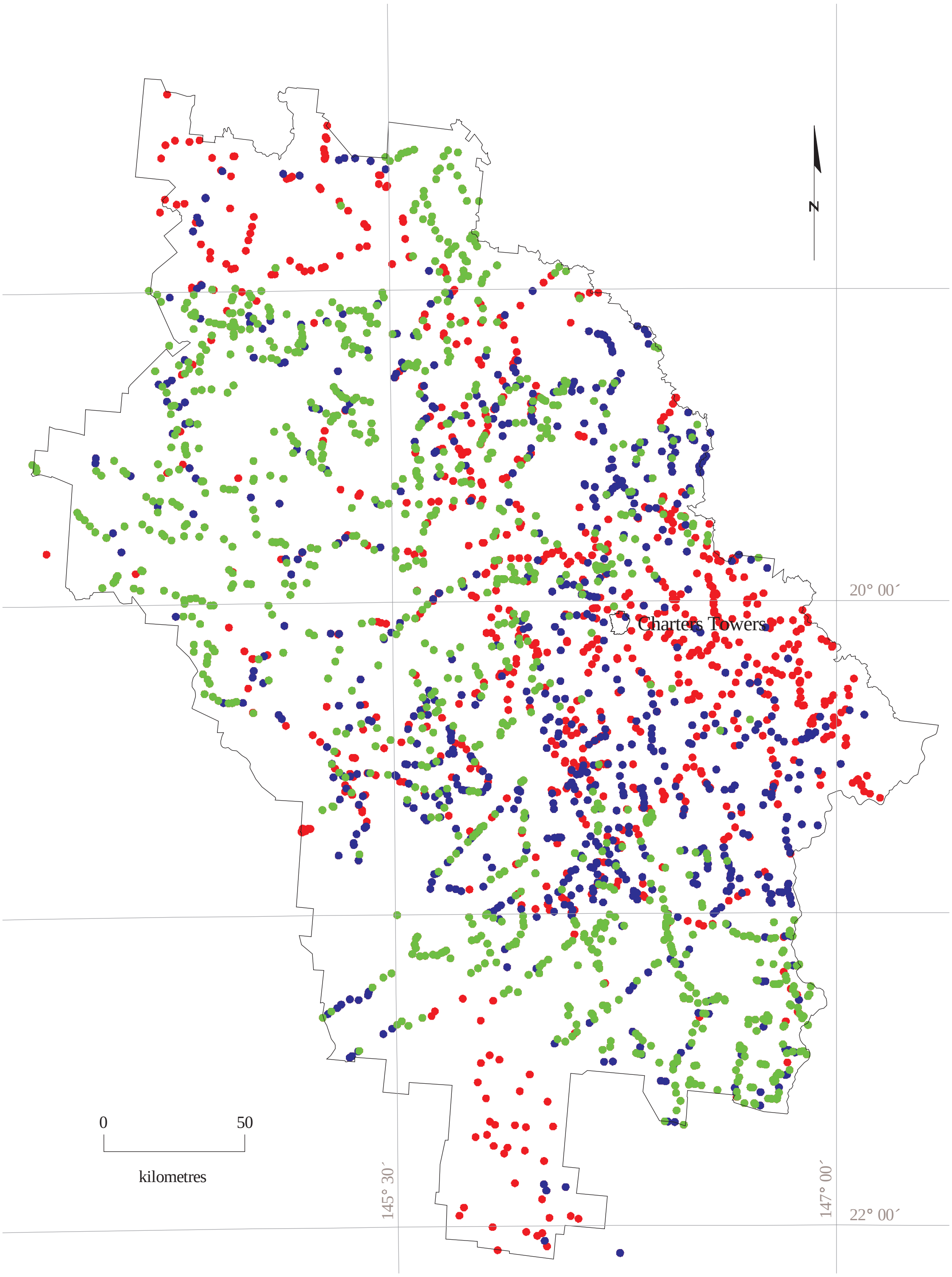
Water storages in the Shire include the Charters Towers Weir on the Burdekin river (1906 ML), Gap Creek Dam at Mt. Leyshon mine (pumps from Charters Towers Weir when it overflows), Paluma Dam north east of Charters Towers in an area of high rainfall on the coastal ranges (11 800 ML, which is piped to the Townsville area) and the Burdekin Falls Dam. The Burdekin Falls Dam is on the Burdekin River located on the south-east edge of the Shire and is the largest water storage in Queensland. The dam supplies water to irrigation areas on the lower Burdekin and emergency supplies to the Ross River Dam, which services the Townsville population centre. The dam has a capacity of 1 860 000 ML covering an area of 22 400 ha.

Groundwater reserves are pumped by bores and used mostly for stock watering points. Good quality groundwater with total dissolved ions (TDI) less than 1000 milligrams per litre is associated with aquifers in the basalt country and alluvial areas. The remaining areas have poor quality groundwater (TDI greater than 3000 mg/l) with isolated areas having TDI 1000–3000 mg/l.

Table 3. Annual discharges (megalitres) of major rivers in Dalrymple Shire

River	Maximum	Mean	Minimum
Burdekin at Sellheim	24 203 847	1 185 750	6 247
Clarke at Wandovale	588 370	83 885	56
Running at Mt. Bradley	186 563	24 401	0

(DPI Water Resources, 1994)



LEGEND

- No Sample
- Sampled for pH and EC
- Sampled for various laboratory analyses

Figure 11. Location of survey sites in the Dalrymple Shire

METHODS

Field work in the first year of the survey (1990) was undertaken to establish the framework of the continuing land resource survey and to determine the degradation status of the Shire. After consultation with local extension staff from DPI and the Dalrymple Landcare Committee, factors such as pasture species, exotic weed invasion, regrowth, soil erosion and salinity hazard were considered important for land management decisions. These factors were included in the survey to be recorded at each study site. This report follows the format and methodology in an initial preliminary study by DeCorte *et al.* (1994).

Data collection and site database

The data presented is from 2559 sites (Figure 11), chosen using a free survey technique (Gunn *et al.* 1988) to represent the dominant soil types, landscapes and vegetation communities. Data from previous surveys accounted for 118 sites. The remaining 2441 sites were located by a GPS (global positioning system) to an accuracy of 100 m with the size of each site approximately one hectare (100 m x 100 m) unless constrained by landform element. Data recorded included descriptions of landform, soil profile morphology, vegetation form and species, and degradation status. Data from all sites were coded and recorded in a special purpose soils database, WARIS (Rosenthal *et al.*, 1986). Where possible the codes match those found in McDonald *et al.* (1990). A list of attributes recorded at each site and the corresponding codes is given in Appendix II.

Vegetation data

Vegetation data was collected at each of the study sites. It included information on the structural formation of the vegetation of the upper, mid and lower stratum. Also recorded were the three dominant species of the different strata; the percentage distribution of each of the dominant species in each of the strata; the tree basal area; the crown cover of the mid stratum species; the grass basal area; and the exotic and native weed species present and, their percentage cover. A list of plant species recorded is given in Appendix I. Tree basal area (TBA) was assessed by counting all trunks as wide or wider than a rod (6.7 mm width) held at arms length (approx 0.7 m) when sighting along the arm (modified method of Grosenbaugh, 1952). The count was conducted through 360º and included all trees that satisfied the criteria. A separate count was made of the mid-stratum. Using this method, 10 counts approximate to 2.29 m^2/ha. The percentage distribution and foliage cover of each of the dominant species of each of the strata, as well as the cover of the exotic weeds were determined by visual estimates. The grass basal area was determined visually after extensive practice comparing visual estimates with the wheel point technique (Tidmarsh and Havenga, 1955). A listing of average grass and tree basal area data for each soil type is in Table 18.

Soil erosion data

Erosion data was collected at each study site. Attributes included visual estimates of width and depth of gully, rill and sheet erosion and length and width estimates of scalds. Data is presented for percentage of sites with various forms of erosion on page 89.

Chemical and physical analysis

From a total of 2559 sites, 1835 (72%) were analysed for chemical analysis. 1637 profiles were sampled (approx. 100 g) at the centre of each horizon and subsampled if the horizon was greater than 30 cm thick. These samples were assessed for 1:5 soil/water pH and electrical conductivity (EC) using the method described in Bruce and Rayment (1982). Of the 1637 sampled sites, 625 were analysed for basic cations and cation exchange capacity, while of these, 339 sites were analysed in addition for acid and bicarbonate extractable phosphorus and extractable sulfur. All 625 sampled sites were taken from 0–10 cm in the A horizon and from the top of the B horizon.

In addition 187 reference sites with a detailed profile description and chemical and physical analyses were also sampled. Eleven sites described and analysed from previous soil projects were included with incomplete analyses. Appendix II lists the analyses and methods used and lists descriptions of the reference sites. The location of the reference sites is printed on the accompanying maps.

Soil samples taken during the survey were used as part of a wider phosphorus study by DPI (Ahern *et al.*, 1994). The data from that survey was used to rate soil types for supplement and crop production using levels suggested by Ahern *et al.* (1994). Their map was generated using sheet 4, Isbell *et al.* (1967) and sheet 7, Isbell *et al.* .(1968) of the Atlas of Australian Soils, a 1:2 000 000 scale map.

Dispersion score

The Emerson dispersion score (using a modified method of Loveday and Pyle, 1973) was conducted on 937 sites to determine a possible erosivity index for the soil types. The Loveday and Pyle (1973) method was preferred to the method described by Emerson (1967) because the simple numbering system was easier to use for ranking the samples and less prone to operator bias.

The score was determined using the scale below at 2 and 20 hours on air dry aggregates. When no dispersion occurs a subsample is taken, wet to field capacity and remoulded where the dispersion is again scored at 2 and 20 hours. The four scores are summed to give a score of 0 to 16. Dispersive soils are generally prone to erosion and have a summed score of 8 or greater. Where dispersion occurs on the air dry sample, a value of 8 is added to the score as it is assumed that complete dispersion will occur upon remoulding at 2 and 20 hours. This assumption did not hold true in a number of samples. Care also should be taken when choosing appropriate clods as mottled soils gave different scores between the colour mottles.

Emerson dispersion score

- **0** no dispersion.
- **1** slight dispersion, recognised by a slight milkiness of water adjacent to the aggregate and sometimes by a narrow edging of dispersed clay to part of the aggregate.
- **2** moderate dispersion clearly visible, less than 50% of the aggregate affected.
- **3** strong dispersion with considerable milkiness and about 50% of the aggregate dispersed away.
- **4** complete dispersion leaving only sand grains in a cloud of clay.

Infiltration and plant available water

Fifteen sites representing the major soils of the Shire were chosen to obtain infiltration figures for the surface horizon and the subsoil using a modified approach of Talsma (1969). Infiltration rates were measured for the surface horizon with treatments of bare ground, grassed areas and areas under tree canopy. These treatments were chosen to approximate a potential runoff figure given the surface condition of any particular soil. Samples were taken to determine available water for plant growth (difference in stored water on samples subject to 10 kpa and 1500 kpa suction expressed on an oven dry basis) and particle size analyses by the method of Coventry and Fett (1979). The lower limit of retained moisture (1500 kpa suction) is the considered standard for the majority of conventional crops, however measurements taken on native trees and grasses to determine lower limits of available moisture show transpiration occurring at suctions of 4000 kpa (Penny, *pers. comm.*; Beyer, *pers. comm.*). This implies that some native species are capable of extracting more of the total water store.

UMA-unique mapping area database

The database created from this survey has two parts; a site database mentioned earlier (page 23) and a UMA database. A UMA is a unique mapping area that occurs on the map as a polygon or discrete parcel of land. Each UMA is given a number that appears on the map and is an identifier for the UMA database that provides summary land resource information. A list of the attributes recorded and codes used for the UMA database is in Appendix IV. A subset of the database listing UMA number, map unit code, area (ha), map number, secondary limitation codes, minor soil types, minimum average and maximum slopes, salinity, observed erosion, complexity and data source codes is in Appendix V.

Each UMA on the map is labelled with a code (map symbol) which describes the dominant soil type, slope of the landform and major limitation of the UMA. Flooded, disturbed (urban and mining) and miscellaneous units were also mapped. The data source for each UMA is coded in the database and includes study sites, Landsat images, black and white aerial photography, geology maps and other surveys.

The UMA database was compiled from the above sources. Estimates are made of the component soils, the slope and the soil erosion in UMAs where no sites were recorded. A '# ' was recorded whenever an attribute could not be recorded due to insufficient data. The erosion severity and extent scores are based on visual estimates using black and white aerial photography from the mid-sixties.

Map preparation

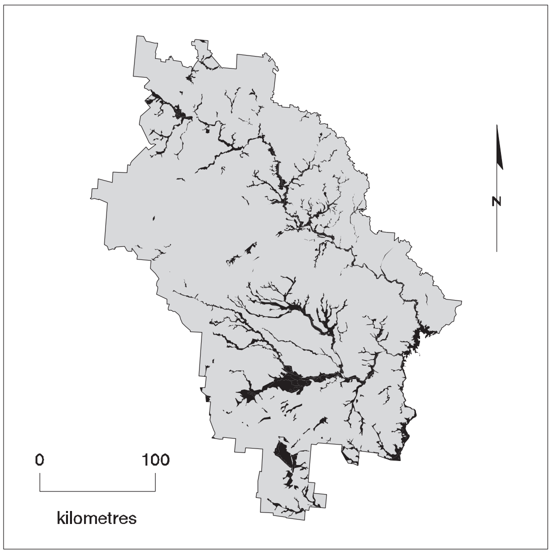
Initial linework for the maps was prepared by air photo interpretation using black and white 1:80 000 air photos dated around the mid to late-sixties. The photos were the only set available to give uniform coverage of the Shire and were used to distinguish landform features. The base maps for field mapping were 1:100 000 Landsat Thematic Mapper (TM) maps taken from a series of TM scenes dated from 1986 to 1992. These images were rectified from a 1:100 000 topographic base except for map sheet six where provisional 1:100 000 cadastral and published 1:250 000 topographic sheets were used. The base maps followed closely to the published 1:100 000 series map grid and were annotated with a latitude and longitude grid. The colours and patterns on the image were related to field observations and site location. Navigation and location in the field was by global positioning system and following the latitude and longitude grid on the image.

Each 1: 100 000 base map was separately enhanced for soil and vegetation features using bands 1, 5 and 7 (blue and two short wave infared bands) described by Bui and Rogers (1993). Initial linework on the air photos was transferred to the image base maps and modified after field checking. Editing and preparation of the published maps was done using the 1:100 000 image base maps.

The enhanced Landsat images were not suitable to assess erosion status but did help to determine soil type and spatial occurrence. The ability to discriminate soil types using the satellite imagery diminished rapidly as structural formation classes increased from woodland to open forest. Vegetation communities could be separated at a coarse level with *Acacia* species showing a black colour as did softwood scrubs. Clay soils and red and yellow earths were also readily distinguished. Landsat imagery was able to improve the use of the older photography but required extensive ground truthing. Outlays for the imagery was also significantly less than the option to obtain recent aerial photography for the Shire.

GEOLOGICAL LANDSCAPES

Alluvial landscapes



These landscapes occupy 608 500 ha (9.0%) of the Shire (see adjacent figure), occurring mainly in the southern half of the Shire, Central Plains and Lowlands (Bellamy, 1972). The major rivers are the Burdekin, Campaspe, Cape and Suttor. Smaller areas occur along the Clarke, Basalt and Star rivers and on Lolworth Creek.

The dominant landform is a complex of level to very gently inclined alluvial plains, including clay soils with gilgai microrelief in open depressions and lower slopes, and moderately well drained texture contrast soils to well drained gradational soils on low rises. The terraces and levees are predominantly well drained gradational soils of sandy to loamy texture. Extensive alluvial plains along major streams frequently exhibit numerous braided channels. Throughout the Shire, narrow alluvial plains occur along minor streams but are not mappable at the 1:250 000 scale. However these narrow strips of alluvium carry important reserves of better quality native pastures due to higher soil fertility.

Geology

Alluvial deposits are of Quaternary age (less than 1.8 million years) consisting of sand, silt, gravel and clay from present streams including the Burdekin, Cape, Campaspe, Suttor, Clarke, Basalt and Star Rivers.

Soils

Eight soil types are recognised. Burdekin and Pandanus are loamy and sandy soils of the alluvial terraces and levees. Creek and Cape are texture contrast soils occurring commonly away from the stream banks or on older less active flood plains. Creek has loamy topsoils with neutral subsoils while Cape has slightly heavier topsoils with alkaline subsoils. Fanning River and Gainsford are gradational soils situated on the larger high terraces and have reasonable drainage. Gainsford soil has lighter surface textures and red to yellow subsoils while Fanning River has darker subsoils. Yarraman and Manoa are clay soils occurring in depressions of the terraces and levees of the major drainage lines; they include many of the seasonal lagoons and lakes scattered throughout Dalrymple Shire. Yarraman has a well structured surface while Manoa is generally massive.

Salinity

Electrical conductivity (EC) measurements show salt accumulation in all soils except the rapidly drained Pandanus soil. The other soils ranged from 10% of sites with moderate (0.3-<1.2 mS cm^{-1}) salinity levels for Burdekin, Creek and Fanning River soils through to more than 70% of sites with moderate (0.3-<1.2 mS cm^{-1}) to severe (. >=1.2 mS cm^{-1}) salinity levels for Cape, Manoa and Yarraman soils. These higher readings correspond to the high clay content of the subsoils with Cape soil also dominated by exchangeable sodium.

Soil degradation

Soil erosion occurred at 40% of sites. The major forms were sheet erosion and scalds. Scalds were recorded at 23% of the sites and ranged from 1 to 80 m long and 1 to 20 m wide. Sheet erosion occurred at 18 % of sites and ranged from 2 to 15 cm deep and 5 to 50 m wide. Rill erosion occurred at 2% sites, and ranged from 15 to 20 cm deep and 1 to 3 m wide. Gullies occurred on 7% of sites. Severe gully erosion occurs on some stream banks in Cape, Burdekin and Creek soil. Examples occur at Big Bend on the Burdekin River, the junction of the Basalt River and the Burdekin River and on Fletcher Creek near the junction with the Burdekin River. The texture contrast and cracking clay soils have moderate to highly dispersible subsoils, consequently the maintenance of a stable surface is critical to the control of erosion. The extensive sheet and scalds readily form rills and gullies once the subsoil has been exposed. Features such as cattle pads and cuttings for vehicle access expose the subsoil leading to gully erosion and stream bank instability (see Photo 1). To reduce this risk, limited grazing and increased off-stream water points along unstable stream banks should be a priority.

Tree species

The vegetation of the alluvial landscapes varies considerably. Communities range from mid-high to tall woodland, grading locally to open forest of Coolibah (*Eucalyptus coolibah*), Reid River box and narrow-leaved ironbark (*E. crebra*). Ghost gum, Moreton Bay ash and poplar gum are common associated species. False sandalwood and bauhinia are common mid-stratum species on texture contrast soils. Mid-high open forests of brigalow, gidgee and Dawson gum occur on texture contrast and cracking clay soils. Reid River box or wattles were the major sources of regrowth, and at two sites accounted for greater than 35% of foliage cover.

Pasture composition

Black spear grass and bluegrass were recorded as the dominant in previous surveys (Isbell and Murtha, 1972), however black spear grass (20%), wire grasses (14%) and golden beard grass (10%) are now dominant. In all, 39 species were recorded as dominating the pasture sward of the 264 sites assessed.

Photo 1. Erosion gully in levee bank showing that gullies can advance rapidly into alluvial plains

In terms of grass basal area, 44% of sites had poor pastures, 13.5% had marginal pasture condition and 42.5% of the pastures assessed were in good condition.

Exotic weeds

Nine exotic weeds were identified in this landscape. These were rubber vine (15% of sites), chinee apple (6%), parkinsonia (5%), prickly acacia (3%), belly ache bush (2%), lantana (1%), parthenium (1%), Harrisa cactus (1%) and calotropis (1%). Rubber vine, lantana and belly ache bush had the densest stands and are well established. Parthenium was prevalent on the alluvium of the Suttor River and most of the alluvial landscapes immediately south of the Shire boundary. Parkinsonia was observed in isolated occurrences with one severe invasion on the alluvial plain of the Cape River along the Scartwater Road.

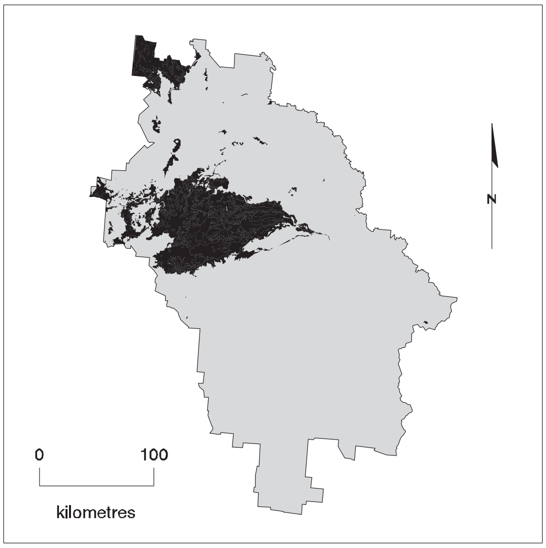
Native weeds

Currant bush (*Carrisa* spp.) occurred at 60% of sites and exhibited a ground cover of 1% to 80%. Mimosa bush (*Acacia farnesiana*) was observed at <2% of sites. The occurrence of a large weed population in the alluvial landscape is of major concern. Seed dispersal ability through flood events and the more fertile soils make this landscape an ideal location for weed establishment.

Table 4. Degradation categories recorded for Alluvial landscapes

Landscape/ Soil number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Alluvial landscape (317)	18	2	7	23	22	61	44
Burdekin (47)	19	0	4	23	35	63	36
Creek (51)	24	0	12	20	18	61	37
Cape (70)	20	6	9	36	20	70	52
Fanning River (36)	19	6	6	19	30	70	42
Gainsford (21)	19	5	5	14	24	57	32
Manoa (29)	21	0	14	34	10	52	50
Pandanus (39)	13	3	0	10	20	55	48
Yarraman (24)	4	0	8	21	24	52	58

Basalt landscapes



These areas comprise approximately 906 000 ha or 13% of the Shire (see adjacent figure) and are considered to be the most productive regions. The basalt landscapes comprise three distinct basalt provinces: Nulla to the east, Chudleigh to the west and McBride to the north. The main agricultural activity is extensive beef cattle production with minor localised areas of irrigation for supplementary fodder production. The dominant landforms are level plains with a number of low residual hills, remnants of volcanic vents and numerous low rocky ridges and scarps.

Geology

The most common rock types are alkali olivine basalts, and although other variants occur, available evidence suggests limited differences between the provinces with a continuum of chemical and mineralogical compositions in each (Isbell *et al*., 1976). The age of the flows range from Miocene (9 million years) (Coventry, R.J. and Stephenson, P.J., *pers. comm.*) to Holocene (12 000 yrs) (Henderson and Stephenson, 1980).

Soils

Eight soil types and three miscellaneous units have been identified. The miscellaneous unit, Basalt rock, delineates the basalt rock flows that are devoid of soil, the best example being the 'Great Basalt Wall'. Miscellaneous Basalt soil describes areas of silty material that are dominated by diatomaceous earth found in wet areas associated with the Basalt Rock unit. Miscellaneous carbonate describes eroded areas of highly calcareous materials, these units are found in dissected areas. Nulla soil is derived from rocky basalt flows that contain shallow soils and are found as low rocky ridges and small scarps. Felspar, Hillgrove and Pin Gin are freely drained gradational soils with red subsoils found on level to very gently inclined plains. Felspar and Hillgrove are similar soils, however Hillgrove has a massive A horizon and Felspar has a well structured A horizon. Conjuboy has yellowish brown subsoils and is otherwise similar to Hillgrove, while Glencoe has dark brown subsoils with higher clay content throughout and is found in similar landforms to Hillgrove. Pin Gin is limited to minor occurrences in the higher rainfall rainforest areas in the north-east of the Shire. Lolworth and Maryvale are black to dark grey cracking clays that generally occupy the drainage lines and lower positions in the landscape but may be found on more elevated gentle slopes and crests. Lolworth has alkaline subsoils while Maryvale is alkaline throughout.

Salinity

Moderate salinity levels (0.3-<1.2 mS cm^{-1}) were recorded at 16% of sites with 86% of these being the cracking clay soils. The cracking clay plains appear to be the accumulation zone for much of the salt in this landscape. Both these soils (Vertosols) have lower internal drainage compared to the other basalt soils (Ferrosols). Land use change through extensive tree clearing or irrigation could mobilise these stored salts through changing the water balance and salinisation risks should be assessed before development of these landscapes.

Soil degradation

Scalds were the major form of land degradation being recorded at 25% of 222 sites assessed, and ranged from 1 to 15 m long and 1 to 12 m wide. Sheet erosion occurred on 10% of sites with soil loss ranging from 1 to 6 cm deep and 2 to 70 m wide. Two sites with rill erosion were recorded and gully erosion occurred at nine sites. Tunnel erosion was recorded at one site. Why scalds occur in such a relatively fertile landscape is not clear as its occurrence is random and not readily connected with stock movement. Wind erosion does occur in connection with the scalds but the soil is generally redistributed locally rather than removed.

Tree species

There were 90 combinations of dominant tree-grass species described in the basalt lands. The dominant association is a woodland, grading locally into open woodland (see Photo 2) of narrow-leaved ironbark with either kangaroo grass (13% of sites) or black spear grass (11%). Redbarked bloodwood and ghost gum are the most common associated species. Open woodlands of Reid River box and mountain coolibah may be locally prominent or dominant. The black cracking clay soils are commonly dominated by treeless grassy plains, with black tea-tree in the lower slope positions. The black tea-tree is found on Maryvale soil where salinity levels are higher. A shrub or mid-stratum layer is usually absent.

Pasture composition

From Isbell and Murtha (1972), the basalt pastures of 20 years ago were dominated by kangaroo grass with lesser black spear grass, giant spear grass, desert bluegrass and wire grasses. Recently, the pastures have become more diverse, however kangaroo grass, desert bluegrass and/or black spear grass are still dominant and were recorded at 51% of the sites. But golden beard grass, Queensland bluegrass, curly bluegrass and wire grasses are now an important component of the pastures. The

Photo 2. Open woodland of narrow-leaved ironbark trees on a Red Ferrosol (Hillgrove soil)

presence of Indian couch in the Nulla basalt province indicates recent high grazing pressure in these landscapes. The grass basal area data indicated that 30% of sites had poor pastures, 14% had marginal pasture condition and 56% of pastures assessed were in good condition.

Exotic weeds

Seven exotic weeds were observed in the basalt lands but at present they appear to be of limited extent. Of the exotic weeds, rubber vine is the most common which was recorded at 8% of the sites and mostly in disturbed areas. The worst occurrences of rubber vine were in pastures that had been cleared. Prickly acacia was recorded at 5% of the sites and was consistently on cracking clay soils. Chinee apple was present at three sites that may indicate its potential for further expansion. Parkinsonia was present at 3% of the sites but was regularly observed along creek lines and main access roads. Parthenium has been reported in the basalt country, but was not observed in this study. Calotropis was observed in creek lines and disturbed areas of the McBride Province only and could become a problem in the future.

Native weeds

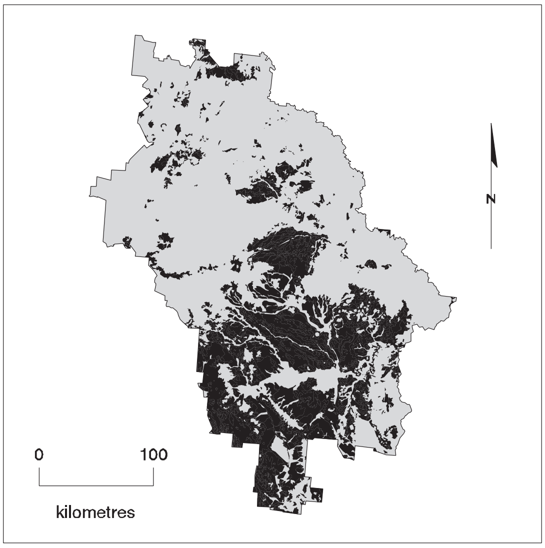
The woody weed currant bush occurred at 17% of the sites and ranged from less than one to 30% of the ground cover. Mimosa bush was observed at 5% of sites and, like the exotic prickly acacia (*Acacia nilotica*), was predominantly on cracking clay soils. Eucalypt and acacia regrowth were observed on cleared land.

Table 5. Degradation categories recorded for Basalt landscapes

Landscape/ Soil* number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Basalt landscape (216)	10	1	4	25	17	22	30
Conjuboy (43)	14	0	5	42	9	16	32
Felspar (14)	21	0	0	50	29	7	36
Glencoe (29)	17	0	3	21	14	21	18
Hillgrove (41)	17	0	2	34	7	20	15
Lolworth (58)	3	2	21	9	18	28	44
Maryvale (30)	0	14	10	10	29	28	30
Nulla (1)	0	0	0	100	0	0	0

*The following units are not listed due to limited data: miscellaneous carbonate, miscellaneous basalt, basalt rock and pin gin soil.

Cainozoic landscapes



The Cainozoic landscapes comprise approximately 2 303 500 ha or 34% of the Shire (see adjacent figure) and are commonly referred to locally as the desert uplands or spinifex country. Tertiary sediments are included with this landscape as little to no difference was found in the soil morphology and chemistry, or vegetation of both geological groups.

The landform is dominated by gently undulating plains with several major drainage lines and broad, rarely active flood plains. Isolated remnants of the Cainozoic landscape occur sporadically throughout the Shire across all other geological landscapes. These surfaces occur as mesas and as more subtle erosion surfaces.

Geology

Eighteen geological map units representing sediments of Cainozoic age occur on the 1:250 000 geological series maps covering the study area. Lithologies range from fluvial, sedimentary (argillaceous sandstone), laterite/ferricrete to semi-consolidated sand, soil, silt and gravel. There is a wide range of materials within this landscape but the uniform.

Soils

There are 16 soil types and one miscellaneous mapping unit (Featherby) that have been recognised. Barkla (see Photo 3) are shallow sands on ferricrete whereas Featherby is associated with ferricrete exposures and scarps. Level to gently undulating plains include the gradational soils of Boston and Wattle Vale, being yellow loamy and sandy soils respectively, while Pentland and Rangeside are red loamy and sandy gradational soils. Burra is a grey gradational soil while Rishton is unconsolidated sand. Egera and Wambiana are self-mulching clay soils with Egera having an alkaline subsoil. Other clay soils include Powlathanga and Victoria Downs which are predominantly hardsetting clay soils that are found on lower slopes and in gentle depressions. Both of these soils have alkaline subsoils although Powlathanga soil goes acid with depth. Corea and Liontown are brown texture contrast soils, while Nosnillor, Pallamana, and Rolston are yellow, grey and red texture contrast soils respectively.

Salinity

Profile salinity was significant with 32% of sites having moderate (0.3–1.2 mS cm^{-1}) or severe (>1.2 mS cm^{-1}) salinity levels in the soil profile. The dominant saline soils were the cracking clays (60%) and texture contrast soils (28%). The cracking clays Egera and Powlathanga were the dominant soils where severe salinity levels were recorded (see table 23). The typical landscape position for salt accumulation is at the margins of drainage lines within the extensive undulating plains. It is assumed that the soils are accumulating salts through hydrological movement from adjacent well drained areas. Bui (1995) used a combination of earlier small scale mapping by Isbell *et al.* (1968) and site salinity levels from this study to predict possible salinity hazard areas within the Shire. This work highlighted the effect of clearing trees on groundwater levels. While saline clay soils were identified, it was the tree clearing on the associated well drained soils that affected groundwater levels.

Photo 3. An exposure of ferricrete with shallow sandy 'Barkla' soils in the foreground

Soil degradation

Soil erosion occurred at 50% of the assessed sites with sheet erosion (28%) and scalds (27%) accounting for the majority of the erosion. The gentle slopes found over the majority of this landscape have made it less susceptible to large scale soil erosion events. There are however, examples where tree clearing on slopes as low as 2%–4% have been accompanied by extensive sheet erosion leaving a very hard scalded surface which is not easily revegetated. Rills (5%) and gullys (6% of sites) were rarely observed and mainly found where tree clearing or roadworks had occurred.

Tree species

Across the landscape 233 tree-grass and 19 grassland communities were recognised. The most common tree-grass combination was silver-leaved ironbark (*Eucalyptus shirleyi*)–wire grasses (6%) of sites and narrow-leaved ironbark-wire grasses (5%) which dominated 8 of the 17 soil types. These associations were found predominantly on the red and yellow gradational soils. The most common grassland was bluegrasses on cracking clay soils. There are 49 dominant tree species and the three most common are silver-leaved ironbark (15% of sites), narrow-leaved ironbark (21%) and Reid River box (20%). There are eight *Acacia* species that are locally dominant and amongst them, blackwood (4%) and gidgee (3%) are the more common minor species. The *Acacia* species are not extensive within the Shire, but many occur as dense woodlands or forests.

Pasture composition

There were 49 species of pasture plants which dominate the pasture communities, the most common being wire grasses (25% of sites), black spear grass (19%), golden beard grass (13%) and spinifex (12%). Wire grasses were dominant in this survey and in an earlier survey by Isbell and Murtha (1972). The grass basal area data indicated that 46% of sites had poor pastures, 12% had marginal pasture condition and 42% of pastures assessed were in good condition.

Exotic weeds

There were nine exotic weeds encountered in this landscape occurring at 10% of sites. Of these, rubber vine was present at 65% of sites and ranged from individual plants to 70% ground cover. The remainder of the weed species occurred as less than 20% cover although an occurrence of sicklepod covered 30% at one site.

Native weeds

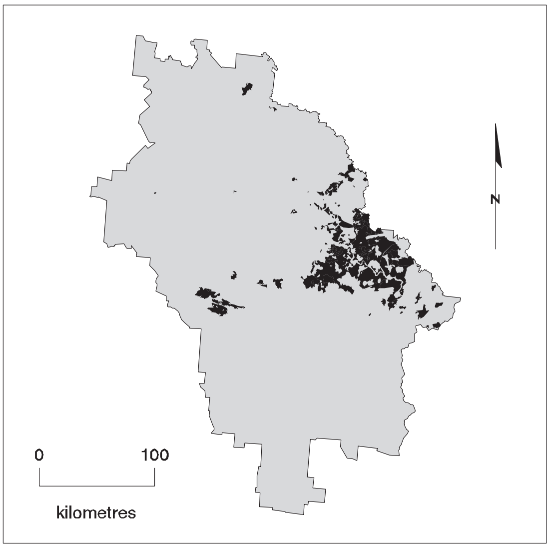
Native weeds occurred at 61% of sites consisting of currant bush (97%) and mimosa bush (3%) of the sites. The currant bush occurred across all soil types and the infestations covered up to 90% of the ground surface. Mimosa bush was only noted on the cracking clay soils and the densest recording was 30% ground cover.

Table 6. Degradation categories recorded for Cainozoic landscapes

Landscape/ Soil* number of sites (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Cainozoic landscape (861)	28	5	6	27	10	61	46
Barkla (8)	25	0	0	0	13	63	43
Boston (127)	34	6	5	21	3	60	43
Burra (24)	17	0	8	38	0	50	22
Corea (100)	35	6	8	19	11	63	42
Egera (47)	2	2	0	32	20	72	29
Liontown (73)	30	14	0	32	12	89	52
Nosnillor (54)	43	13	17	35	18	76	61
Pallamana (44)	45	7	9	30	13	58	44
Pentland (99)	13	2.6	0	10	3	40	37
Powlathanga (30)	10	3	0	30	23	83	64
Rangeside (39)	33	8	3	33	5	40	49
Rishton (86)	21	2	4	12	7	48	46
Rolston (26)	46	15	23	38	23	58	48
Victoria Downs()	12	0	2	40	22	78	40
Wattle Vale (67)	22	6	3	13	3	55	38
Wambiana (37)	11	3	0	24	11	58	43

*Featherby not listed due to limited data

Granodiorite landscapes



These landscapes comprise approximately 483 000 ha (7%) of the Shire (see adjacent figure). They encompass many of the gold mining areas of the early part of this century and more recent reworking of the old diggings. There are also small occurrences to the north of Pentland and minor units near Greenvale. Generally these landscapes support grazing with minor horticultural activities on smaller holdings near Charters Towers.

Geology

Clarke and Payne (1970) described the Middle Ordovician Ravenswood Granodiorite Complex as having eight sub-units ranging in composition from acid granite to intermediate diorite to basic olivine gabbro. Recent mapping of the 'Ravenswood Batholith' by Rienks (1991), Hutton and Crouch (1993), and Hutton *et al.* (1994) have highlighted the complex mineralogy of this variable geological landscape. These surveys identified thirty four igneous units in the Charters Towers and Dotswood 1:100 000 topographic sheets alone (Hutton and Crouch, 1993). The majority of units are granodiorite and have uniform bodies of soils. However where the granite, gabbro, diorite or minor metamorphic rocks occur there are marked soil differences. Where areas of tonnalite and rhyolite occur the soil is generally the same as that formed on granodiorite.

Soils

Four soil types dominate in this geological landscape. Dalrymple and Charters Towers are red texture contrast soils, the former having a neutral subsoil pH and the latter alkaline. Mingela is a brown texture contrast soil with alkaline subsoils and Mount Ravenswood is a brown gradational soil. Mingela soil is predominantly in drainage lines or broad depressions and may have an unnamed cracking clay associated. There are small occurrences of Tertiary age alluvium overlying the Ravenswood Batholith. They are usually in the form of mesas eg. Puzzler wall and Featherby wall, but may be less apparent where the alluvium may have infilled old surface depressions. Pentland and Boston (red and yellow gradational soils) are examples of Tertiary surfaces. Miscellaneous granodiorite units describe steep and hilly terrain with shallow and stony soils with rock outcrop.

Strong to very strongly alkaline subsoils occurred at 38% of the study sites. The occurrence of salinity/alkalinity on different soil types and in various landscape positions indicates a potential degradation hazard if slopes or rises are cleared.

Salinity

Moderate levels of salinity (0.3-<1.2 mS cm^{-1}) were recorded for Mingela and Bluff soils at 63% and 30% of assessed sites respectively. These soils generally dominated lower positions in the landscape.

Soil degradation

The level of disturbance was high for this landscape with 79% of sites disturbed by grazing, and the remainder with higher levels of disturbance. Soil erosion occurred at 56% of sites, predominantly on crests and hillslopes with a gradient of two percent or more, sheet erosion and scalds being the dominant forms. Sheet erosion occurred at 31% of sites and ranged from 2 to 10 cm deep and 1 to 50 m wide. Scalds were recorded at 30% of sites, from 1 to 30 m long and 1 to 10 m wide.

Rill erosion occurred at 8% of sites, and ranged from 10 to 30 cm in depth and 1 to 5 m wide. Gully erosion occurred at 14% of sites and ranged from 1 to 4 m deep and 2 to 7 m wide. Tunnel erosion was also recorded at one site. Although these landscapes have several extensively eroded sites, the most severe gullies occur in association with roadworks and abandoned mining areas.

Vegetation

The vegetation of these landscapes is open woodland, grading locally into woodland, dominated by narrow-leaved ironbark at 46% of sites, red-barked bloodwood at 37% of sites and some ghost gum. On the Lolworth Range, the relatively rare *E. quadricostata* (narrow-leaved ironbark) occurs. Locally, Reid River box may be dominant, predominantly on Mingela soil type or on lower slope or drainage lines. There are 32 dominant tree grass combinations although the most common two combinations are red-barked bloodwood-Indian couch at 29% of sites and narrow leaved ironbark-Indian couch at 21% of sites.

Pasture composition

The ground flora as recorded by Isbell and Murtha (1972) was dominated by perennial grasses, chiefly black spear grass and desert bluegrass. Kangaroo grass was dominant in pastures that were less intensively grazed (Crack and Isbell, 1971). The pasture composition has changed considerably in the 20 years since the previous study. Presently there are now 14 dominant grass species with Indian couch dominant at 56% of sites. On 18% of sites, black spear grass was dominant and of the other major grass species, wire grasses were recorded at 41% of sites. The grass basal area data indicated that 14% of sites had poor pastures, 5% had marginal pasture condition and 81% of pastures assessed were in good condition. The high percentage of pastures classified in good condition was largely due to the growth habit of Indian couch that grows as a sod grass (rather than a tussock grass) under heavy grazing.

Photo 4. Rubber vine has invaded many streams and adjacent landforms throughout the Granodiorite landscapes

Exotic weeds

Chinee apple was most common, recorded at 49% of sites. The plant clearly prefers highly disturbed areas, such as abandoned mine sites, homesteads, and townships. However, there are situations where it exists in relatively undisturbed grazing lands. Rubber vine is a conspicuous plant in these landscapes being most prolific in the drainage lines (see Photo 4), where it often forms a dense mass in channels and on levee deposits. While most often observed along the riparian zone, it was recorded at 39% of the upland sites. The remaining notable exotic weeds recorded were lantana at 3% of sites and individual recordings of prickly acacia, parkinsonia, prickly pear and belly ache bush.

Native weeds

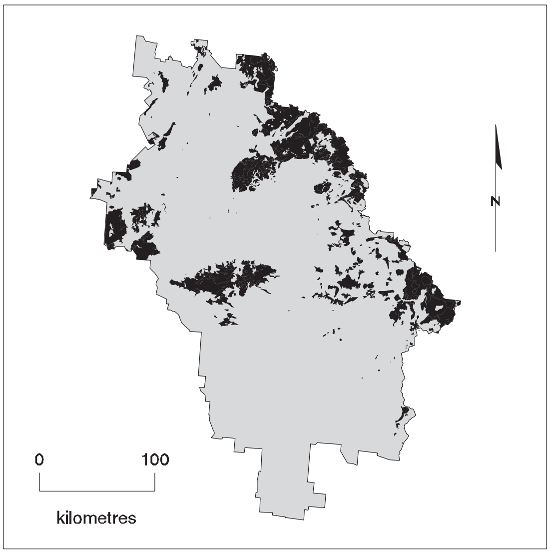
The woody weed currant bush occurred at 49% of sites and covered up to 60% of the ground surface. Mimosa bush was recorded at 6% of sites.

Table 7. Degradation categories recorded for Granodiorite landscapes

Landscape/ Soil number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5 %
Granodiorite landscape (157)	31	8	14	30	61	56	14
Charters Towers (43)	28	16	14	30	61	61	3
Dalrymple (79)	33	3	10	32	49	49	17
Mingela (18)	44	17	28	22	67	67	47
Mount Ravenswood (17)	24	6	18	18	53	53	18

Igneous landscapes

These landscapes comprise approximately 913 000 ha (13.5%) of the Shire (see adjacent figure) with the largest areas in the central west and north-east of the Shire. The area includes igneous rocks other than basalt and granodiorite. The major landforms in these landscapes are strongly undulating lands or dissected hills with steep slopes.



Geology

Published 1:250,000 geological maps show 73 geological units that contain some form of igneous rocks. These have been combined into three major groups; acid (granites, adamellites), basic (gabbro, dolerite, diorite) and acid volcanic (rhyolite). The dominant rocks are coarse-grained acid rocks such as granite, adamellite, quartz syenite and smaller areas of granodiorite. These rocks are of Late Silurian–Early Devonian to Early Permian age.

Soils

There are 13 soil types recognised in these landscapes. Amity, a self-mulching black clay and Tuckers, a red gradational soil, are found on basic rocks such as diorite and gabbro. Bluff and Two Creek are texture contrast soils found on upper to lower slopes of a wide range of granitic rocks. Conolly and Carse O'Gowrie are sandy soils that occur on crests and slopes and are derived from coarse granites and adamellite (see Photo 5). Pinnacle is another sandy soil and is found on acid volcanic rocks. All the sandy soils have low fertility. Hillview, Severin, Thorpe, Umala, Utchee and Worsley are on a range of acid volcanic to coarser grained granitic rocks but are found in higher rainfall coastal ranges and are not widespread in the Shire. The hilly to mountainous regions throughout the Shire have been mapped as Miscellaneous Igneous (MI) and are generally shallow stony soils, with deep, highly weathered soil in rainforest areas. Alma soil (Cannon *et al.,* 1992) has also been recognised, but is not significant in this area and has not been mapped or described.

Salinity

Very few sites had significant salinity levels with Amity soil the exception showing 21% of assessed sites with moderate levels of salinity (0.3-<1.2 mS cm^{-1}). Amity is a cracking clay soil weathered from basic igneous material.

Soil degradation

The major forms of soil degradation were sheet erosion and scalds. Rill and gully erosion were found, usually where some form of major disturbance such as roadworks or fence line clearing had occurred. Sheet erosion occurred at 44% of sites and ranged from 1 to 15 cm deep and 1 to >99 m wide. Scalds were recorded at 17% of sites and ranged from 1 metre in width to 30 metres long. Rill erosion occurred at 12% of sites and were 4 to 30 cm deep and 0.2 to 20 metres wide. Gully erosion occurred at 19% of sites was 1 to 5 metres deep to 1 to 10 metres wide.

Tree species

The vegetation of these landscapes is diverse, due mainly to the range of climatic zones. Mid high to tall woodland account for 50% of sites but the range included 17 forms, from grassland to rainforest. There were 88 dominant tree and grass associations. The most common association was narrow-leaved ironbark and blackspear grass (18%) followed by narrow-leaved ironbark and Indian couch (18%). Narrow-leaved ironbark was present at 48% of sites and black spear grass 27%. In all there were 27 grass species that dominated the pasture and 28 tree species.

Pasture composition

Previous studies found the ground flora to be dominated by perennial grasses, chiefly black spear grass, giant spear grass, desert bluegrass and kangaroo grass, each of which varied locally in dominance. The ground layer which was present 20 years ago is still dominant although golden beared grass (dominant at 9% of sites), wire grasses (13%) and Indian couch (17%) have become more dominant. The grass basal area data indicated that 37% of sites had poor pastures, 11% had marginal pasture condition and 52% of pastures assessed were in good condition.

Exotic weeds

Rubber vine (12% of sites) and chinee apple (16%) were the dominant exotic weeds with chinee apple occuring with up to 70% ground cover. The distribution of chinee apple largely reflects the mining townships or workings of the turn of the century and to a lesser extent cleared homestead paddocks. Rubber vine is associated with creek lines but it also occurs in the wider landscape where the majority of sites have less than 10% cover. Prickly acacia, parthenium, lantana, calatropis and belly ache bush were also recorded and collectively occur at less than 4% of sites.

Native weeds

Currant bush occurred at 28% of sites and had ground cover of up to 40%. The other native weed recorded was mimosa bush, which occurred at 5% of sites, predominantly on Amity soil.

Photo 5. Granite outcrop is common in hilly Igneous landscapes shown here in the background with sandy soil type Carse O' Gowrie in the foreground

Table 8. Degradation categories recorded for Igneous landscapes

Landscape/ Soil* number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Igneous rock landscape (264)	44	12	19	17	26	33	37
Amity (26)	12	0	23	0	41	52	22
Bluff (29)	72	34	62	28	17	55	52
Carse O Gowrie (53)	51	4	9	13	19	9	33
Conolly (28)	57	11	21	21	43	21	54
Hillview (6)	33	0	0	33	17	50	33
Pinnacle (9)	44	0	11	11	22	22	83
Severin (1)	0	0	0	0	0	0	0
Thorpe (7)	29	14	14	29	0	29	43
Tuckers (27)	41	19	4	26	32	29	32
Two Creek (76)	43	14	14	16	26	32	34
Umala (1)	0	0	0	0	0	0	0
Utchee (1)	100	0	0	0	0	0	0

*Worsley soil not listed due to limited data

Metamorphic landscapes

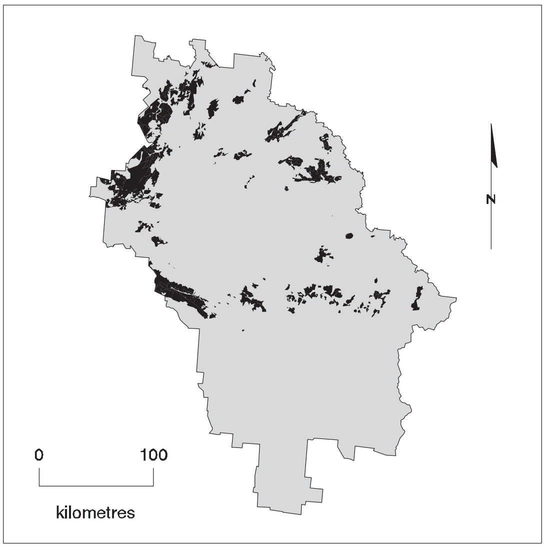
These landscapes comprise approximately 500 000 ha (7.5%) of the Shire (see adjacent figure) and were described within the sedimentary landscape in the preliminary report of DeCorte *et al.* (1994). They include sediments (fluvial and volcanic origin, tuff) which have experienced various degrees of metamorphism. The metamorphism has been brought about by intrusions of major units such as the Ravenswood Granodiorite Complex. There are approximately 40 geological units containing metamorphic rocks that have been recognised from 1:250 000 geological maps within the Shire. The dominant landform consists of low hills to rises with occasional rock outcrops of quartz or schists (see Photo 6). Short slopes and stable gullies are a feature of this landscape.

Soils

There are eight soil types described which are typically covered by rounded to subangular gravels (72% of sites). Argentine and Rangeview are red texture contrast soils, while Wairuna has a gradational texture profile. Paynes and Warawee are brown texture contrast soils. Ewan is a shallow loam overlying the metamorphic rock or saprolite. Star is a cracking clay which occurs as minor inclusions in highly metamorphosed areas. Galmara is found in the high rainfall rainforest area on the coastal ranges to the north. The miscellaneous metamorphic association (MI) includes a wide range of soils, but in the drier regions of the Shire they are generally shallow red texture contrast soils (Rangeview), or shallow loams (Ewan).

Salinity

Argentine, Paynes and Wairuna had ~10% of assessed sites with moderate levels of salinity (0.3-<1.2 mS cm^{-1}). Warawee had 53% of assessed sites with moderate (0.3-<1.2 mS cm^{-1}) to severe (≥1.2 mS cm^{-1}) salinity levels. Warawee is formed from metasediments and has low fertility and dispersive subsoils.



Soil degradation

Sheet erosion is the dominant form of soil erosion occurring at 65% of sites. The sheet erosion occurs equally across the texture contrast soil types with no sheet erosion recorded on the cracking clay soil (Star). Rill erosion occurred at 19% of sites, gully erosion 30% and scalds 27% of sites. These erosion types occurred similarly across all soils with only Star recording scalds. The obvious gully erosion along roadways is not as prevalent in the grazing lands and highlights the unstable nature of these soils once they are disturbed.

Tree species and pasture composition

There are 56 dominant tree-grass combinations described in the survey. Narrow-leaved ironbark and kangaroo grass being the dominant (15% of sites), with narrow-leaved ironbark and pitted blue grass the next dominant (9%). There are 13 dominant tree species all of which are eucalypts with narrow-leaved ironbark (53%) and Reid River box (17%) dominant. Nineteen grass species were recorded as dominating the grass sward. The major grasses included: kangaroo grass (21%), wire grasses (14%), pitted blue grass (14%) and black spear grass (8% of sites). The grass basal area data indicated that 56% of sites had poor pastures, 12% had marginal pasture condition and 32% of pastures assessed were in good condition. The high percentage of stone cover (>20%) at 72% of sites could contribute to the high number of sites with poor pasture condition (low grass basal area).

Exotic weeds

Rubbervine, chinee apple and prickly acacia were the only exotic weeds occurring at the described sites and together amounted to 5% of sites. Lantana was seen in several points along and behind the coastal range and near Charters Towers.

Native weeds

Currant bush occurred at 60% of assessed sites with the highest ground cover being 30% at six sites. Currant bush did not have a preference for any particular soil type. Mimosa bush was recorded at one cracking clay site (Star soil type).

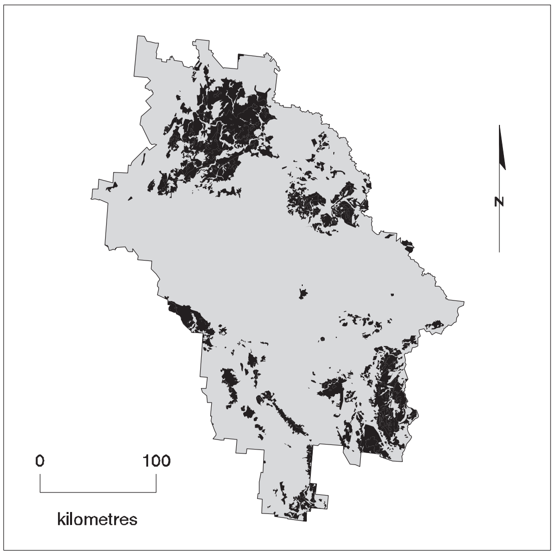
Table 9. Degradation categories recorded for Metamorphic landscapes

Landscape/ Soil* number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Metamorphic landscape (164)	65	19	30	27	5	61	56
Argentine (11)	73	18	36	27	18	73	64
Ewan (15)	73	20	27	53	0	53	67
Paynes (27)	63	22	26	30	4	59	46
Rangeview (49)	69	10	22	24	4	53	30
Star (8)	0	0	0	38	0	63	50
Wairuna (30)	77	17	37	27	3	71	50
Warawee (24)	63	38	58	25	0	75	67

*Galmara not listed due to limited data

Photo 6. This photo shows naturally dissected terrain in metamorphic landscapes which often have quartizite gravels on the surface

Sedimentary Rock landscapes



These landscapes comprise approximately 1 050 000 ha (15.5%) of the Shire (see adjacent figure) and are located south-west and east of Greenvale, near Dotswood homestead, and form many of the ranges and low hills south of Charters Towers.

Geology

There are more than 50 sedimentary geology groups recognised on the 1: 250 000 geology sheets of the Shire. The majority of sediments are of Palaeozoic and Mesozoic age (Cambrian to Lower Cretaceous) and cover a wide range of rocks. They include labile sandstones, siltstone, claystone, conglomerates and limestone. The youngest are of Quaternary age and consist of weakly consolidated sands and clays. These sediments are separated from the 'Cainozoic' group for this report on the basis that the Sedimentary landscapes are rocks or rock-like, whereas the Cainozoic landscapes are unconsolidated materials. This wide range in rock composition has led to the development of a wide range of soils.

Soils

There are nine soil types recognised. Flagstone and Bulliwallah are shallow sands and loams predominantly on crests and exposed rock areas. Greenvale, Ceaser and Nial are texture contrast soils which occur predominantly on slopes and are generally higher in the landscape. Dotswood and Scartwater are texture contrast soils with sodic subsoils which occupy lower slope positions and are usually on finer sediments such as mudstone. Lime View, a red gradational soil, is weathered from limestone deposits, namely the coralline reef formations to the south-west of Greenvale township and near Fanning River homestead. Myrtlevale is a gradational soil of varying colour, and occurs predominantly on finer mudstone or claystone. Miscellaneous Sedimentary association has been used to highlight the steep to rugged terrain not normally considered for grazing, and consists chiefly of shallow stony sands and loams.

Salinity

Of the sites sampled for salinity, 41% had a moderate or severe salinity rating, (see Table 23). The alkaline subsoils of Dotswood, Scartwater and Nial comprised 60% of these saline sites. Whilst no salinity outbreaks were observed, the presence of the many moderate to high levels of salt within the soil profiles could lead to salinity outbreaks if the hydrology of these landscapes were altered in a significant way.

Soil degradation

Soil erosion occurred at 70% of sites with sheet erosion occurring at 55% of sites and ranged from 2 to 15 cm deep and 6 to 70 m wide. Scalds were recorded at 33% of sites and ranged from 1 to 30 m long and 1 to 20 m wide. Rill erosion occurred at 14% of sites and gully erosion occurred at 21%. The rills ranged from 15 to 30 cm deep and 1 to 12 m wide while the gullies ranged from less than 1 to 6 m deep and 1 to 10 m wide. These landscapes contain the most severe examples of all forms of soil erosion in the Dalrymple Shire. This is associated with the general shallow soil depth, very poor nutrient status and a high proportion of dispersible soils. Sustained productive use of these landscapes will require a reduction in grazing pressure in most cases.

Tree species

The vegetation of these landscapes is diverse because of the variability in rock types and climatic zones. More than 30 tree species and 25 grasses were identified as dominant in the landscape and there are over 120 dominant tree-grass combinations. The tallest stratum is dominated by narrow-leaved ironbark (28% of sites) and Reid River box (19%). In the northern part of the Shire, woodlands of narrow-leaved ironbark and grey box (see Photo 7) are dominant with many associated species that vary locally. Ghost gum occurs throughout. In the western and southern parts of the Shire, low open forest of lancewood is dominant with areas of silver-leaved ironbark (*E. shirleyi*, *E. melanophloia*), yellowjack (*E. peltata*), and other eucalypt species (narrow-leaved ironbarks) with no well developed mid-stratum. In the vicinity of Scartwater, low open forest of bendee is dominant with areas of Normanton box, blackwood and lancewood. There is usually no mid-stratum in the bendee communities. False sandalwood and Reid River box are common throughout these landscapes, and are locally dominant.

Pasture composition

Previous studies found the ground flora dominated by black spear grass, forest bluegrass, pitted bluegrass, kangaroo grass and wire grasses. Of the previously dominant grasses only wire grasses (38%) are still well represented; the other grasses are present but no longer dominant. The composition of the pastures, however, is diverse with many other species being recorded; including love grasses, Queensland bluegrasses and urochloa. The grass basal area data indicated that 67% of sites had poor pastures, 15.5% had marginal pasture condition and 17.5% of pastures assessed were in good condition. Where Reid River box and false sandalwood are dominant there is often no grass ground cover.

Exotic weeds

Exotic weeds are not a widespread problem. There were seven exotic weeds identified across seven soil types. The clay soil Myrtlevale, and the gradational soil Lime View, had several rubber vine infested sites.

Native weeds

The native woody weed currant bush, occurred at 63% of sites and covered up to 80% of the ground surface. Mimosa bush occurred at six sites and was the only other native weed recorded in the landscape. Significant regrowth of all *Acacia* species was common where land had been cleared. Eucalypt regrowth in woodland communities was also seen as a problem. Both the acacia and currant bush contributed to the low grass basal area values recorded for this landscape.

Table 10. Degradation categories recorded for Sedimentary landscapes

Landscape/Soil number of sites assessed (n)	Sheet erosion %	Rill erosion %	Gully erosion %	Scald erosion %	Exotic weeds %	Native weeds %	Grass basal area ≤1.5%
Sedimentary landscape (267)	55	14	21	33	7	65	67
Bulliwallah (6)	83	17	33	83	0	50	67
Ceaser (25)	16	4	24	44	0	36	48
Dotswood (63)	60	17	30	30	6	77	62
Flagstone (13)	54	8	0	38	6	50	53
Greenvale (56)	64	20	30	29	2	58	54
Lime View (14)	21	7	14	7	57	64	42
Myrtlevale (37)	35	16	16	41	18	73	74
Nial (21)	52	19	9	33	5	67	52
Scartwater (32)	66	9	9	38	6	84	81

Photo 7. Surface rock is a feature of many Sedimentary landscapes as shown here with grey box (*Eucalyptus normantonensis*)

MAPPING UNITS

Mapping units include soil associations and miscellaneous units. Soil associations are mapping units consisting of two or more kinds of soil. Soil types were derived from the site descriptions made in the field and included some soils from surveys from the tropical coast and tablelands. The site descriptions were organised into seven geological landscapes and then sorted into soil types on the basis of similar lithology and morphological characteristics. The Order of the Australian Soil Classification system (Isbell, 1996) was used as a primary sorting criteria followed by morphological groupings. The summary descriptions of the soil types in this report describe the central concept of the soil. Individual sites as listed in the site database were given a soil name and a phase code if the soil differed from the central concept of the soil. This was done to limit the large number of soil types that would that would have otherwise been created. For example the Boston soil type can have lighter surface textures, or yellower subsoils as phases. These differences are not large enough to place it into a different soil group, but have been recorded to enable more detailed discrimination of the soil types should need arise. Phase codes are listed in Appendix II. A brief description of the mapping units is in Appendix VI. An approximation of the area of each soil type and distribution in the site database is in Appendix VII.

The highest level of the Australian Classification system is the Soil Order and the concepts of the Orders classified in the Shire are listed alphabetically below. The classification is a hierarchical system where keys are provided for each of the classes. A map of Soil Orders for the Dalrymple Shire is presented in Figure 12. See Table 11 for groupings of soils into Orders, and Orders into geological landscapes.

Anthroposols Man-made soils, eg mine spoils etc. (Not described in study, occur in miscellaneous disturbed mapping units)

Calcarosols Soils which are usually calcareous throughout the profile and lack strong contrast between surface and subsoil clay content. (0.2% of Shire, 15 200 ha)

Chromosols Soils with a strong contrast between surface and subsoil clay content. Subsoils are usually not acid. (pH> 5.5) and are non-sodic (ESP < 6). (24% of Shire, 1 601 000 ha)

Dermosols Soils lacking a strong contrast between surface and subsoil clay content. Subsoils are structured. (3.0% of Shire, 203 000 ha)

Ferrosols Soils with structured subsoils which are high in free iron oxide, and which lack strong contrast between surface and subsoil clay content. (8% of Shire, 554 000 ha)

Hydrosols Soils which are wet throughout most of the profile for at least several months of the year. (0.3% of Shire, 21 000 ha)

Kandosols Soils lacking a strong contrast between surface and subsoil clay content. The profile is not calcareous throughout and the subsoils are massive or weakly structured and have a clay content that exceeds 15%. (20% of Shire, 1 343 000 ha)

Rudosols Soils that have little development of soil features, are often shallow and stony, deep and sandy, and commonly stratified with sedimentary layers. (13% of Shire, 860 000 ha)

Sodosols Soils with a strong contrast between surface and subsoil clay content, and that have subsoils that are sodic (exchangeable sodium percentage ESP > 6) and are not strongly acidic. (13% of Shire, 890 000 ha)

Tenosols Soils that have weakly developed profile features other than dark surface horizons or pale subsurface horizons. Subsoils frequently have less than 15% clay. thus have profile features that are more developed than those in Rudosols. (11% of Shire, 718 000 ha)

Vertosols Clay soils with shrink-swell properties that exhibit strong cracking when dry. (7% of Shire, 465 000 ha)

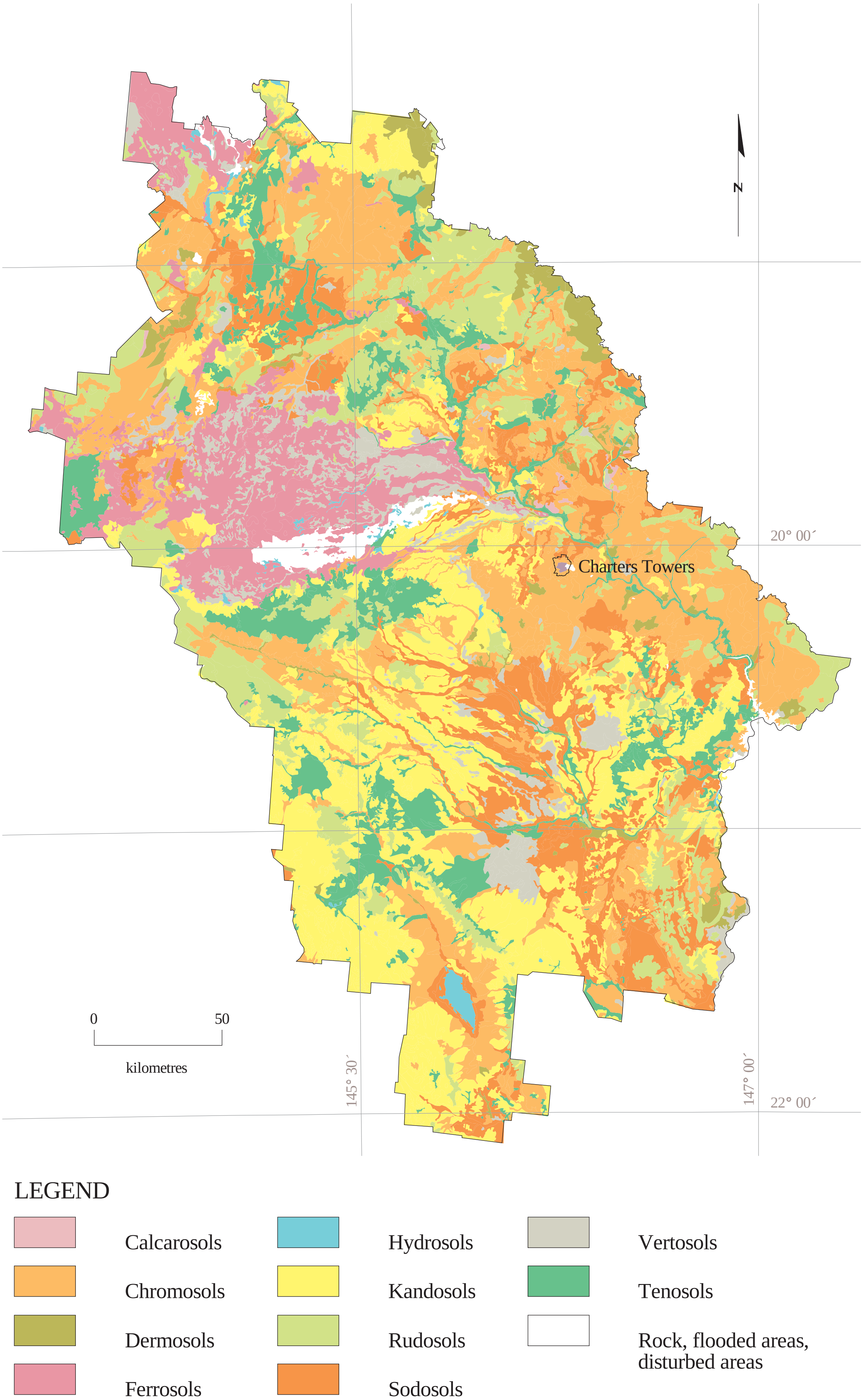


Figure 12. Map of Dalrymple Shire showing Orders of the Australian Soil Classification

Table 11. Soil types grouped on classification (Order of Australian Soil Classification) and geological landscape

Geological landscape	Classification (Order)*	Soil Types
Alluvial	Chromosols	Creek
9% 609,000 ha	Dermosols	Fanning River, Manoa
	Kandosols	Gainsford
	Sodosols	Cape
	Tenosols	Pandanus, Burdekin
	Vertosols	Yarraman
Basalt	Calcarosols	Miscellaneous carbonate
13.5% 906,000 ha	Ferrosols	Conjyboy, Felspar, Glencoe, Hillgrove, Pin Gin
	Hydrosols	Miscellaneous Basalt soils
	Rudosols	Nulla
	Vertosols	Lolworth, Maryvale
Cainozoic	Chromosols	Corea, Pallamana, Rolston
34% 2,304,000 ha	Kandosols	Boston, Burra, Pentland, Rangeside, Wattle Vale
	Sodosols	Liontown, Nosnillor
	Tenosols	Barkla, Rishton
	Vertosols	Egera, Powlathanga, Victoria Downs, Wambiana
Granodiorite	Chromosols	Dalrymple, Charters Towers
7% 483,000 ha	Dermosols	Mt Ravenswood
	Sodosols	Mingela
Igneous	Chromosols	Two Creek
13.5% 913,000 ha	Dermosols	Severin, Tuckers, Umala, Utchee, Worsley
	Kandosols	Hillview, Thorpe
	Rudosols	Conolly, Pinnacle
	Sodosols	Bluff
	Tenosols	Carse O' Gowrie, Conolly
	Vertosols	Amity
Metamorphic	Chromosols	Argentine, Paynes, Rangeview, Warawee
7.5% 498,000 ha	Dermosols	Wairuna, Galmara
	Rudosols	Ewan
	Vertosols	Star
Sedimentary	Calcarosols	Lime View
15.5% 1,050,000 ha	Chromosols	Ceaser, Greenvale, Niall
	Dermosols	Myrtlevale
	Rudosols	Flagstone
	Sodosols	Dotswood, Scartwarter
	Tenosols	Bulliwallah

The following section is a summary of the soil associations and their relevant morphological and chemical characteristics. Soil associations are named after the dominant soil type present. Each association description (presented in alphabetical order) shows the depths of the A (surface) and B (subsoil) horizons, and the texture ranges of the central concept of the soil type. The depth limits for any horizon are one standard deviation around the mean depth for that horizon. The dominant soil type of the association is described in detail as a reference site in Appendix III. The other figure shows the geographical distribution of the association in the Shire. Miscellaneous mapping units are also described.

The dispersion ratings are adapted from Loveday and Pyle (1973). Soil fertility interpretations are based on Baker and Eldershaw (1993) and surface soil phosphorus ratings are taken from Ahearn *et al.* (1994).

The recommendations for stylosanthes production and animal production is following Kerridge *et al.* (1990) who suggested soil phosphorus levels below 3 mg Kg^{-1} will not support *Stylosanthes* growth and cattle liveweight gain will only occur above this level.

The soil moisture characteristics for the soil types are summarised in Table 12. These data are derived from the 15 infiltration sites discussed in the methods section. For comparison purposes, the derived figures assume a profile to be one metre deep unless the mean B horizon lower depth is less. The water required to saturate the profile is given here as the amount remaining in the profile after one hour of free drainage from the saturated state. This is an indication of the water required to fill a dry soil profile. The infiltration component of precipitation would need to equal this figure to fill the profile.

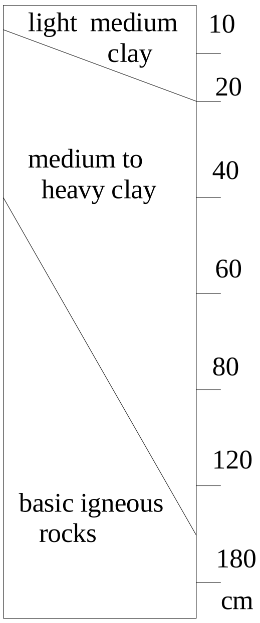
Table 12. Estimated plant available water content and profile saturation of soil types assessed over 1 metre of profile unless constrained by soil depth

Soil Type *less than 6 sites described	Mean A horizon lower depth (cm)	Mean B horizon lower depth (cm)	Plant Available Water Content (mm), and % of total stored		Water required to saturate profile to 1 m or less
			(mm)	%	(mm)
Amity	12	90	100	20	500
Argentine	25	77	90	30	300
Barkla	43	46	60	29	205
Bluff	27	95	90	20	435
Boston	24	81	65	19	340
Bulliwallah	22	47	75	37	200
Burdekin	38	115+	150	33	460
Burra	32	103	80	19	420
Cape	29	110+	110	28	395
Carse O'Gowrie	32	85	110	30	370
Ceaser	23	71	85	19	440
Charters Towers	15	83	65	19	330
Conjuboy	15	84	90	22	420
Conolly	9	52	60	23	245
Corea	33	81	65	20	315
Creek	39	98	120	26	450
Dalrymple	15	68	60	20	290
Dotswood	25	91	110	22	505
Egera	21	143	115	21	555
Ewan	24	53	50	27	195

Table 12 continued

Soil Type *less than 6 sites described	Mean A horizon lower depth (cm)	Mean B horizon lower depth (cm)	Plant Available Water Content (mm), and % of total stored		Water required to saturate profile to 1 m or less
			(mm)	%	(mm)
Fanning River	29	113+	105	27	390
Felspar	14	97	99	23	430
Flagstone	24	45	55	26	205
Gainsford	41	112+	100	26	395
Galmara*	20	100+	95	25	375
Glencoe	18	76	95	22	430
Greenvale	25	91	90	27	340
Hillgrove	13	77	70	18	395
Hillview	20	100+	130	29	440
Lime View	11	86	95	21	460
Liontown	24	90	100	27	355
Lolworth	14	117	110	20	555
Manoa	18	100+	105	28	380
Maryvale	16	154	115	20	555
Mingela	24	87	55	15	375
Mount Ravenswood	9	46	50	21	245
Myrtlevale	13	92	105	20	510
Nial	21	82	95	24	385
Nosnillor	34	93	95	28	335
Nulla	30	NA	45	29	150
Pallamana	31	83	85	28	310
Pandanus	44	107+	50	12	425
Paynes	28	78	70	21	335
Pentland	20	109+	95	25	375
Pin Gin*	15	100+	90	17	515
Pinnacle	26	43	50	27	195
Powlathanga	16	142+	105	28	380
Rangeside	26	107	50	11	435
Rangeview	20	76	85	25	355
Rishton	42	82	45	12	345
Rolston	22	70	80	25	320
Scartwater	21	80	85	27	315
Severin*	16	100+	90	25	370
Star	7	79	85	20	435
Thorpe	20	90	90	25	360
Tuckers	21	100+	95	18	515
Two Creek	31	77	70	22	310
Umala*	16	100+	90	25	370
Utchee*	16	100+	90	25	370
Victoria Downs	17	124+	95	28	345
Wairuna	16	86	95	23	410
Wambiana	21	104	115	21	555
Warawee	23	85	90	28	330
Wattle Vale	35	88	70	18	380
Worsley*	16	100+	90	25	370
Yarraman	14	161+	110	20	555

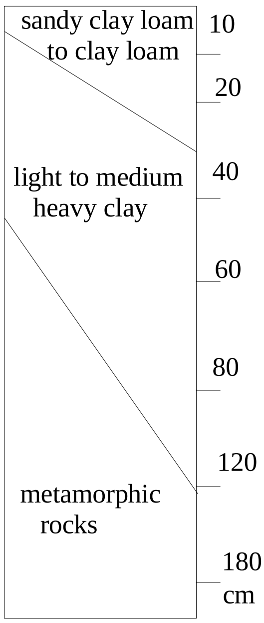
Amity association



Amity soil is a self mulching black cracking clay with an alkaline structured subsoil, often with free lime. There are red and brown cracking clay variants commonly in the association. Surface stone may occur but is not a common feature. The landform is gently undulating plains. The dominant vegetation is a grassland to mid-high open woodland of Red-barked bloodwood and narrow-leaved ironbark. The grassland is dominated locally by Indian couch, black spear grass and desert bluegrass with buffel grass the dominant introduced species. The associated soils are *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay and *Tuckers*, a moderately structured reddish brown to dark brown clay loam grading to structured dark reddish brown to yellowish red clay.

Amity soil is formed from basic rock and has moderate to high fertility. It is commonly saline at depth. Amity requires approximately 500 mm of rainfall to fill to a depth of one metre of which 100 mm will be available for most plant species. The surface and subsoil of Amity is not dispersive. It has extremely low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if introduced pastures are to be established. *Stylosanthes* spp. are not presently suited to Amity soil, however buffel grass and Urochloa are established in areas.

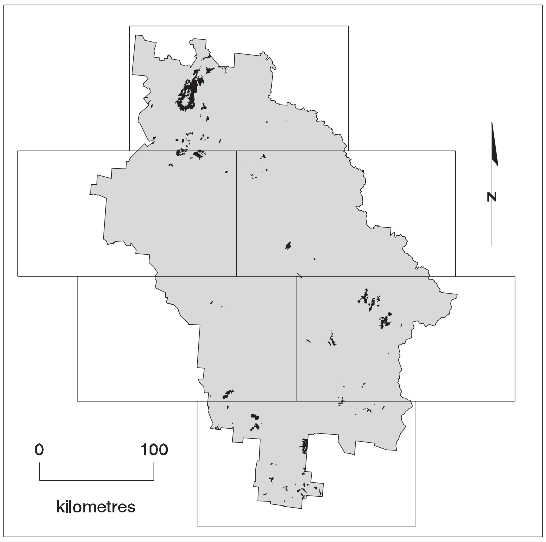
Argentine association

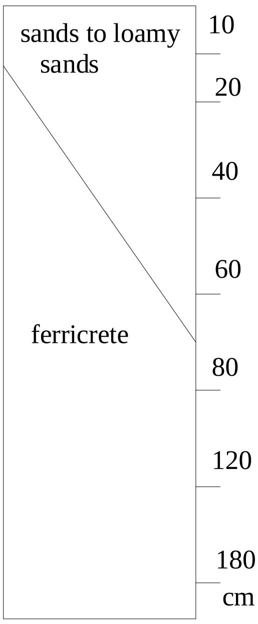


Argentine soil is a dark brown sandy clay loam to clay loam, often gravely over alkaline structured red clay. Quartz gravels and mica flecks are common throughout the profile. The landform is gentle slopes to gently undulating rises with the dominant vegetation a mid-high woodland of narrow-leaved ironbark and Reid River box. Lower stratum includes *Bothriochloa* species, wire grasses, golden beard grass and black spear grass. The most commonly associated soil is *Paynes*, a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay.

Argentine is formed from metamorphosed sediments and may have formed from metamorphosed sediments and may have inclusions of sedimentary soils where the metamorphism has not altered the country rock. Argentine requires approximately 300 mm of rainfall to fill the 77 cm mean maximum depth of which 90 mm will be available for most plants. The surface and subsoil horizons of Argentine are not dispersive. Argentine has extremely low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Barkla association

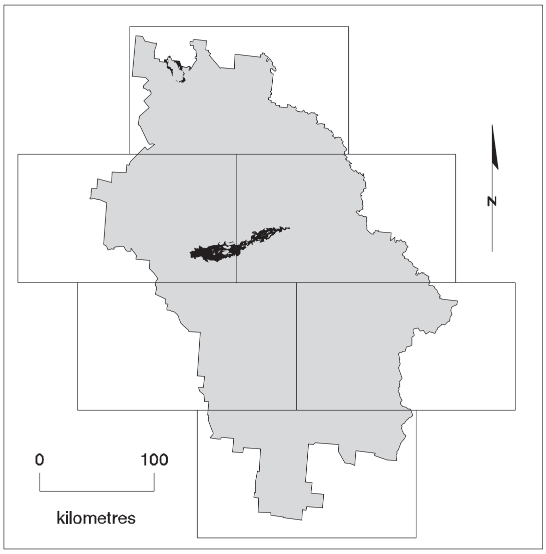




Barkla soil is a greyish brown sand grading to yellowish brown loamy sand on ferricrete. The landform is gently undulating plains and mesas. The vegetation is a mid-high woodland of narrow-leaved ironbark, quinine bush and Reid River box. The ground layer is buck spinifex, golden beard grass and love grasses. Associated soils are: *Rishton*, a uniform sand with a dark brown loose to soft surface and yellowish brown subsoil, often with a bleached A2 horizon; *Wattle Vale*, a dark greyish brown, loose to firm, loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam; and *Featherby* is characterised by laterite outcrop.

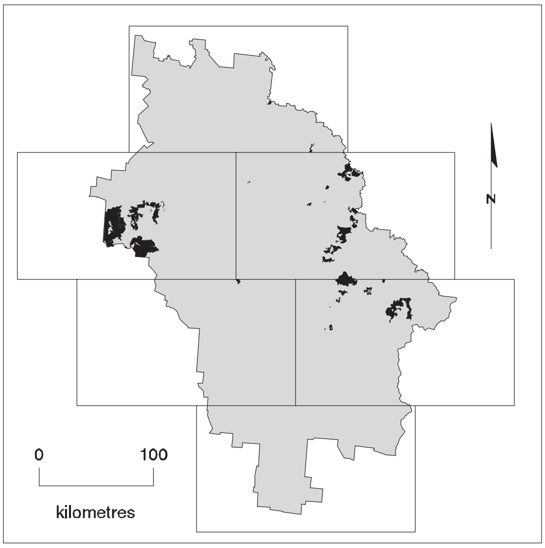
Barkla soil is shallow, has low fertility and is formed from ferruginous sediments. Barkla requires approximately 205 mm of rainfall to fill the 46 cm mean maximum depth, 60 mm of which will be available for most plant species. Barkla has extremely low bicarbonate phosphorus in the surface and cattle grazing pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

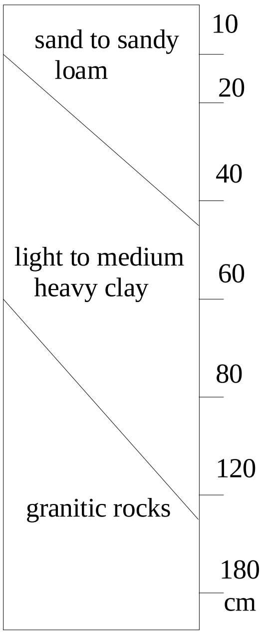
Basalt Rock association



Basalt Rock is a mapping unit of largley bare basalt flows in the Nulla, Toomba, Chudleigh and McBride basalt geological provinces, described in the basalt landscapes. The flows are typically covered discontinuously by a closed forest of softwood species with black tea-tree at the perimeters. Areas of *Nulla* soil, a dark reddish brown loam, may be found in pockets amongst the flows as well as *Miscellaneous Basalt* soil which is a silty material dominated by diatomaceous earth and clayey peats. [*no profile diagram*]

Bluff association

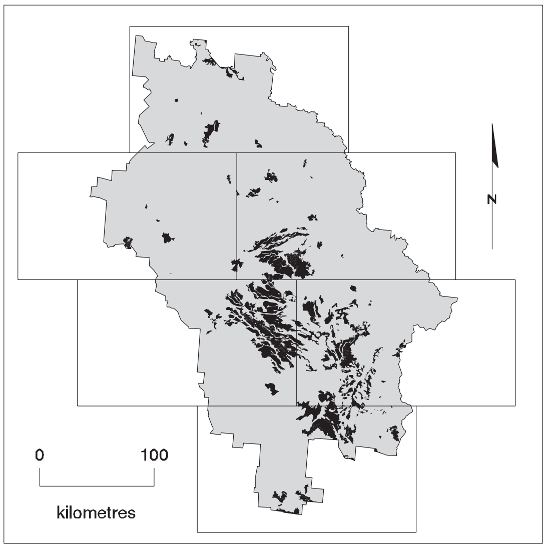


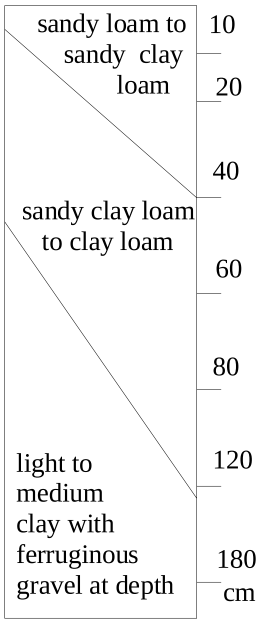


Bluff soil is a greyish brown sand to sandy loam over alkaline structured yellowish brown clay. The landform is undulating rises with granite tors or outcrops a common feature. Vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box and poplar gum. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Two Creek*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; *Conolly*, a grey, brown or yellowish brown sand; and *Carse O' Gowrie*, a dark brown sand over yellowish brown sand.

Bluff is formed from coarse grained granitic rocks and has low soil fertility. Bluff soil requires approximately 435 mm of rainfall to fill a mean maximum depth of 95 cm and have approximately 90 mm available for plant growth. The surface of Bluff is moderately dispersive and the subsoil is highly dispersive. Bluff has extremely low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Boston association

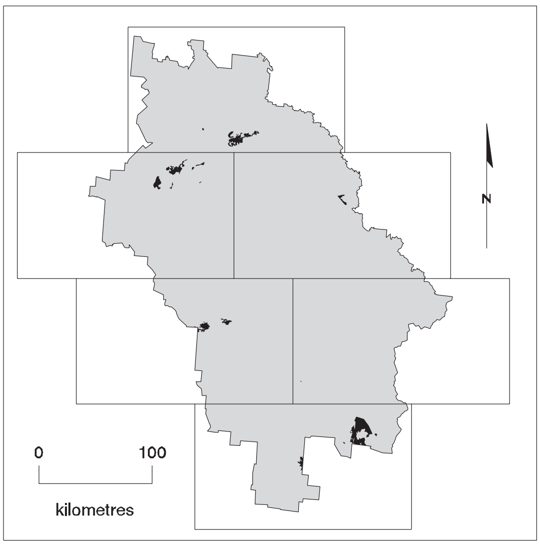




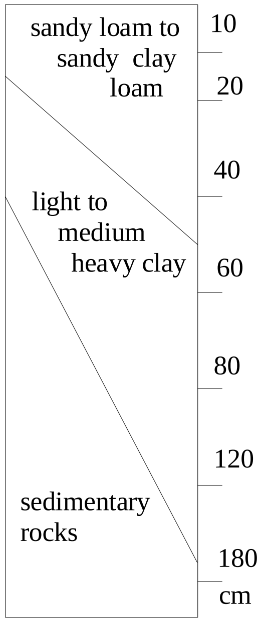
Boston soil is a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay. The soil may have considerable amounts of ferruginous gravels in the profile and is often quarried for road base. The landform is level to gently undulating plains with occasional mesas. Common vegetation is a mid-high woodland of silver and/or narrow-leaved ironbark and less commonly Reid River box as the dominant tallest stratum. *Acacia* species (lancewood, bendee) may be locally dominant, quinine bush is common in the mid-stratum. Wire grasses, golden beard grass, black spear grass and buck spinifex are locally dominant grass species. Associated soils are: *Pentland*, a dark reddish brown to dark brown sandy clay loam grading to an earthy red light clay; *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay; and *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam. In the Cape River area the following soils are associated: *Liontown,* a dark brown to greyish brown sandy loam to sandy clay loam with bleached A2 over alkaline structured dark brown to yellowish brown and grey clay; and *Powlathanga,* a very dark grey to dark brown clay with a massive to blocky surface, over an alkaline upper subsoil and a structured acid lower subsoil.

Boston is formed from Cainozoic sediments and has low fertility. Boston requires approximately 340 mm of rainfall to fill a mean maximum depth of 81 cm and of this 65 mm would be available for plant growth. The surface and subsoils are not dispersive and the soil has extremely low bicarbonate phosphorus in the soil surface. Cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production. Research done near Redlands homestead (Probert and Williams 1985) on this soil suggest an acid extractable phosphorus level of 12 ppm is necessary to ensure maximum yield of *Stylosanthes.*

Bulliwallah association

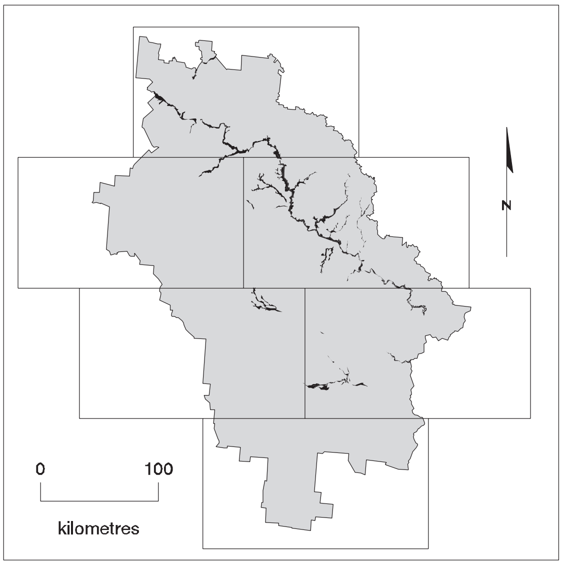


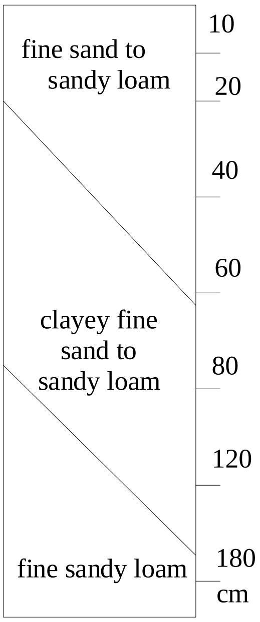
Bulliwallah soil is a dark brown to yellowish brown sandy loam to sandy clay loam over sandstone, mudstone or siltstone. The landform is undulating rises with sedimentary gravels or outcrop a common feature. Vegetation is dominated by a tall woodland of narrow-leaved ironbark, ghost gum and Reid River box with a mid-story of false sandalwood and *Acacia* species. The ground layer is dominated by pitted bluegrass, black spear grass, buck spinifex and wire grasses. Common associated soils: are *Flagstone,* a very dark greyish brown to yellowish brown sand to sandy loam over sedimentary rock; *Greenvale,* a dark greyish brown to brown sand to sandy loam over structured dark yellowish brown to brownish yellow clay; and *Ceaser,* a dark brown sandy loam over structured red clay.



Bulliwallah is formed from coarse to fine grained sedimentary rocks but is typically found on fine grained rocks such as mudstone and siltstone. The soil has low fertility, however there are some sedimentary rocks and their derived soils that are higher in phosphorus. Bulliwallah requires approximately 200 mm of rainfall to fill a mean maximum depth of 47 cm and 75 mm would be available for plant growth. The surface soil has low dispersion as does the weathered rock. Bulliwallah has extremely low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Burdekin association

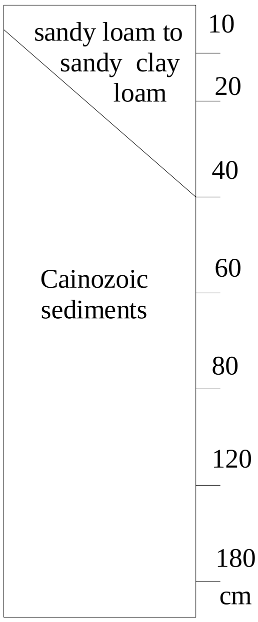




Burdekin soil is a dark yellowish brown fine sand grading to a brown loam. Landform is level to gently undulating alluvial plains with the soil found on the bank or levee(s) of most streams and rivers of the Shire. Vegetation is a tall woodland dominated by narrow-leaved ironbark, Reid River box, long-fruited grey bloodwood and Moreton Bay ash. The ground layer is dominated by black spear grass, golden beard grass, wire grasses and bluegrasses. Associated soils: are *Fanning River*, a dark greyish brown to brown sandy loam to sandy clay loam grading to structured dark brown to dark yellowish brown clay; *Gainsford*, a dark reddish brown to grey brown loam grading to reddish brown to red clay; *Pandanus*, a uniform sand, with a dark brown, soft surface grading to a yellowish red to brownish yellow subsoil; and *Creek*, a dark greyish brown sandy loam to sandy clayloam over structured yellowish brown to grey clay.

Burdekin requires approximately 460 mm of rainfall to fill to one metre and of this 150 mm would be available for plant growth. The soil is not dispersive in the surface, but is weakly dispersive in the upper subsoil. Deeper subsoil layers may be highly dispersive as evidenced in gullies in many river crossings. Burdekin generally has extremely low bicarbonate phosphorus in the surface, however there are sites with very high levels of phosphorus reflecting the source materials that have formed the deposits. Cattle grazing of pastures on this soil will require phosphorus supplementation in most instances *Stylosanthes* pastures will generally not require phosphorus fertiliser.

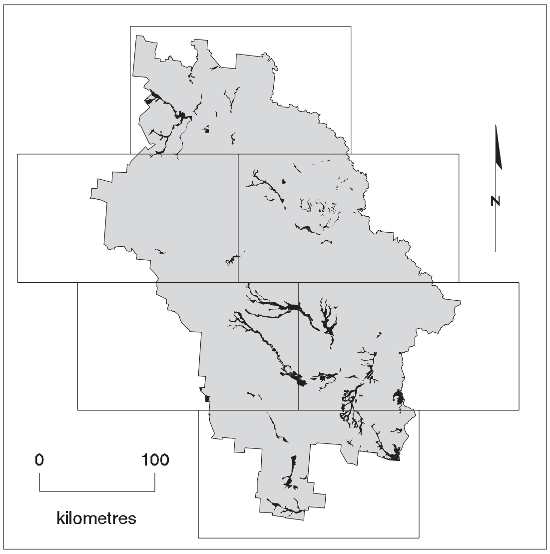
Burra association

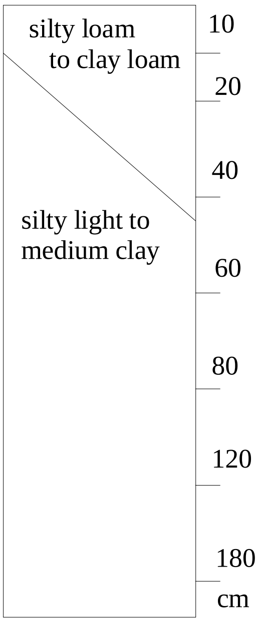


Burra soil is a dark greyish brown sandy loam to sandy clay loam grading to a mottled grey clay. The landform is level plain and gently undulating rises. The dominant vegetation is a mid-high woodland of silver and/or narrow-leaved ironbark, with *Acacia* species. The ground layer is dominated by golden beard grass, wire grasses, black spear grass and buck spinifex. Associated soils are: *Barkla*, a greyish brown sand grading to yellowish brown loamy sand on ferricrete; *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam; and *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay.

Burra is formed from Cainozoic sediments and has low fertility. Burra soil requires approximately 420 mm of rainfall to fill to one metre and of this 80 mm is available for plant growth. The soil is not dispersive in the surface or in the subsoil. The bicarbonate extractable phosphorus is extremely low in the soil surface and cattle grazing pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Cape association

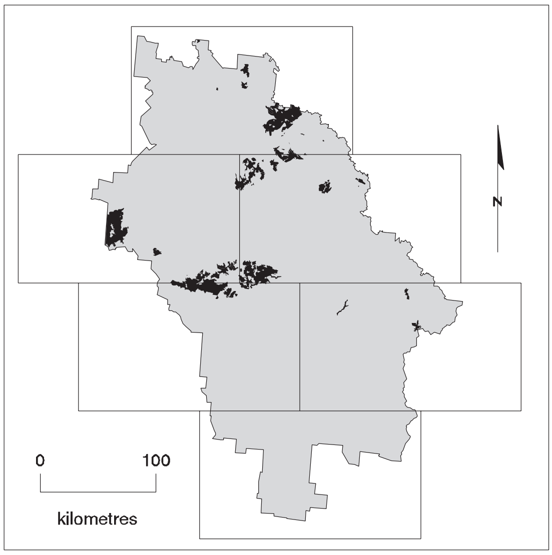




Cape soil is a very dark greyish brown silty loam to clay loam over alkaline structured dark brownish yellow or brown clay. The subsoil is often mottled. The landform is level to gently undulating alluvial plains with small lagoons and meander channels as associated landform features. The dominant vegetation is a tall woodland of Reid River box, narrow-leaved ironbark and coolibah. Mid-stratum consists of false sandalwood and upper stratum saplings. The ground layer is dominated by black spear grass, golden beard grass and wire grasses. Associated soils are: *Creek*, a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay; *Gainsford*, a dark reddish brown to grey brown loam grading to reddish brown to red clay; *Manoa*, a dark grey to dark yellowish brown clay with a structured neutral to alkaline subsoil; and *Yarraman*, a black, brown or grey clay with a self-mulching to blocky surface and an alkaline structured subsoil.

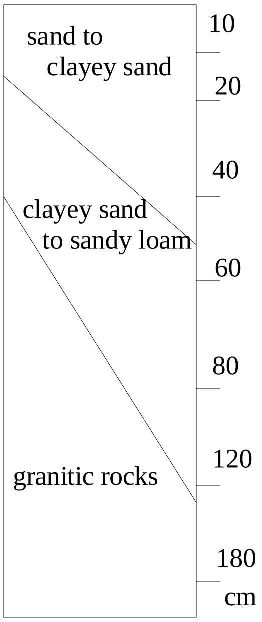
Fertility of Cape soil is generally low to moderate. Cape requires approximately 395 mm of rainfall to fill to one metre of which 110 mm is available for plant growth. The soil is weak to moderately dispersive in the surface and moderate to highly dispersive in the subsoil. Bicarbonate phosphorus levels range from extremely low to high, however phosphorus supplementation is generally necessary for cattle grazing of pastures on this soil. Phosphorus fertiliser may be necessary for optimum *Stylosanthes* growth.

Carse O' Gowrie association

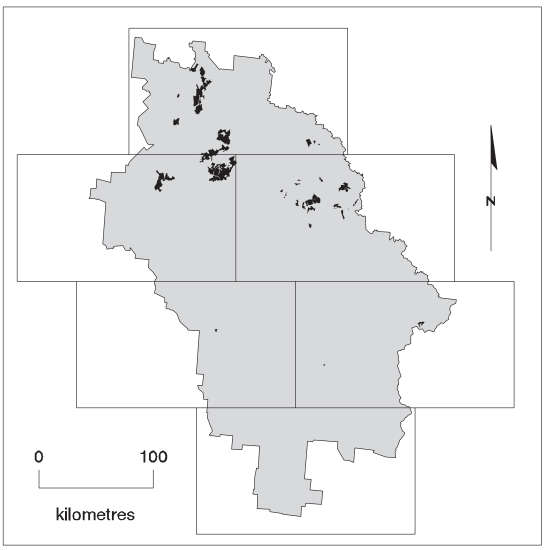


Carse O'Gowrie soil (see previous page) is a dark brown sand to clayey sand over yellowish brown sand to sandy loam. The landform is undulating rises with granite tors or outcrops an occasional feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, long-fruited grey bloodwood and silver-leaved ironbark (*Eucalyptus shirleyi*), with quinine bush or tea tree in the mid-stratum. The ground layer is dominated by black spear grass, wire grasses and golden beard grass. Associated soils are: *Conolly*, a grey, brown and yellowish brown sand; *Two Creek*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; and *Bluff*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay.

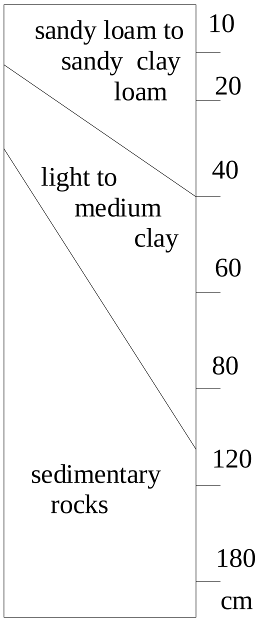
Carse O'Gowrie is formed from coarse grained granitic rocks and is generally low in fertility. The soils require approximately 370 mm of rainfall to fill to a mean maximum depth of 85 cm and of which 110 mm is available for plant growth. The soil is not dispersive in the surface or the subsoil. Carse O'Gowrie has extremely low bicarbonate phosphorus in the soil surface and phosphorus supplementation is recommended for cattle grazing. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.



Ceaser association

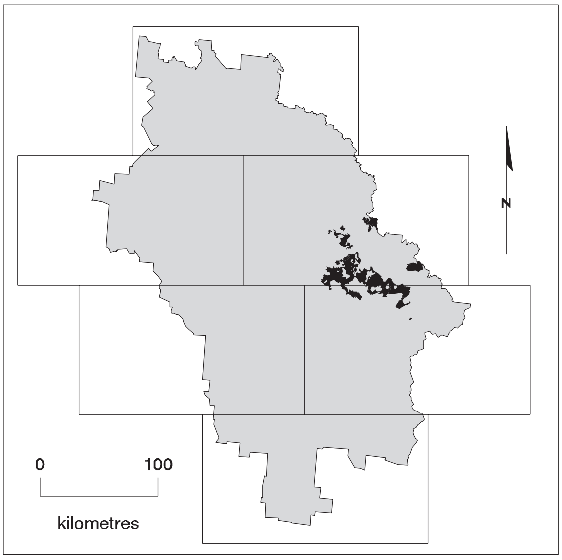


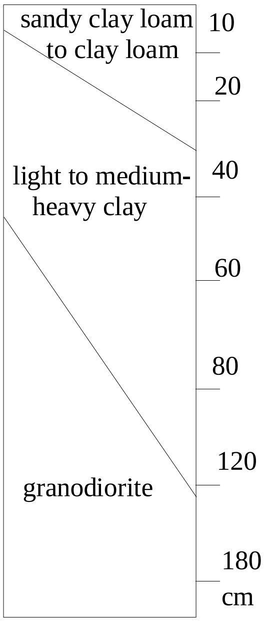
Ceaser soil is a dark brown sandy loam to sandy clay loam over structured red clay. The landform is undulating rises with surface gravel and sedimentary rock exposure a common surface feature. The dominant vegetation is a mid-high woodland of narrow and silver-leaved ironbark and occasionally Reid River box with a false sandalwood mid-stratum. The ground layer is dominated by black spear grass, wire grasses, buck spinifex and kangaroo grass. Associated soils are: *Flagstone*, a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock; *Greenvale*, a dark greyish brown to brown sand to sandy loam over structured dark yellowish brown to brownish yellow clay; and *Dotswood*, a dark brown to yellowish brown sandy loam to sandy clay loam over alkaline structured brown to yellowish brown clay.



Ceaser is formed from coarse and fine sedimentary rocks and is generally low to moderate in fertility. The soil requires approximately 440 mm of rainfall to fill to a mean maximum depth of 71 cm and of this 85 mm is available for plant growth. Ceaser is not or only weakly dispersive in the surface and subsoil and has extremely low bicarbonate phosphorus in the surface. Cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.

Charters Towers association

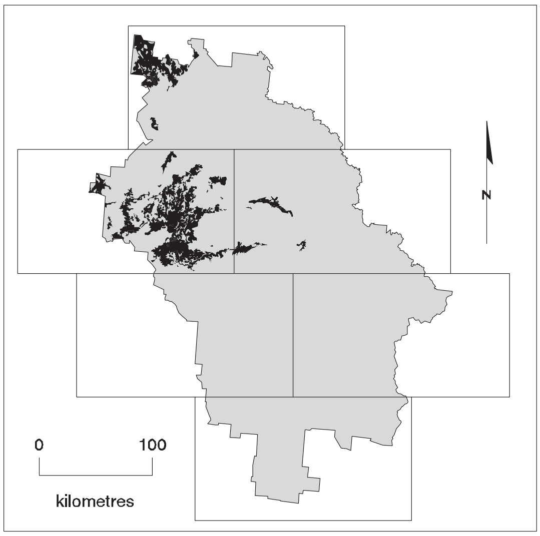


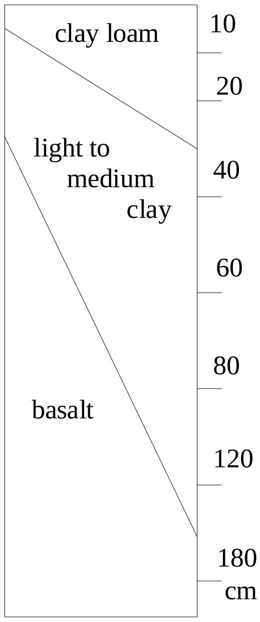


Charters Towers soil is a dark brown sandy clay loam to clay loam over structured red to reddish brown clay, alkaline at depth. The landform is gently undulating rises to undulating rises with granite tors or granodiorite outcrop a common feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, red barked bloodwood and ghost gum. *Eucalyptus* species and individual *Acacia* species such as corkwood form the sparse mid-story. The ground layer is dominated by Indian couch, blacks spear grass and desert bluegrass with golden beard grass and wire grasses locally dominant. Associated soils are: *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay; and *Mount Ravenswood*, a very dark greyish brown to yellowish brown light clay grading to alkaline structured dark yellowish brown to reddish brown medium clay.

Charters Towers soil is formed from granodiorite and closely associated granitic rock which weather to a moderately fertile soil. Charters Towers soil requires approximately 330 mm of rainfall to fill to a mean maximum depth of 83 cm and of this 65 mm is available for plant growth. The soil is not dispersive in either the surface or the subsoil and has extremely low bicarbonate phosphorus in the surface so that cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of Stylosanthes pastures.

Conjuboy association

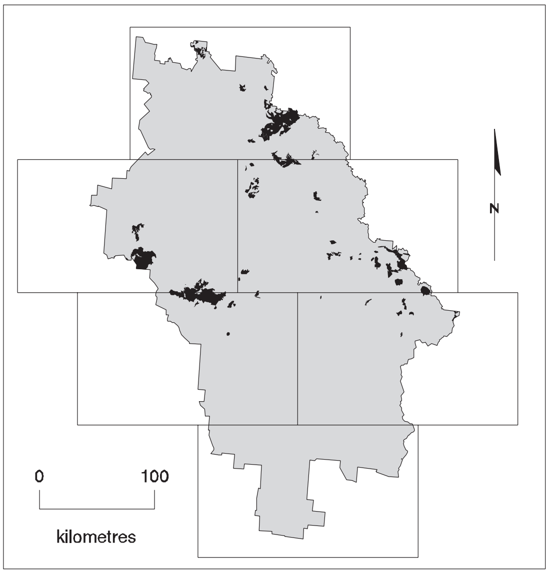




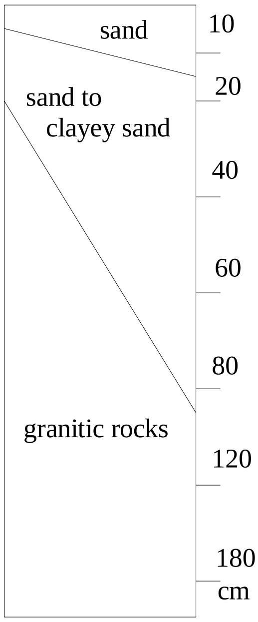
Conjuboy soil is a dark brown clay loam grading to yellowish brown structured clay. The landform is level to gently undulating plains with nil to high amounts of basalt rock on the surface or in the soil profile. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and the ground layer is dominated by kangaroo grass, black spear grass and desert bluegrass. Associated soils are: *Glencoe*, a structured dark brown clay loam to light clay grading to structured dark brown clay; *Lolworth*, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules; and *Maryvale*, a grey to black self mulching alkaline clay with carbonate nodules through out profile.

Conjuboy is formed from basalt flows of various age from the Quaternary to the Tertiary and is generally moderate to highly fertile. Conjuboy requires approximately 420 mm of rainfall to fill to a mean maximum depth of 84 cm and of this 90 mm is available for plant growth. The soil is not dispersive in the surface or subsoil. Surface soil bicarbonate phosphorus levels range from low to very high. Ghost gum may be an indicator of low phosphorus levels from our limited data. Cattle grazing of pastures on this soil in the majority of cases may not require phosphorus supplementation. Phosphorus fertiliser is generally not necessary for establishment of *Stylosanthes* pastures.

Conolly association

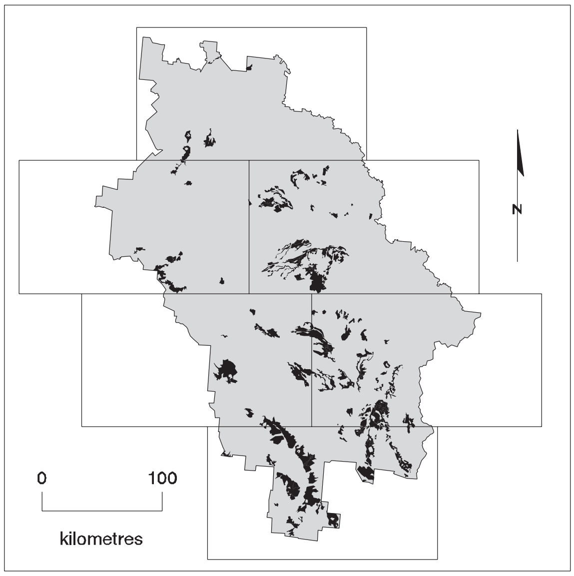


Conolly soil is a grey, brown and yellowish brown sand. The landform is undulating rises with granite tors or outcrops a common feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and silver-leaved ironbark (*E. shirleyi*). The mid-story may be quinine bush and/or *Acacia* species. The ground layer is dominated by black spear grass, Indian couch and wire grasses. Associated soils are: *Two Creek*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; *Bluff*, a greyish brown sand to sandy loam over alkaline structured yellowish brown clay and *Carse O' Gowrie*, a dark brown sand over; yellowish brown sand. Conolly soil is formed from coarse grained granitic rock and generally has low fertility. The soil requires

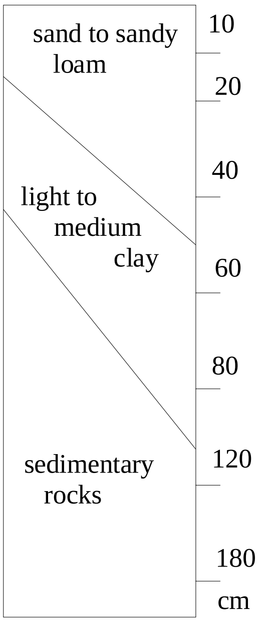


approximately 245 mm of rainfall to fill to a mean maximum depth of 52 cm and of this 55 mm is available to the plant. The surface and the subsoils are not dispersive. Surface soil bicarbonate phosphorus levels are extremely low and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.

Corea association



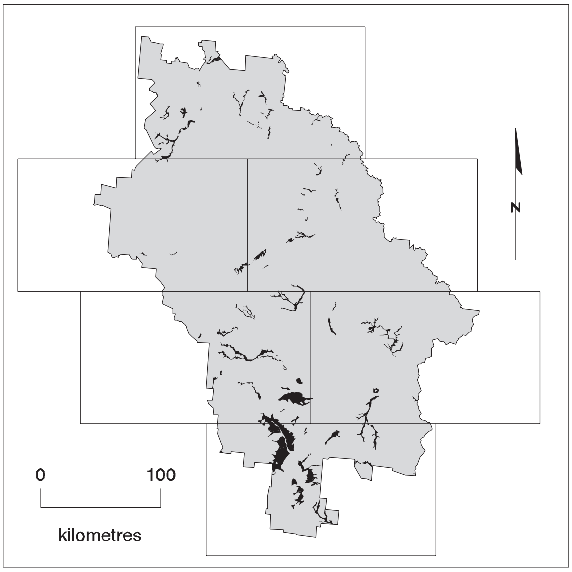
Corea soil is a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay. Ironstone and clayey globules may be concentrated on top of the subsoil or above the parent material or other substrate layer. The landform is gently undulating plains and lower slopes at the margins of undulating rises. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box and silver-leaved ironbark (*Eucalyptus melanopholia*). Quinine bush and *Acacia* species are the common mid storey. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam; *Liontown*, a dark brown to greyish brown sandy loam to sandy clay loam with bleached A2 over alkaline structured dark brown to yellowish brown and grey clay; and *Victoria Downs*, a uniform clay of massive to blocky structured dark grey to greyish brown surface grading to alkaline structured dark grey to yellowish brown subsoil.

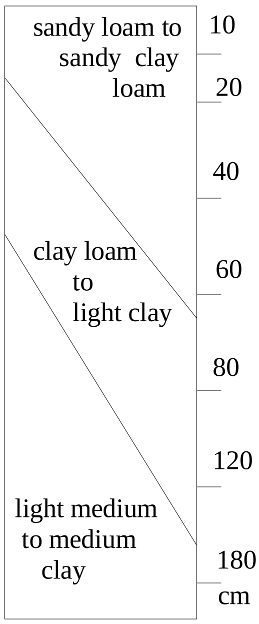


Corea soil is formed from Cainozoic sediments of varying origin and generally has low fertility. Corea requires approximately 315 mm of rainfall to fill to a mean maximum depth of 81 cm and of this 63 mm is available for plant growth. The soil is weak to moderately dispersive in the surface and weak to highly dispersive in the subsoil. Corea has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.

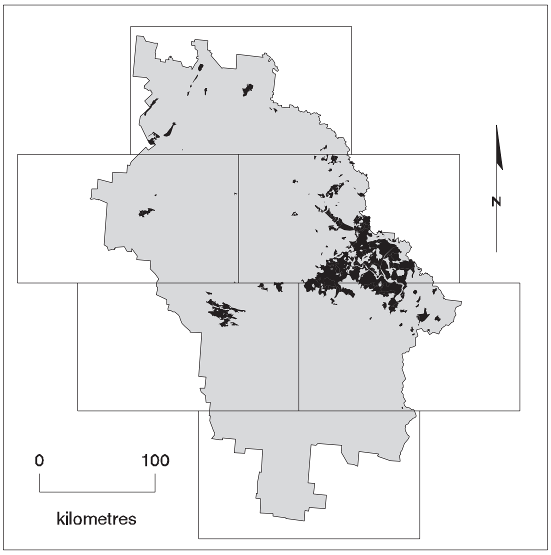
Creek association

Creek soil is a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay. The landform is level to gently undulating alluvial plains; small lagoons and meander channels are an associated feature. A tall woodland of narrow-leaved ironbark, Reid River box, poplar gum and Moreton Bay ash are the common tallest stratum species with false sandalwood the mid-stratum species. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Cape*, a very dark greyish brown silty loam to clay loam over alkaline structured dark brownish yellowish or brown clay, often mottled; *Gainsford*, a dark reddish brown to grey brown loam grading to reddish brown to red clay; *Manoa*, a dark grey to dark yellowish brown clay with a structured neutral to alkaline subsoil; and *Yarraman*, a black, brown or grey clay with a self-mulching to blocky surface and an alkaline structured subsoil.

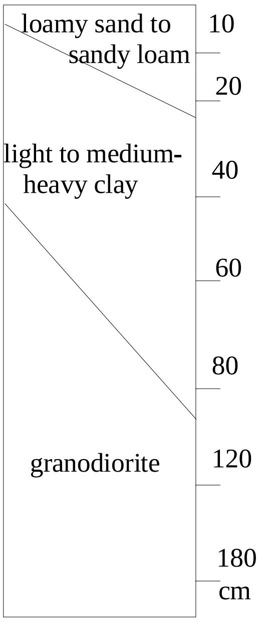




Creek soil is formed from alluvium of mixed origins and has low to high soil nutrient levels. Creek soil requires approximately 450 mm of rainfall to fill to a mean maximum depth of 98 cm and of this 120 mm is available for plant growth. The soil is weakly to moderately dispersive in the surface and weak to highly dispersive in the subsoil. Levels of bicarbonate phosphorus in the surface soil ranges from extremely low to high. Cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.



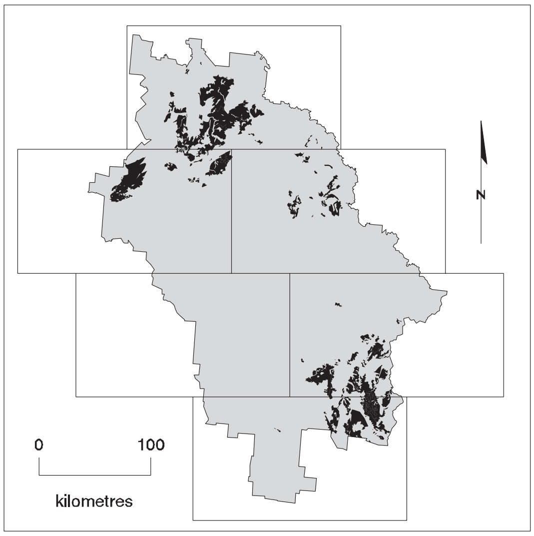
Dalrymple Association

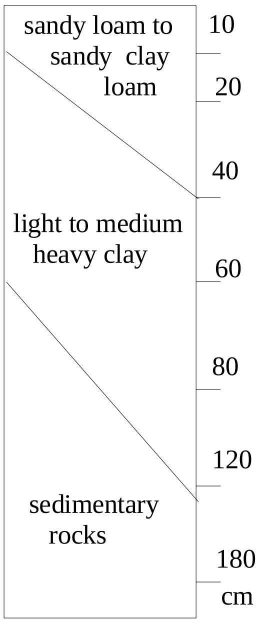


Dalrymple soil is a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay. The landform is undulating rises with granite tors or granodiorite exposures a common feature. The tallest stratum is a mid-high woodland of narrow-leaved ironbark and red barked bloodwood. The ground layer is dominated by Indian couch, blackspear and golden beard grass. Wire grasses may be locally dominant. Associated soils are: *Mingela*, a very dark greyish brown to brown sandy clay loam to clay loam over alkaline structured dark brown to yellowish brown clay; *Conolly*, a grey, brown and yellowish brown sand and; *Amity*, a self mulching black cracking clay with an alkaline structured subsoil often with free lime.

Dalrymple soil is formed from granodiorite and similar granitic rock and is moderately fertile. Dalrymple requires approximately 290 mm of rainfall to fill to a mean maximum soil depth of 68 cm and of this 55 mm is available for plant growth. The soil is weak to moderately dispersive in the surface and not dispersive in the subsoil. Levels of bicarbonate phosphorus in the surface soil ranges from extremely low to low. Cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of Stylosanthes pastures. However, studies by Probert and Jones (1982) on similar soils at Virginia Park found only sulfur to be limiting for *Stylosanthes hamata* production.

Dotswood association



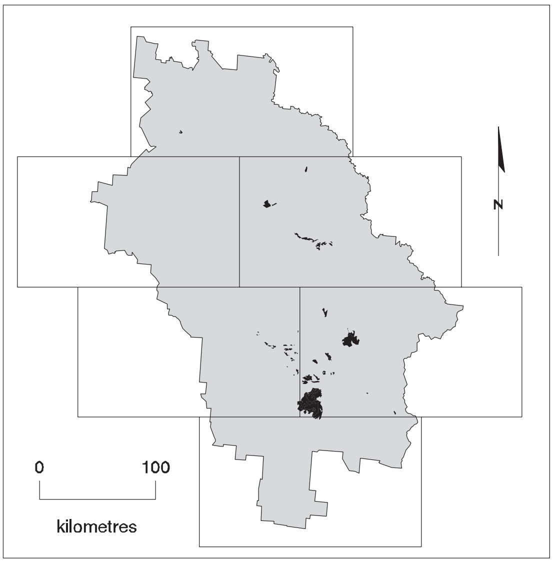


Dotswood soil is a dark brown to yellowish brown sandy loam to sandy clay loam over alkaline structured brown to yellowish brown clay. The landform is gently undulating plains to undulating rises with surface stone and sedimentary rock exposures a common feature. The dominant vegetation is a mid-high woodland of Reid River box, narrow-leaved ironbark and locally dominant blackwood closed forests. The mid-story may have false sandalwood and *Acacia* species with some areas heavily infested with the native woody weed currant bush. The ground layer is dominated by wire grasses, black spear grass and buck spinifex. Associated soils are: *Flagstone*, a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock; *Greenvale*, a dark greyish brown to brown sand to sandy loam over structured dark yellowish brown to brownish yellow clay; *Ceaser*, a dark brown sandy loam over structured red clay; and occasionally *Myrtlevale*, a very dark greyish brown to dark brown light clay grading to alkaline structured dark brown to yellowish brown medium heavy clay.

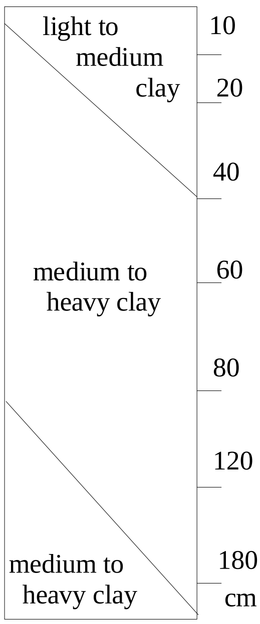
Dotswood soil is formed from sedimentary rock of both coarse (sandstone, conglomerate) and fine (siltstone, mudstone) texture but all weather to a soil which has generally low fertility. Dotswood soil requires approximately 505 mm of rainfall to fill to a mean maximum depth of 91 cm and of this 110 mm is available for plant growth. The soil is weak to moderately dispersive in the surface and weak to highly dispersive in the subsoil. The soil has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures. Gillard (1979) demonstrated that while stylosanthes pastures can be established on these soils, fertiliser is needed for optimum growth.

Egera association

Egera soil is a self mulching grey cracking clay often with free lime in the subsoil. The landform is level to gently undulating plains. A grassland or mid-high woodland to dense forest of blackwood, gidgee, brigalow and yellow wood may be locally dominant. Bauhinia and false sandalwood may be present in the mid-stratum. The grassland is predominantly blue grasses (*Bothriochloa* or *Dicanthium* species) and silky brown-top grass. Buffel grass is the dominant introduced grass and is well established. Associated soils are: *Liontown*, a dark brown to greyish brown sandy loam to sandy clay loam with bleached A2 horizon over alkaline structured dark brown to yellowish brown and grey clay; *Victoria Downs*, a uniform clay with a dark grey to greyish brown massive to blocky structured surface grading to a dark grey to yellowish brown alkaline structured

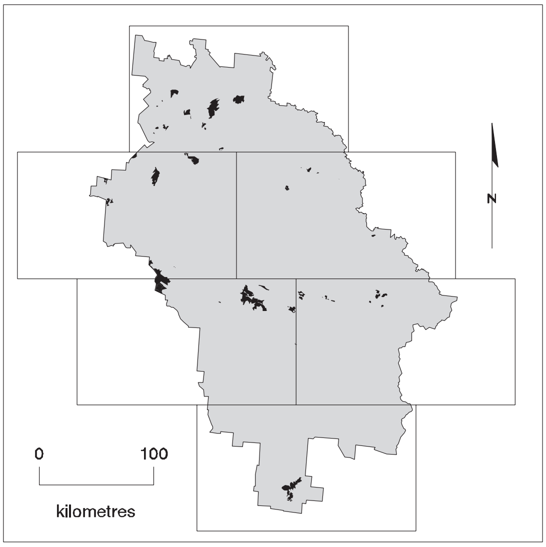


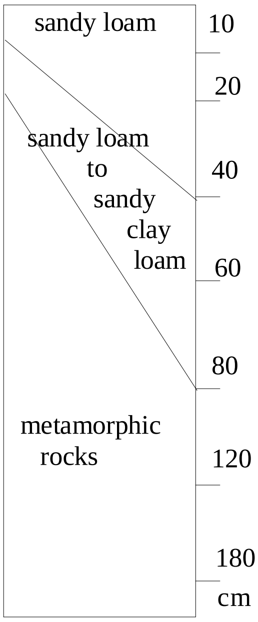
subsoil; and *Wambiana*, a uniform clay, structured dark grey to greyish brown with a neutral pH profile.



Egera soil is formed from Cainozoic sediments of unknown origin but are generally moderately high in fertility especially total nitrogen when associated with *Acacia* species. Egera requires approximately 555 mm of rainfall to fill to one metre and of this 115 mm is available for plant growth. The soil is either not or weakly dispersive in the surface and moderate to highly dispersive in the subsoil. The soil has extremely low bicarbonate phosphorus levels in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for successful improved pasture establishment. There are at presently no *Stylosanthes* pasture species suited to this soil however buffel and urochloa are suited. There appears to be no significant difference in phosphorus levels under grassland or acacia scrubs, such as gidgee.

Ewan association

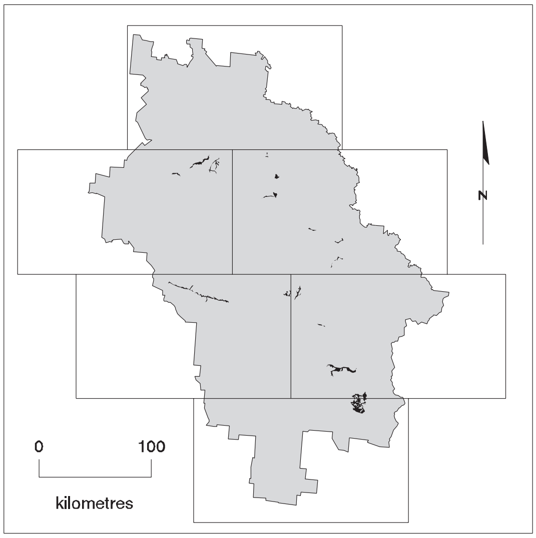


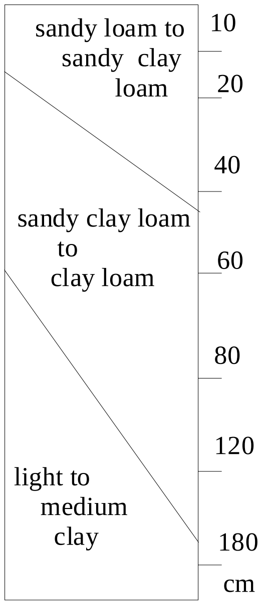


Ewan soil is a shallow massive brown sandy loam over metamorphic rock. The landform is undulating rises with rounded surface stone on the surface and in the soil profile. A mid-high woodland of narrow-leaved ironbark, silver-leaved ironbark (*E. shirleyi*) are the common tallest stratum with quinine bush and currant bush dominant in the mid-stratum. Wire grasses, pitted bluegrass and black spear grass are the dominant grasses. Associated soils are: *Paynes*, a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay; *Warawee*, a dark brown clay loam over alkaline structured yellowish brown clay; and *Rangeview*, a dark reddish brown loam over structured red to yellowish red clay.

Ewan is formed from metamorphic rock which is predominantly metamorphosed sediments and as such has generally of low fertility. Ewan requires approximately 195 mm of rainfall to fill to a mean maximum depth of 53 cm and of this 50 mm is available for plant growth. The soil is not dispersive to weakly dispersive in the surface and the weathered parent material varies from not dispersive to highly dispersive. Ewan has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.

Fanning River association

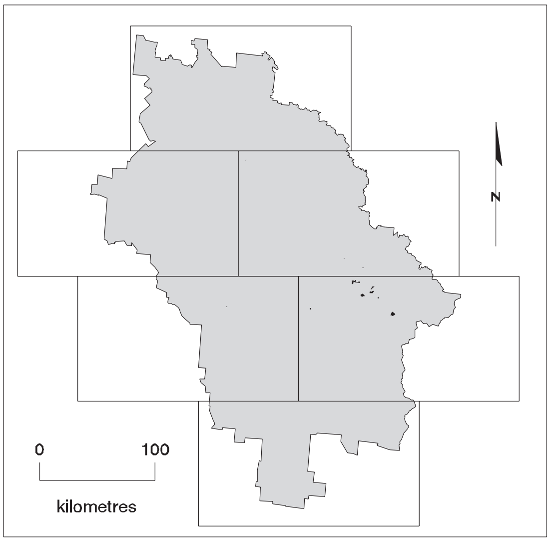




Fanning River soil is a dark greyish brown to brown sandy loam to sandy clay loam grading to structured dark brown to dark yellowish brown clay. The landform is level to gently undulating alluvial plains, predominantly levees and terraces. The vegetation is dominated by a tall woodland of Reid River box, narrow-leaved ironbark and Moreton Bay ash. Mid-storey species are predominantly saplings of the tallest stratum but false sandalwood can also occur. Dense infestations of chinee apple and rubber vine are common as many sites have been cleared for cultivation on the moderate to high fertility soils. The ground layer is dominated by *Bothriochloa* species, black spear grass, golden beard grass and bluegrasses. Associated soils are: *Burdekin*, a dark yellowish brown fine sand grading to brown loam; *Creek*, a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay; *Cape* a very dark greyish brown silty loam to clay loam over alkaline structured dark brownish yellow or brown clay, often mottled; and *Yarraman* a black, brown or grey clay with a self mulching to blocky surface and an alkaline structured subsoil.

Fanning River soil is formed from alluvium and is moderately to highly fertile. The soil requires approximately 390 mm of rainfall to fill to one metre and of this 105 mm will be available for plant growth. The soil is non to moderately dispersive in the surface and moderate to highly dispersive in the subsoil. Bicarbonate phosphorus levels are low and cattle grazing of pastures on this soil may require phosphorus supplementation. Phosphorus fertiliser is generally not necessary to establish *Stylosanthes* pastures.

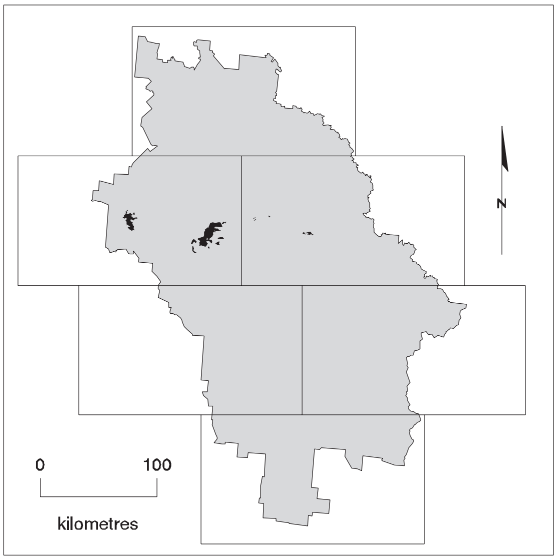
Featherby association

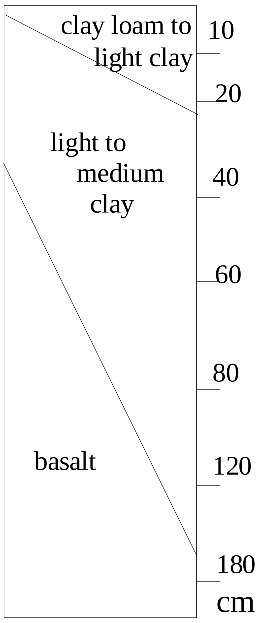


[*no profile diagram*]

Featherby mapping unit is dominated by laterite outcrop or exposed ferruginous gravel beds with little or no soil. The landform is the margins of undulating plains or mesas in the form of breakaways and low rises. The association is more commonly found as an inclusion where breaks in slope occur in most of the Cainozoic landforms. The dominant vegetation is a mid-high woodland to forest of *Acacia* species (lancewood, Bendee) and grows in the weathered substrate or where this substrate is exposed. The dominant grass is spinifex and occasionally wire grasses. Associated soils are: *Pentland*, a dark reddish brown to dark brown sandy clay loam grading to earthy red light clay; and *Barkla*, a greyish brown sand grading to yellowish brown loamy sand on ferricrete. Featherby has high rates of water runoff although fractures and eroded faces may expose substrates that are capable of storing water. Featherby is not suitable for any form of agricultural use.

Felspar association



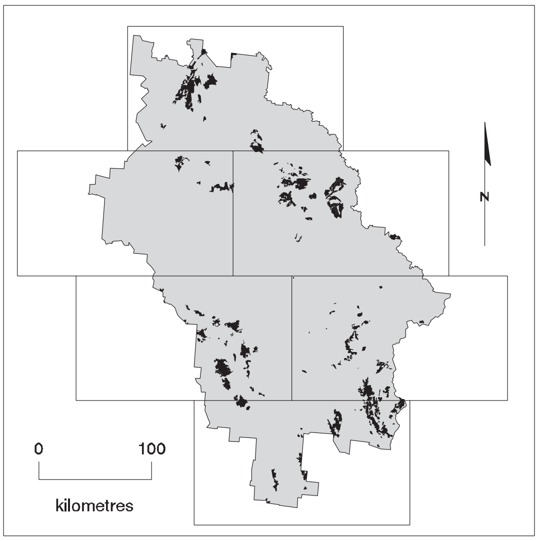


Felspar soil is a structured dark red to reddish brown clay loam to light clay over structured red clay. The landform is level plains with minor rock outcrop but basalt rocks may occur on the surface and throughout the soil profile. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and red barked bloodwood with mountain coolibah locally dominant. The ground layer is dominated by black spear grass, kangaroo grass and bluegrasses. Associated soils are: *Hillgrove*, a dark reddish brown to dark brown clay loam grading to structured red to dark reddish brown clay; and

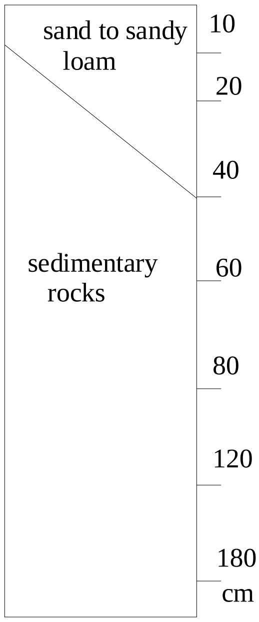
Lolworth, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules.

Felspar soil is formed from basalt of Quaternary to Cainozoic age and has moderate to high fertility. Felspar requires approximately 190 mm of rainfall to fill to a mean maximum depth of 97 cm and of this 99 mm is available for plant growth. The soil is weakly dispersive in the surface and not dispersive in the subsoil and has low to very high bicarbonate phosphorus in the surface. Cattle grazing of pastures on this soil would not require phosphorus supplementation. *Stylosanthes* pastures would be suited to this soil. Silver- leaved ironbark may be an indicator of low levels of phosphorus.

Flagstone association

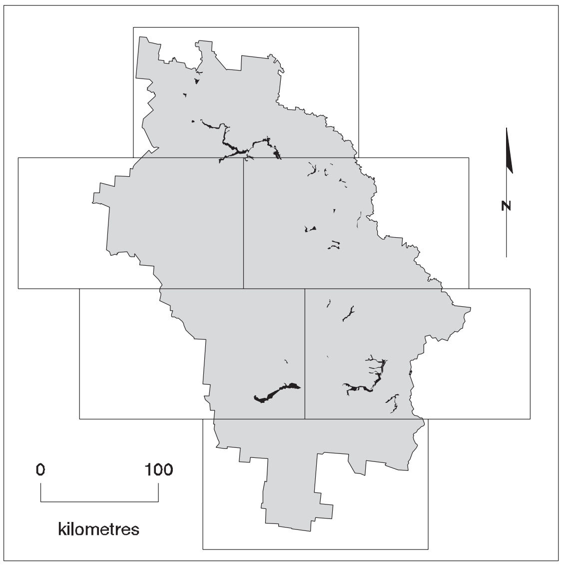


Flagstone soil is a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock. The landform is undulating rises with surface stone with sedimentary rock exposures a common feature. The dominant vegetation is a mid-high open forest to closed forest of narrow-leaved ironbark, lancewood and silver-leaved ironbark (*E. shirleyi*). Quinine bush and false sandalwood are the common mid-stratum. The ground layer is dominated by wire grasses, buck spinifex, golden beard grass and love grasses. Associated soils are: *Dotswood*, a dark brown to yellowish brown sandy loam to sandy clay over alkaline structured brown to yellowish brown clay; *Greenvale*, a dark brown to yellowish brown sand to sandy loam over alkaline structured brown to yellowish brown clay; and *Rishton*, a uniform sand often with a bleached A2 horizon and a dark brown, loose to soft surface, and a yellowish brown subsoil.

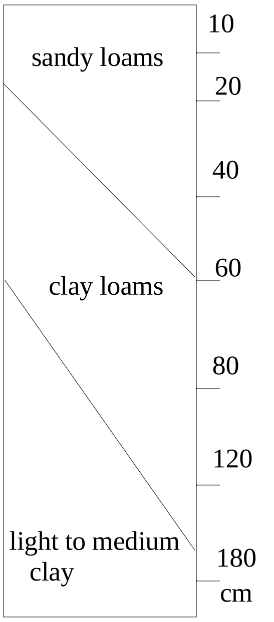


Flagstone soil is formed from coarse sediments (sandstone, conglomerate) has low fertility. The soil requires approximately 390 mm of rainfall to fill to a mean maximum depth of 45 cm and of this 54 mm is available for plant growth. The soil is non to moderately dispersive in the surface and not dispersive in the weathered parent material. Flagstone has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures.

Gainsford association



Gainsford soil is a dark reddish brown to grey brown sandy loam grading to reddish brown to red clay. The landform is level to gently undulating alluvial plains, the landform element is mainly older terraces. The dominant vegetation is a tall woodland of narrow-leaved ironbark, Reid River box, Moreton Bay ash and poplar gum.The mid-storey may have relatively dense stands of saplings in common with the tallest stratum as well as tea tree and blue gum. The ground layer is dominated by *Bothriochloa* species, wire grasses and golden beard grass. Associated soils are: *Burdekin*, a dark yellowish brown fine sand grading to brown sandy loam; *Creek*, a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay; and *Manoa*, a dark grey to dark yellowish brown clay with a structured neutral to alkaline subsoil.



The soil generally has moderate to high fertility. Gainsford requires approximately 395 mm of rainfall to fill to one metre and of this 100 mm is available for plant growth. The soil is not dispersive to weakly dispersive in the surface and weak to moderately dispersive in the subsoils. Gainsford has extremely low or very low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if *Stylosanthes* pastures are to reach optimum production.

Galmara association

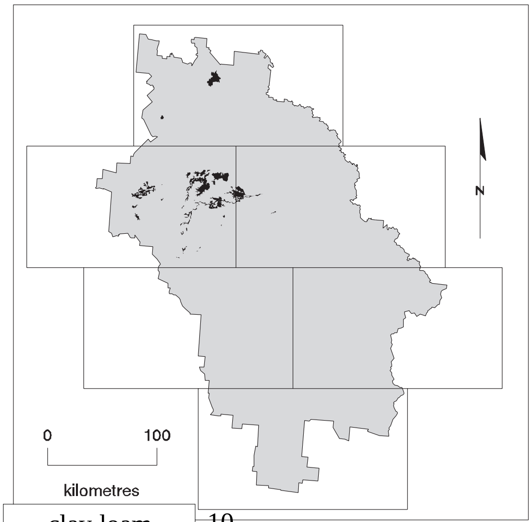
Galmara soil is a dark brown clay loam over structured red silty medium clay. The landform is hills and ranges. The vegetation is rainforest and sclerophyll forest and is located predominantly within the World Heritage Estate. Agricultural industries are limited on this soil due to most areas having a conservation status. Associated soils are unnamed yellow and grey subsoil variants of Galmara.

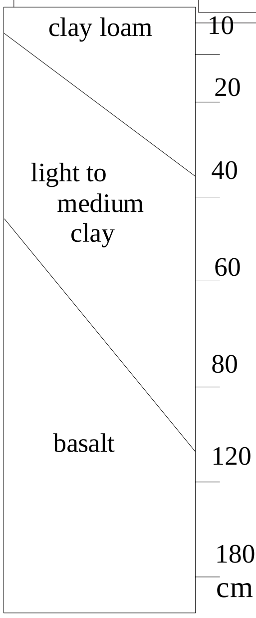
Galmara is formed from deeply weathered metamorphosed sediments and has very low fertility. The soil requires approximately 375 mm of rainfall to fill to one metre and of this 95 mm is available for plant growth. Galmara soil has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary for optimum growth of *Stylosanthes* pastures.

[*No profile diagram, no distribution figure*]

Glencoe association

Glencoe soil is a structured dark brown clay loam to light clay grading to structured dark brown

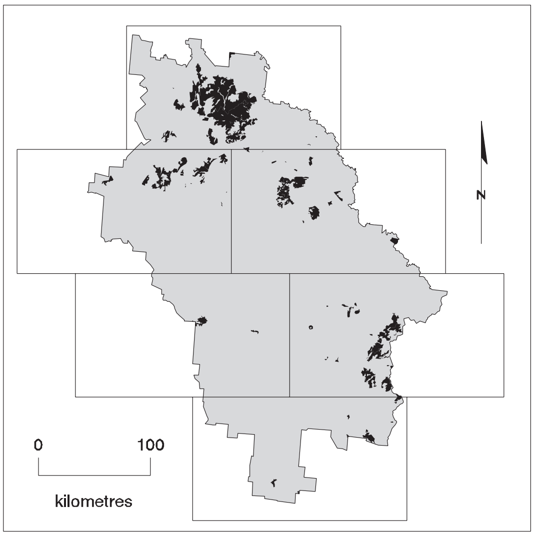


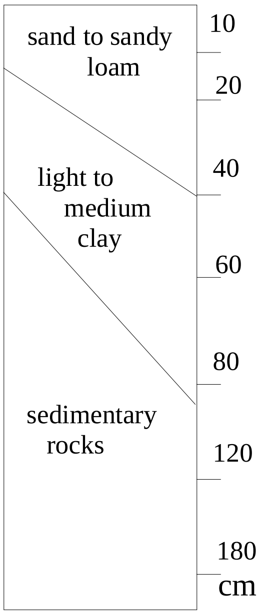


clay. The landform is level to gently undulating plains with basalt rock and surface stones a common feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and/or mountain coolibah. The ground layer is dominated by kangaroo grass, desert blue grassand *Dichanthium* species. Associated soils are: *Hillgrove*, a dark reddish brown to dark brown clay loam grading to structured red to dark reddish brown clay; and *Nulla*, a stony dark reddish brown loam.

Glencoe soil is formed from basalt of Quaternary to Cainozoic age and has moderate to good fertility. The soil requires approximately 430 mm of rainfall to fill to a mean maximum depth of 76 cm and of this 95 mm is available for plant growth. The soil is weakly dispersive in the surface and not dispersive in the subsoil. Glencoe has extremely low to very high bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally not require phosphorus supplementation. *Stylosanthes* pastures should establish satisfactorily on this soil. Research on similar soils at the Hillgrove ECOSAT site suggest sulfur is limiting for introduced pasture species (McIvor *et al.,* 1988).

Greenvale association

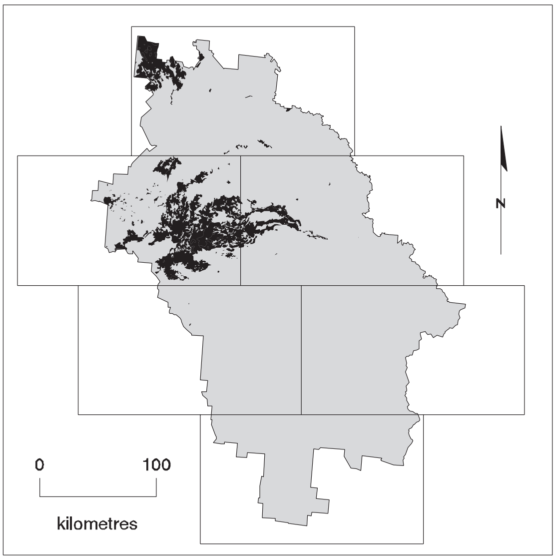




Greenvale soil is a dark brown to yellowish brown sand to sandy loam over alkaline structured brown to yellowish brown clay. The landform is undulating rises with sedimentary rock and surface gravel. The dominant vegetation is a tall woodland of narrow-leaved ironbark, Reid River box, and silver-leaved ironbark. *Acacia* species and currant bush may be locally dominant in the mid-stratum. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Ceaser*, a dark brown sandy loam over structured red clay; *Flagstone*, a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock; and *Scartwater*, a dark grey to dark brown sandy loam to clay loam, with a bleached A2 horizon over alkaline, structured dark greyish brown clay.

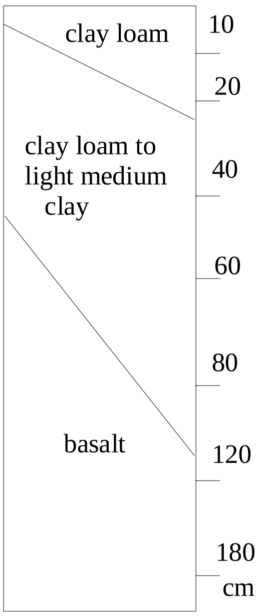
Greenvale soil is formed from coarse (sandstone, conglomerate) and fine (siltstone, mudstone) grained sedimentary rock and generally has low fertility. The soil requires approximately 340 mm of rainfall to fill to a mean maximum depth 91 cm and of this 90 mm will be available for plant growth. The soil is weak to moderately dispersive in the both the surface and the subsoil. Greenvale has extremely low bicarbonate phosphorus in the surface and cattle grazing pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylosanthes* pastures. Gillard (1979) demonstrated that *Stylosanthes* pastures could be established on this soil however fertiliser is needed for optimum growth.

Hillgrove association



Hillgrove soil is a dark reddish brown to dark brown clay loam grading to structured red to dark reddish brown clay. The landform is level to gently undulating plains with basalt rock and surface stones a common feature. The dominant vegetation is a tall woodland of narrow-leaved ironbark and red barked bloodwood with ghost gum locally dominant. The ground layer is dominated by black spear grass, kangaroo grass and *Bothriochloa* species. Associated soils are:

Conjuboy, a dark brown clay loam grading to yellowish brown structured clay; *Glencoe*, structured dark brown clay loams to light clay grading to structured dark brown clay; *Lolworth*, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules; and *Nulla*, dark reddish brown loams in rocky areas.



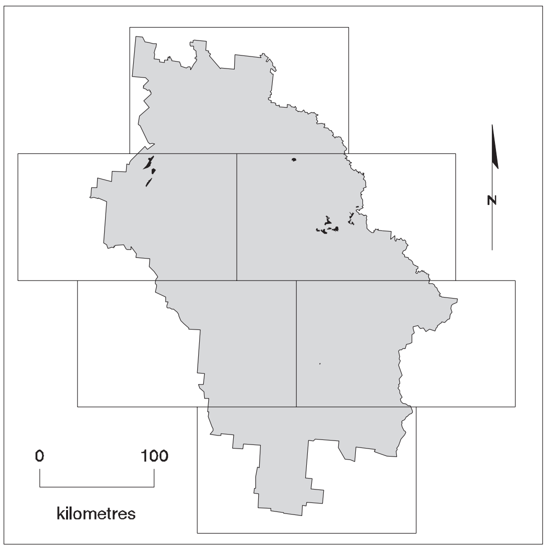
Hillgrove soil is formed from basalt of Quaternary to Cainozoic age and has moderate to good fertility. Hillgrove requires approximately 395 mm of rainfall to fill to a mean maximum depth of 77 cm and of this 70 mm is available for plant growth. The soil is not dispersive in the surface or subsoil. Surface phosphorus levels are low to very high. Ghost gum in the tallest stratum may be an indicator of low phosphorus levels. In the majority of cases cattle would not require supplementation and *Stylosanthes* pasture would readily establish without fertiliser. McIvor *et al.* (1988) suggests sulfur is the limiting nutrient for increased pasture production.

Hillview association

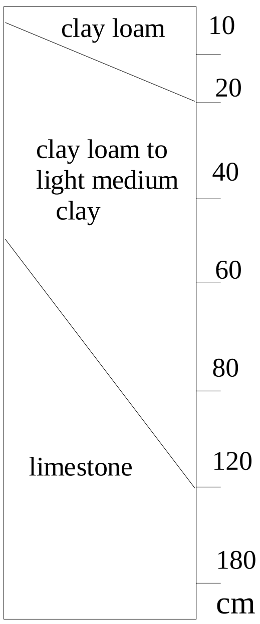
Hillview soil is a grey brown loamy sand to sandy loam grading to red sandy clay. The landform is gentle slopes and undulating rises with granite tors or outcrops a common feature. The dominant vegetation is a tall woodland of narrow-leaved ironbark and poplar gum. The ground layer is dominated by black spear grass, blady grass and kangaroo grass. Associated soils are: *Thorpe*, a dark grey sandy loam grading to yellow sandy light clay; *Two Creek,* a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; and *Conolly* a grey, brown and yellowish brown sand.

Hillview soil is formed from coarse grained granitic rock and has low fertility. The soil requires approximately 440 mm of rainfall to fill to one metre and of this 125 mm is available for plant growth. The soil is weakly dispersive in the surface and subsoil. Hillview has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser may be necessary if *Stylosanthes* pastures are to reach optimum production. Phosphorus sorption may be high on this soil where black surface horizons occur. [*No profile diagram]*

Lime View association

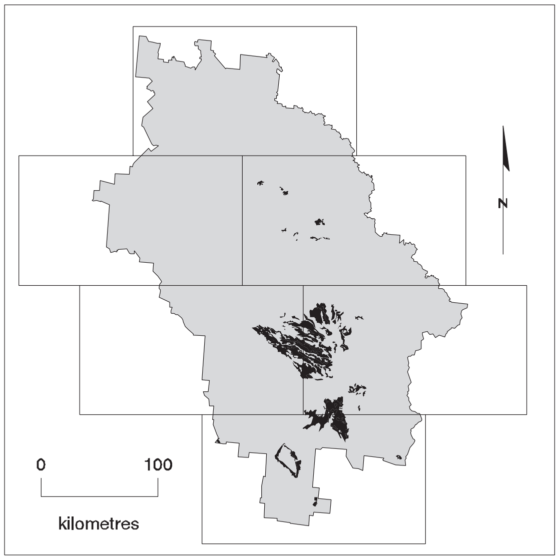


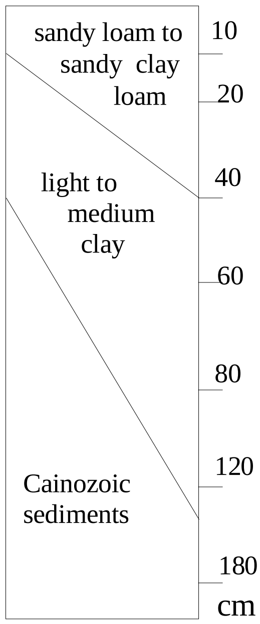
Lime View soil is a very dark grey clay loam, often alkaline over alkaline structured brown to red clay. The landform is undulating rises with limestone cobble and outcrop a common feature. The dominant vegetation is a tall woodland of Red barked bloodwood and narrow-leaved ironbark. Softwood species such as *Brachichiton* species are common in outcrops of limestone and gidgee may also be locally dominant. Black tea tree and *Angophora* species are common on lower slopes and drainage lines. The ground layer is dominated by Indian couch and desert bluegrass. Buffel grass is the dominant introduced pasture. Associated soils are: *Nial*, a dark reddish brown to yellowish brown sandy loam to sandy clay loam over alkaline structured red to reddish brown clay; and *Bulliwallah*, a dark brown to yellowish brown brown sandy loam to sandy clay loam over sandstone, mudstone or siltstone.



Lime View soil is formed from limestone, generally coralline which may contain fossils. The soil requires approximately 460 mm of rainfall to fill to a mean maximum depth of 86 cm and of this 95 mm is available for plant growth. The soil is weakly dispersive in the surface and subsoil. Lime View has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary for improved pasture introduction. Buffel grass and urochloa are more suited to this soil than *Stylosanthes.*

Liontown association

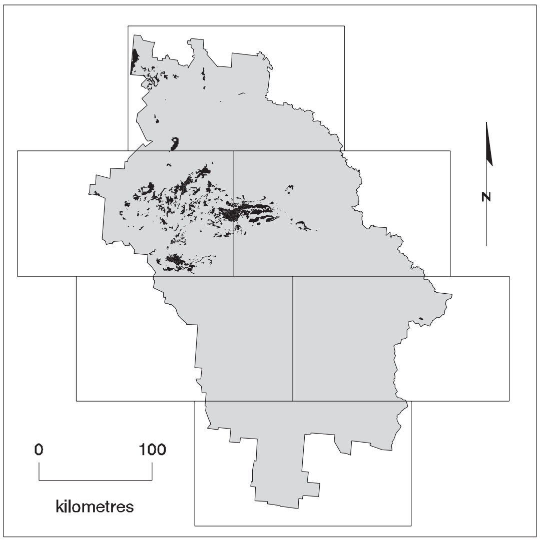


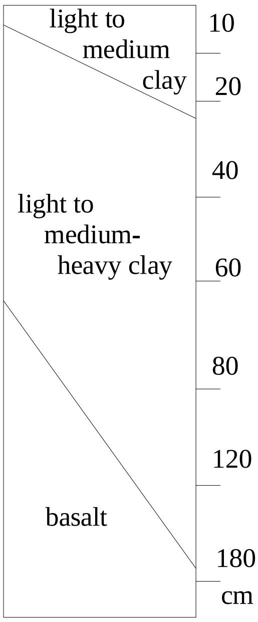


Liontown soil is a dark brown to greyish brown sandy loam to sandy clay loam with a bleached A2 horizon over alkaline structured dark brown to yellowish brown and grey clay. The landform is level to gently undulating plains. The dominant vegetation is a mid-high woodland of Reid River box and commonly dense stands of blackwood. The mid-stratum is usually false sandalwood, with dense stands of currant bush occurring locally. The ground layer is dominated by golden beard grass, *Sporobolus* species, black spear grass, wire grasses and bluegrasses. Associated soils are: *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay; *Powlathanga*, a very dark grey to dark brown clay with a massive to blocky surface over alkaline upper subsoil over a structured acid subsoil; and *Egera*, a grey self mulching clay often with free lime in subsoil.

Liontown soil is formed from Cainozoic sediments of mixed origin and has low fertility, but may have moderate levels of nitrogen when covered with *Acacia* species. The soil requires approximately 355 mm of rainfall to fill to a mean maximum depth of 90 cm and of this 95 mm is available for plant growth. The soil is weakly dispersive in the surface and moderate to highly dispersive in subsoil. Liontown has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary for optimum growth of *Stylothanes* pastures. There appears to be no difference in surface phosphorus levels between dense *Acacia* scrubs and open woodlands.

Lolworth association



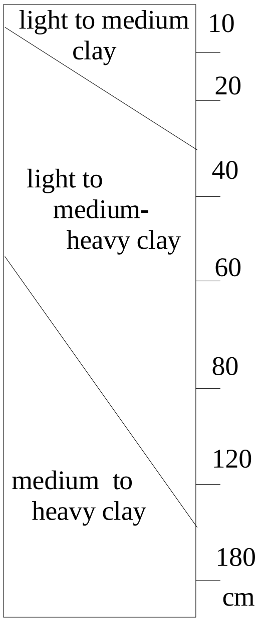


Lolworth soil is a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules. The landform is level to gently undulating plains with surface basalt stone locally a common feature. The dominant vegetation is a grassland dominated by bluegrasses, (*Dicanthium* and *Bothriochloa*) silky brown-top grass, cane grass and black spear grass. Individual tall trees of narrow-leaved ironbark, red barked bloodwood and mountain coolibah may also occur. Black tea tree occurs on the margins and along water courses. The associated soil is *Maryvale*, a grey to black self mulching alkaline clay with carbonate nodules throughout the profile.

Lolworth soil is formed from basalt of Quaternary to Cainozoic age and is moderately fertile. The soil requires approximately 555 mm of rainfall to fill to one metre and of this 110 mm is available for plant growth. The soil is weakly dispersive in the surface and may be moderately dispersive in the subsoil. Maryvale has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* lines suited to this soil at present. There is no significant difference in phosphorus levels between grasslands or woodlands for this soil.

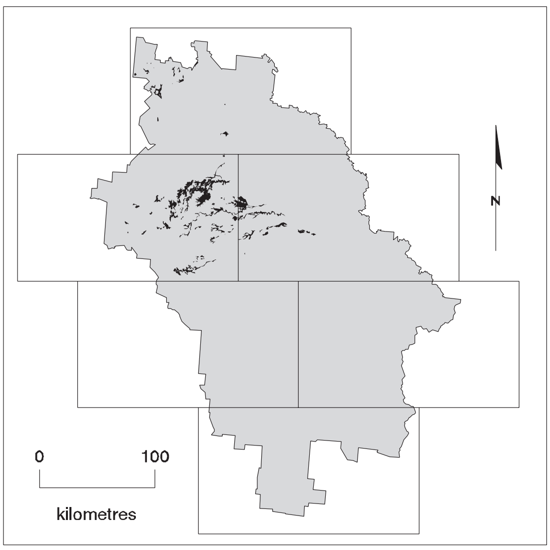
Manoa association

Manoa soil is a dark grey to dark yellowish brown clay with structured neutral to alkaline subsoil. The landform is level alluvial plains with the soil predominantly associated with shallow meander channels away from the major streams. The dominant vegetation is a mid-high woodland of Blackwood, coolibah, and Reid River box. False sandalwood and saplings of the tallest stratum are the most common mid-stratum species. The ground layer is dominated by kangaroo grass, *Bothriochloa* species, bluegrasses and love grasses. Associated soils are: *Cape*, a very dark greyish brown silty loam to clay loam over alkaline structured dark brownish yellow or brown clay, often mottled; and *Yarraman*, a black, brown or grey clay with a self mulching to blocky surface and an alkaline structured subsoil.

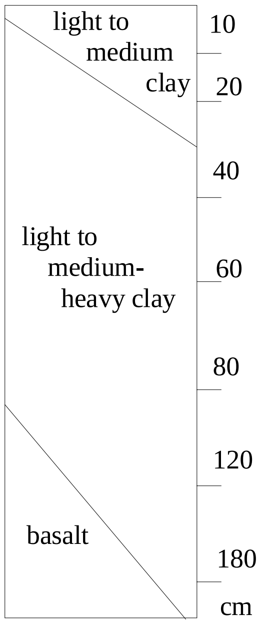


Manoa soil is formed from alluvium of mixed origin and has low to high soil nutrient levels. The soil requires approximately 380 mm of rainfall to fill to one metre and of this 105 mm is available for plant growth. The soil can be dispersive in the surface and subsoils. Manoa has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary for optimum growth of improved pastures. There are no *Stylosanthes* lines suited to this soil at present. Urochloa is a suitable introduced species for this soil. There is no significant difference in phosphorus levels between grasslands or woodlands for this soil.

Maryvale association

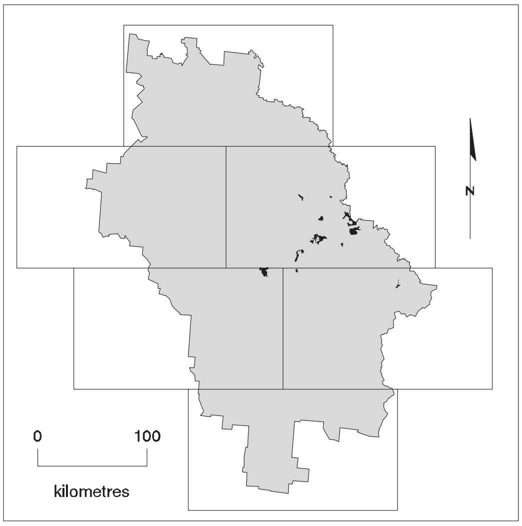


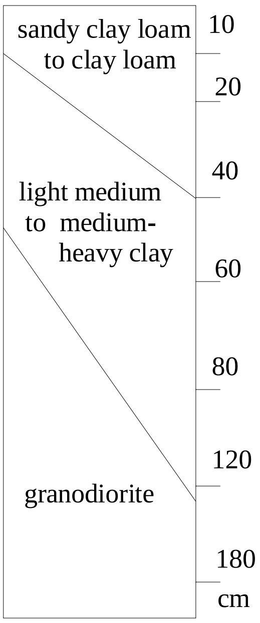
Maryvale soil is a grey to black self mulching alkaline clay with carbonate nodules throughout the profile. The landform is level to gently undulating plains with locally common surface basalt stone. The dominant vegetation is a grassland to mid-high forest of black tea tree, Reid River box, red barked bloodwood and mountain coolibah. The grasslands are dominated by blue grasses, (*Dicanthium* and *Bothriochloa*) silky brown-top grass, cane grass and black spear grass. Associated soils are: *Lolworth*, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules; *Nulla*, a dark reddish brown loam in rocky areas; and *Hillgrove*, a dark reddish brown to dark brown clay loam grading to structured red to dark reddish brown clay.



Maryvale soil is formed from basalt of Quaternary to Cainozoic age and has moderate to high fertility. Maryvale requires approximately 555 mm of rainfall to fill to one metre and of this 115 mm is available for plant growth. The soil is not dispersive in the surface horizons nor the subsoils. They have extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary for improved pastures. There are no *Stylosanthes* suited to this soil at present. Buffel grass and urochloa are suitable introduced species. There appears to be no difference in phosphorus levels in soils under grassland or woodlands.

Mingela association

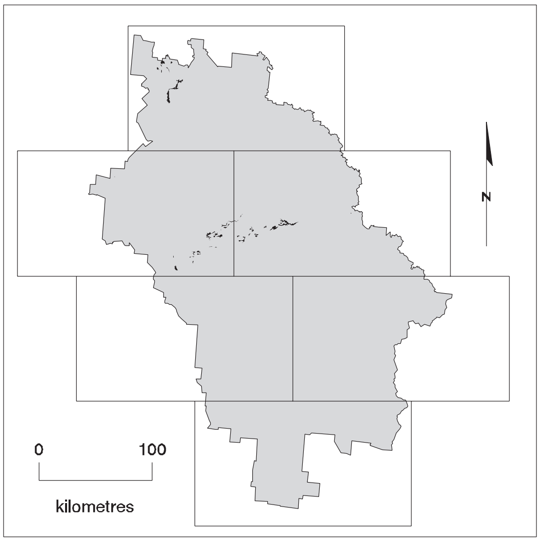




Mingela soil is a very dark greyish brown to brown sandy clay loam to clay loam over alkaline structured dark brown to yellowish brown clay. The landform is gently undulating rises with the soil occurring predominantly in drainage lines and at the base of slopes or slight depressions. Surface stone may occur but generally covers no greater than 2–10% of the surface. The dominant vegetation is a mid-high woodland of Reid River box, narrow-leaved ironbark, false sandalwood and *Acacia* species. The grasslands are Indian couch, golden beard grass, red natal grass, wire grasses and love grasses. The associated soil is *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay.

The soil is formed from granodiorite and has low to moderate fertility. Mingela soil is the most saline in the granodiorite landscape, mainly due to landscape position. The soil requires approximately 375 mm of rainfall to fill to a mean maximum depth of 87 cm and of this 55 mm will be available for plant growth. The soil is not dispersive in surface horizons but is weak to highly dispersive in the subsoil. Mingela has extremely low to very low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if optimum growth of *Stylosanthes* pastures.

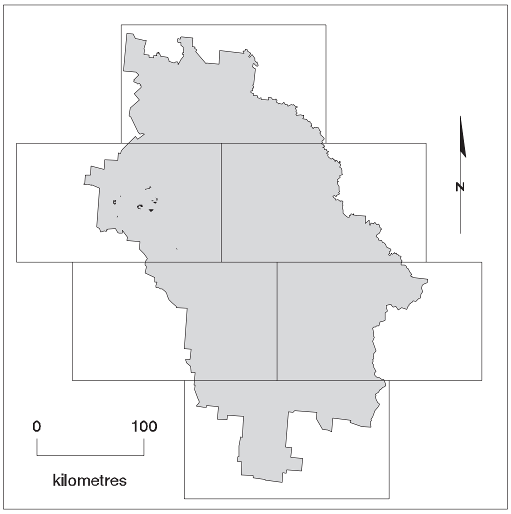
Miscellaneous Basalt association



Miscellaneous Basalt soil is a silty soil dominated by diatomaceous earth and clayey peats. The landform is swamps and small plains located within the basalt flows. Black tea tree is the dominant tree species, couch, reeds and sedges cover the open plains. Associated soils are: *Maryvale*, a grey to black self mulching alkaline clay with carbonate nodules through out the profile; and *Lolworth*, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules.

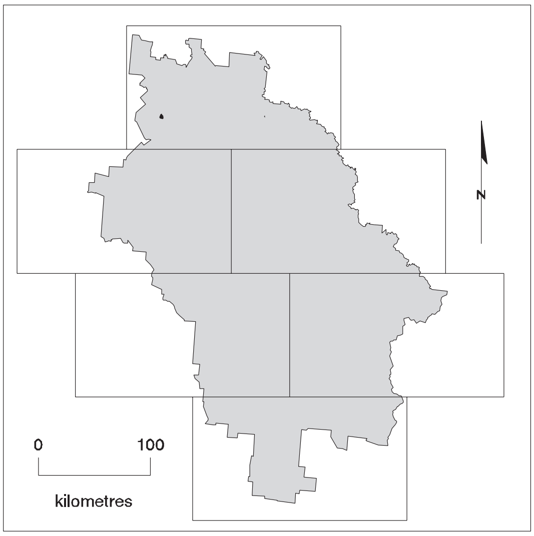
The soil is formed from diatoms and sediments from the surrounding flows and is generally low in fertility. The soil is moderately dispersive in both the surface and subsoil. The diatomaceous material is dilatant ie. the material changes from the solid to liquid phase through vibration and returns to the solid state when compressed. The soil has very high bicarbonate phosphorus in the surface and phosphorus supplementation of cattle grazing pastures on this soil is not necessary. Stylo pastures would not require phosphorus fertiliser. Phosphorus retention may be high on the soils which have high organic levels. This soil is better suited to grass species such as *Brachiaria* because of their tolerance to site wetness. [*No profile diagram*]

Miscellaneous Carbonate association



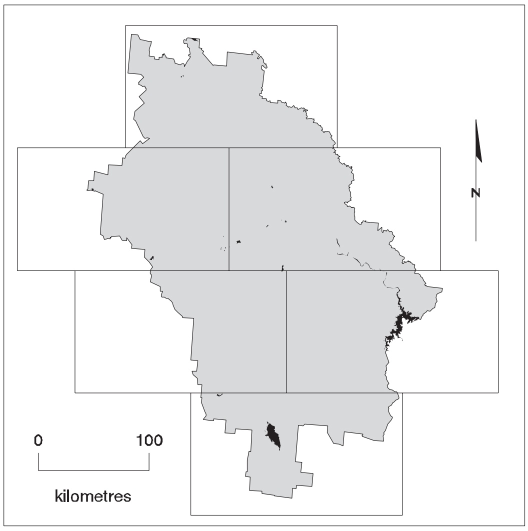
Miscellaneous Carbonate association are areas of carbonaceous materials of sandy clay loam texture that appear intermittently throughout the basalt lands. They support predominantly grasslands of bluegrass and black spear grass with individual red barked bloodwood and ghost gum occurring occasionally.
[*No profile diagram*]

Miscellaneous disturbed association



Miscellaneous Disturbed association are where the normal soil landscape has been changed dramatically by man, for example mining activities. These areas would normally not revert to their natural state without major reclamation. Soil types within this mapping unit have not been described.
[*No profile diagram*]

Miscellaneous flooded association

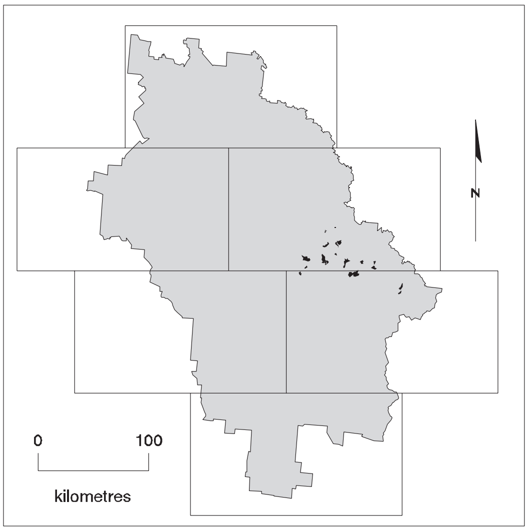


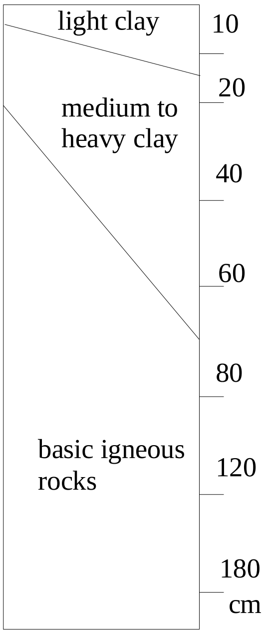
Miscellaneous Flooded map unit includes major water bodies such as Lake Dalrymple and the larger ephemeral lakes such as Lake Toomba and those in and around the Valley of Lagoons. The majority of these water bodies have clayey deposits similar to *Manoa* soils, a dark grey to dark yellowish brown clay with structured neutral to alkaline subsoil. In some instances this soil may be saline; Lake Buchanan is an example.
[*No profile diagram*]

Miscellaneous Terrain association

Miscellaneous Terrain (Lacustrine) association are dominated by a mixture of dune and swale topography on the shores of Lake Buchanan and is described by Lorimer (1998).
[*No profile diagram; no distribution figure*]

Mount Ravenswood association



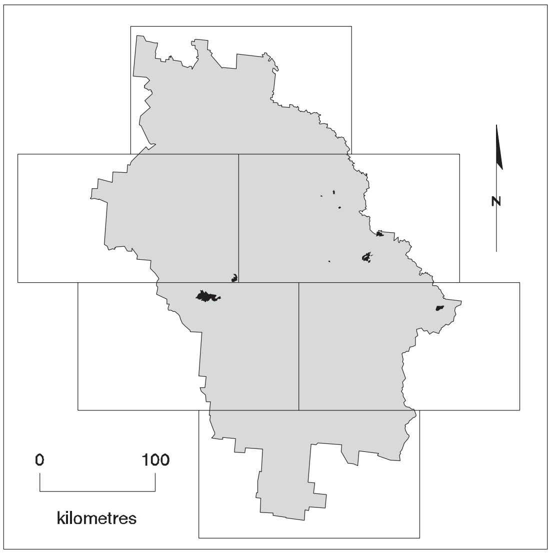


Mount Ravenswood soil is a very dark greyish brown to yellowish brown light clay grading to alkaline structured dark yellowish brown to reddish brown medium clay overlying calcareous material above the basic parent material. The calcareous layer is commonly used for road surfacing. The landform is gently undulating rises with surface stone of 2–10% cover a common feature. The soil is generally moderately shallow, < 1 m which precludes them from dryland cropping in most years. The dominant vegetation is a mid-high woodland of redbarked bloodwood and narrow-leaved ironbark. The ground layer is dominated by Indian couch, wire grasses, desert bluegrass and black spear grass. Associated soils are: *Amity*, a self mulching black clay with an alkaline structured subsoil often with free lime; and *Charters Towers*, a dark brown sandy clay loam to clay loam over alkaline structured red to reddish brown clay.

Mount Ravenswood soil is formed from calcareous intermediate to basic rock and generally has moderate to high fertility except for phosphorus. The soil requires approximately 245 mm of rainfall to fill to a mean maximum soil depth of 46 cm and of this 50 mm is available for plant growth. The surface and subsoils are not dispersive. The soil has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* suited to this soil at present. Buffel grass and urochloa are suitable introduced species for this soil. There appears to be no difference in soil phosphorus levels under grassland or woodland.

Miscellaneous Granodiorite association

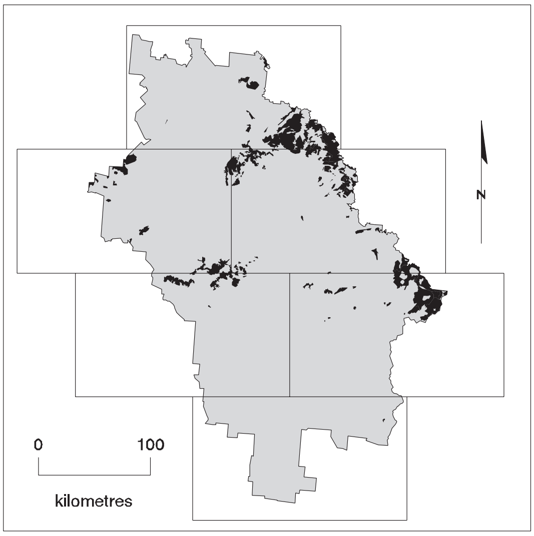
Miscellaneous Granodiorite association includes shallow soils on mountainous terrain



which are often rocky with deeper soils along minor creek lines. Rainforest units have deep loams to clays. The map unit is dominated by: *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay; and *Conolly*, a grey, brown and yellowish brown sand. The landform is steep with slopes generally in excess of 40% The association identifies areas of particularly rugged as well as steep lands which would normally not be considered for agricultural uses. Grazing is carried out on this unit generally only in times of drought. Vegetation varies from dense rainforest to low silver-leaved ironbark (*Eucalyptus shirleyi*) but is predominantly mid-high narrow-leaved ironbark. Kangaroo grass dominates much of the eastern side of the Shire and black spear grass the mid to western parts of the Shire. Water runoff is rapid and tree clearing is not a suitable land use option. [*No profile diagram*]

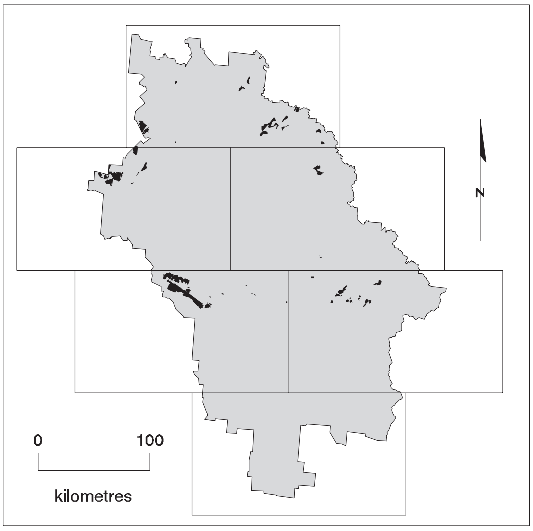
Miscellaneous Igneous association

This association consists of shallow soils on



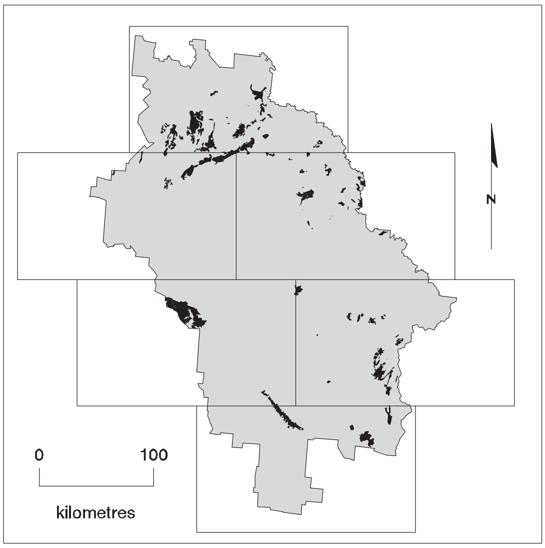
slopes, often rocky, and deeper soils along minor creek lines. Rainforest units have deep loams to clays. The association is dominated by *Conolly*, a grey, brown and yellowish brown sand associated with: *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay; *Utchee*, (rainforest areas) a dark reddish brown clay loam grading to structured red medium clay; and *Pinnacle*, a dark brown to grey uniform rocky sand to sandy loam. The landform is steep with slopes generally in excess of 40%. Grazing is carried out on much of this land but generally only in times of drought. In the case of the higher rainfall areas such as around Mount Fox, grazing is carried out in the latter part of the dry and the cattle are then removed for the wetter months. Vegetation varies from dense rainforest to low silver-leaved ironbark (*Eucalyptus shirleyi*) but is predominantly mid-high narrow-leaved ironbark. Kangaroo grass dominates much of the eastern side of the Shire and black spear grass and spinifex the mid to western parts of the shire. Water runoff is rapid and tree clearing is not a suitable land use option.
[*No profile diagram*]

Miscellaneous Metamorphic association



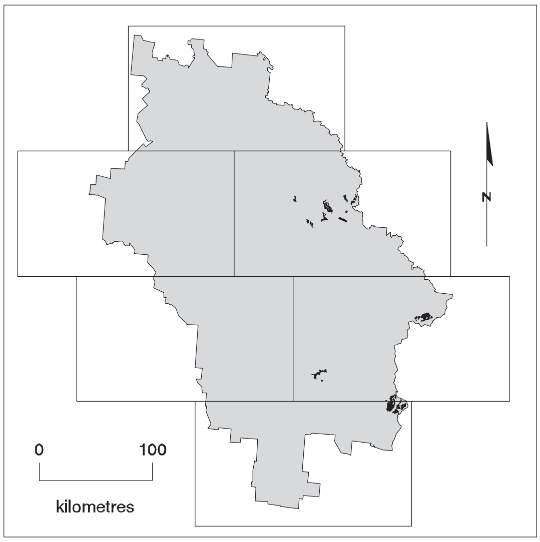
Miscellaneous Metamorphic association are shallow soils on slopes, often rocky and deeper soils along minor creek lines. Rainforest units have deep loams to clays. The association is dominated by *Ewan*, a shallow massive brown sandy loam over metamorphic rock associated with: *Rangeview*, a dark reddish brown loam over structured red to yellowish red clay and in the rainforest areas; and *Galmara*, (rainforest areas) a dark brown clay loam over structured red silty medium clay. The landform is steep with slopes generally in excess of 40%. Grazing is carried out on much of this land but generally only in times of drought. Vegetation varies from dense rainforest to low silver-leaved ironbark (*Eucalyptus shirleyi*) but is predominantly mid-high narrow-leaved ironbark and Reid River box. Kangaroo grass dominates much of the eastern side of the Shire and black spear grass and spinifex the mid to western parts of the Shire. Water runoff is rapid and tree clearing is not a suitable land use option. [*No profile diagram*]

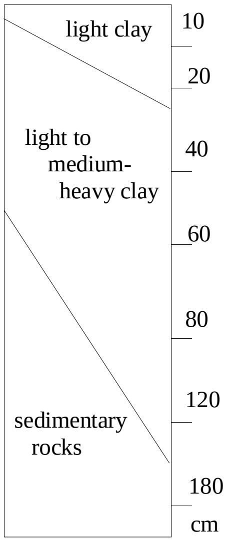
Miscellaneous Sedimentary association



Miscellaneous Sedimentary association are shallow soils on slopes, often rocky and deeper soils along minor creek lines. Rainforest units have deep loams to clays. The association is dominated by: *Bulliwallah*, dark brown to yellowish brown brown sandy loam to sandy clay loam over sandstone, mudstone or siltstone; *Ceaser*, dark brown sandy loams over structured red clay; and *Flagstone*, very dark greyish brown to yellowish brown sands to sandy loam over sandstone rock. The landform is steep with slopes generally in excess of 40%. Grazing is carried out on much of this land but generally only in times of drought. Vegetation varies from dense rainforest to low silver-leaved ironbark (*Eucalyptus shirleyi*) but is predominantly mid-high narrow-leaved ironbark, silver-leaved ironbark and Reid River box. Kangaroo grass dominates much of the eastern side of the shire and black spear grass, wire grasses, *Sporobolus* species and spinifex the mid to western parts of the Shire. Water runoff is rapid and tree clearing is not a suitable land use option. The sedimentary uplands have more shallow soil profiles than the other geological groups. The rock is deeply weathered and allows trees in particular to utilise the moisture reserves in the weathered zones. [*No profile diagram*]

Myrtlevale association



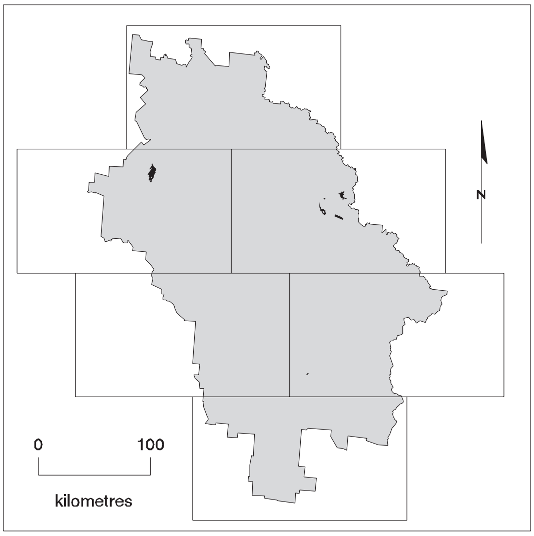


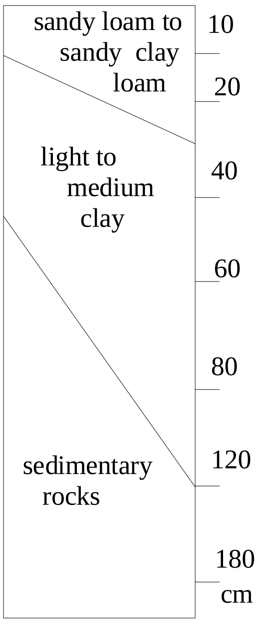
Myrtlevale soil is a very dark greyish brown to dark brown light clay grading to alkaline structured dark brown to yellowish brown medium heavy clay. The landform is gently undulating plains with the soil occurring where finer grained sedimentary rock (siltstone and mudstone) have been exposed. The dominant vegetation is a mid-high open woodland of narrow-leaved ironbark, Reid River box, red barked bloodwood and poplar gum, acacias such as brigalow and gidgee may be locally dominant. The mid-stratum may be a complex of false sandalwood, yellow wood and bauhinia. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Nial*, a dark reddish brown to yellowish brown sandy loam to sandy clay loam over alkaline structured red to reddish brown clay; and *Scartwater*, a dark grey to dark brown sandy loam to clay loam, with a bleached A2 horizon over alkaline structured dark greyish brown clay.

Myrtlevale soil is formed from fine (siltstone, mudstone) grained sedimentary rock and has low to moderate fertility. The soil requires approximately 510 mm of rainfall to fill to a mean maximum depth of 92 cm and of this 105 mm is available for plant growth.

The surface is weak to moderately dispersive and the subsoil is weak to highly dispersive. Myrtlevale has extremely low to low bicarbonate phosphorus in the surface and cattle grazing pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* suited to this soil at present. Buffel grass and urochloa are suitable introduced species for this soil. There appears to be no difference in soil phosphorus levels in grassland or woodland, including the brigalow-yellow wood communities.

Nial association



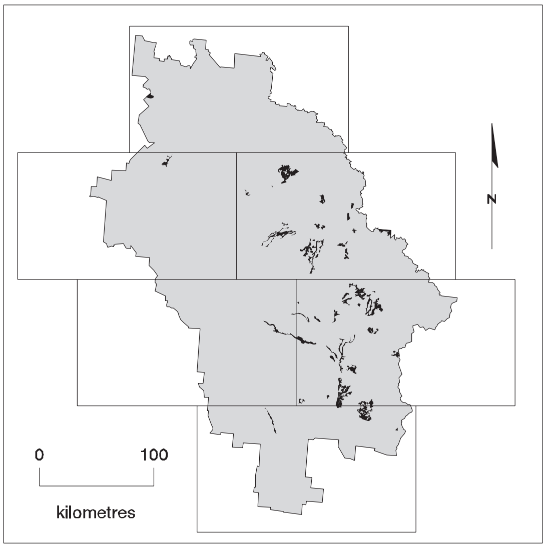


Nial soil is a dark reddish brown to yellowish brown sandy loam to sandy clay loam over alkaline structured red to reddish brown clay. The landform is gently undulating plains to undulating rises, sedimentary rock outcrop and surface stone may be locally dominant. The soil occurs on a range of sedimentary rocks but is mainly found on finer grained sedimentary rocks (siltstone and mudstone).

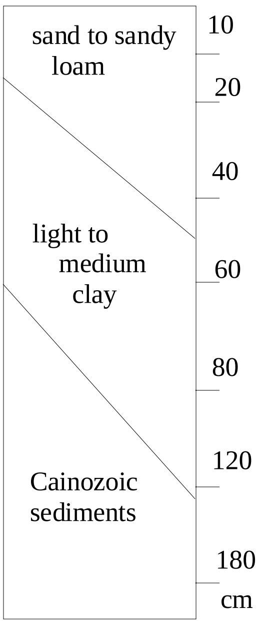
The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and Reid River box to dense stands of blackwood. The mid-stratum of false sandalwood may occur and the ground layer is dominated by black spear grass, golden beard grass and kangaroo grass, *Aristida* species and bluegrasses may be locally dominant. Associated soils are: *Dotswood*, a dark brown to yellowish brown sandy loam over alkaline structured brown to yellowish brown clay; and *Scartwater*, a dark grey to dark brown sandy loam to clay loam, with a bleached A2 horizon over alkaline structured dark greyish brown clay.

Nial soil is generally low in fertility. Nial requires approximately 385 mm of rainfall to fill to a mean maximum depth of 82 cm and 95 mm of this is available for plant growth. The soil is weakly dispersive in the surface and weak to highly dispersive in the subsoil. Nial has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production. Gillard (1979) demonstrated that *Stylosanthes* pastures could be established on this soil however fertiliser is needed for optimum growth.

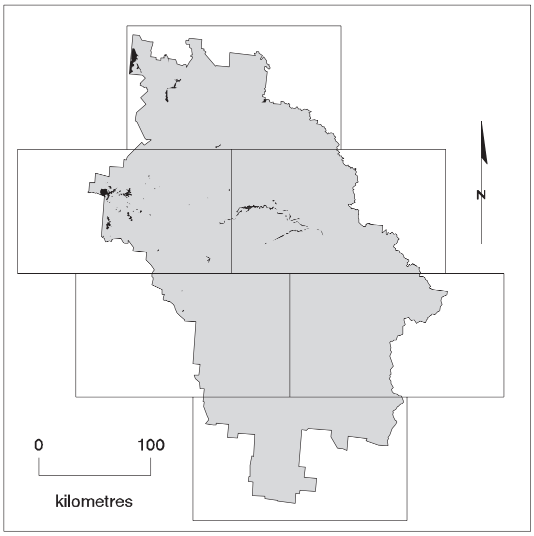
Nosnillor association



Nosnillor soil is a very dark greyish brown to yellowish brown sand to sandy loam, bleached A2 horizon over alkaline structured yellowish brown to yellow clay. Ironstone and clayey globules may be concentrated on top of the subsoil or above the parent material or other substrate layer. The landform is gently undulating plains and lower slopes at the margins of undulating rises. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box and silver-leaved ironbark *(E. melanopholia*). Quinine bush, false sandalwood and *Acacia* species are the common mid-storey. The ground layer is dominated by golden beard grass, buck spinifex, black spear grass and *Aristida* species. Associated soils are: *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay; *Liontown*, a dark brown to greyish brown sandy loam to sandy clay loam with a bleached A2 horizon over alkaline structured dark brown to yellowish brown and grey clay; and *Featherby*, laterite outcrop or exposed ferruginous gravel beds. Nosnillor soil is formed from Cainozoic sediments of varying origin and generally has low fertility. The soil requires approximately 335 mm of rainfall to fill to a mean maximum depth of 93 cm and of this 95 mm will be available for plant growth. The soil is weakly dispersive in the surface and highly dispersive in the subsoil. Nosnillor has extremely low to very low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary in the majority of cases if *Stylosanthes* pastures are to reach optimum production.



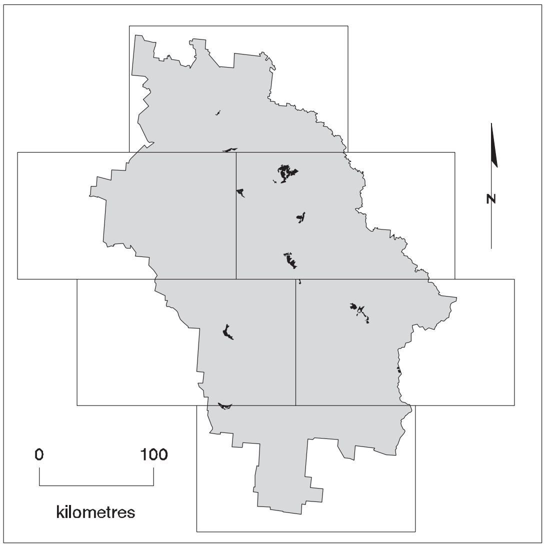
Nulla association

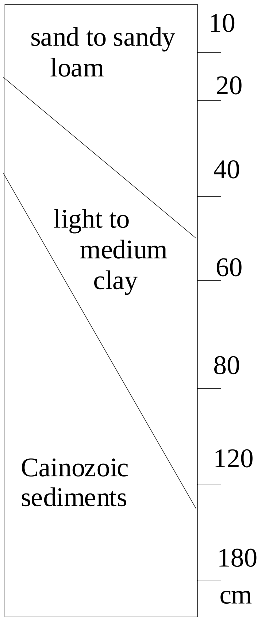


Nulla soil is a dark reddish brown sandy clay loam found in rocky areas. The landform is level to gently undulating plains. The dominant vegetation is a tall woodland of narrow-leaved ironbark and red barked bloodwood with ghost gum locally dominant. The ground layer is dominated by black spear grass, kangaroo grass and *Bothriochloa* species. Associated soils are: *Hillgrove*, a dark reddish brown to dark brown clay loam grading to structured red to dark reddish brown clay; *Conjuboy*, a dark brown clay loam grading to yellowish brown structured clay; *Glencoe*, a structured dark brown clay loam to light clay grading to structured dark brown clay; and *Lolworth*, a very dark grey to greyish brown self mulching clay with an alkaline black to greyish brown clay subsoil, often with carbonate nodules.

Nulla is formed from basalt of Quaternary to Cainozoic age and has moderate to good fertility. The soil requires approximately 150 mm of rainfall to fill to a mean maximum depth of 30 cm and of this 45 mm is available for plant growth. Stored water will be lower due to the large amounts of stone and gravel in the profile. Surface phosphorus levels have not been assessed in this survey, however analyses of similar shallow soils by McIvor *et al.* (1991) reported moderate levels.
[*No profile diagram*]

Pallamana association

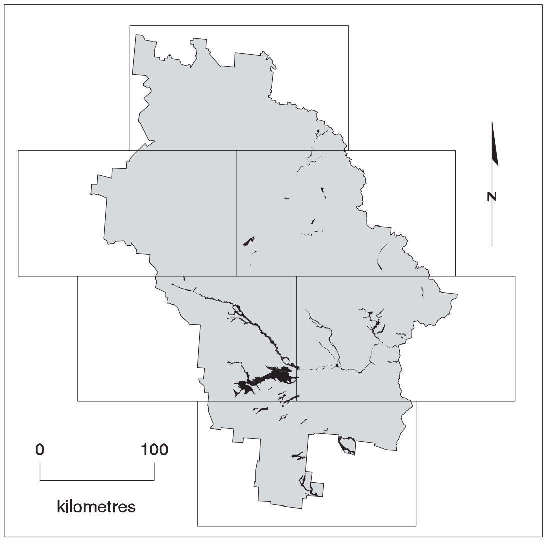




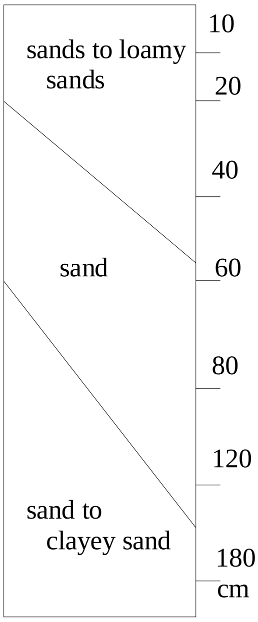
Pallamana soil is a very dark greyish brown to yellowish brown sand to sandy loam over structured mottled dark grey to brownish yellow clay. The landform is gently undulating plains and lower slopes at the margins of undulating rises. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box and silver-leaved ironbark (*E. melanopholia*). Quinine bush, false sandalwood and *Acacia* species are the common mid-storey. The ground layer is dominated by golden beard grass, black spear grass and *Aristida* species. Associated soils are: *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loams; *Liontown*, a dark brown to greyish brown sandy clay loam with bleached A2 over alkaline structured dark brown to yellowish brown and grey clay; and *Rangeside*, a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam.

Pallamana soil is formed from Cainozoic sediments of varying origin and generally has low fertility. The soil requires approximately 310 mm of rainfall to fill to a mean maximum depth of 83 cm and of this 85 mm is available for plant growth. Pallamana is weakly dispersive in the surface and moderate to highly dispersive in the subsoil. The soil has extremely low bicarbonate phosphorus in the surface and cattle grazing on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Pandanus association



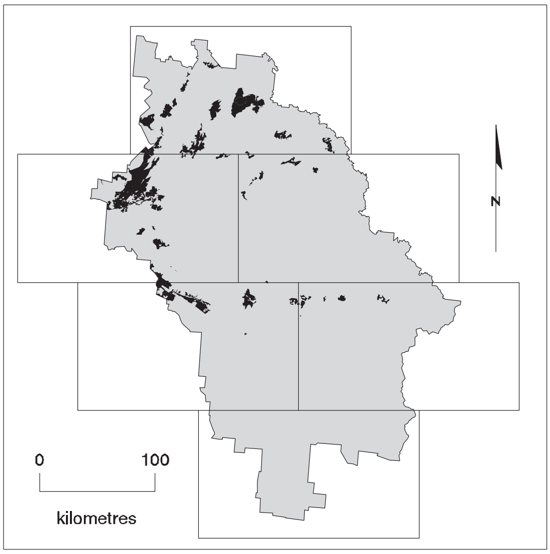
Pandanus soil is a uniform sand with a dark brown soft surface grading to yellowish red to brownish yellow subsoils. The landform is level to gently undulating alluvial plains. The soil is found in levees, lower terraces and stream beds of most streams and rivers of the Shire. In the 'desert uplands' they form large sand sheets. The dominant vegetation is a tall woodland of narrow-leaved ironbark, long-fruited grey bloodwood, coolibah, *Acacia* species, *Melaleuca* species and Moreton Bay ash. The ground layer is dominated by black spear grass, golden beard grass, *Aristida* species and bluegrasses. Associated soils are:



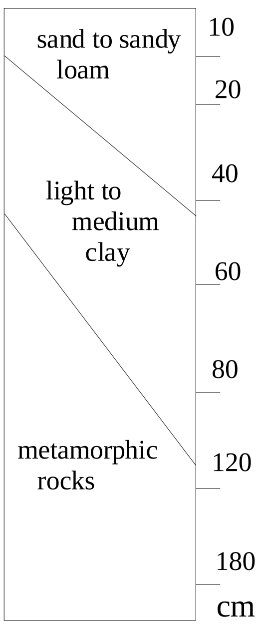
Creek, a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay; and *Burdekin*, a dark yellowish brown fine sand grading to brown sandy loam.

Pandanus soil requires approximately 425 mm of rainfall to fill to one metre and of this 50 mm would be available for plant growth. The soil is not dispersive in the surface or subsoil. Pandanus has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Paynes association

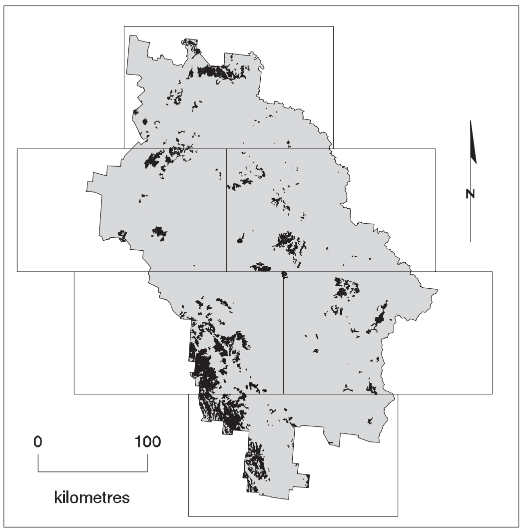


Paynes soil is a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay. The landform is gentle slopes to gently undulating rises with quartz veins and exposed metamorphic rocks and gravels a common surface feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box with a mid-stratum of false sandalwood. The ground cover is dominated by kangaroo grass, *Aristida* species, golden beard grass and black spear grass. The most commonly associated soils are *Argentine*, a dark brown sandy clay loam to clay loam, often gravely over alkaline, structured red clay; *Rangeview*, a dark reddish brown sandy clay loam to clay loam over structured red to yellowish red clay; and *Warawee*, a dark brown clay loam over alkaline structured yellowish brown clay.

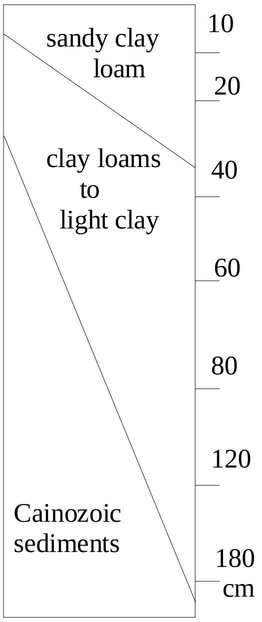


Paynes is formed from metamorphosed sediments and may have inclusions of sedimentary soil where the metamorphism has not been as strong. Soil fertility is generally low. The soil requires approximately 335 mm rainfall to fill to a mean maximum depth of 78 cm and of this 70 mm will be available for plant growth. The soil is weakly dispersive in the surface and weak to highly dispersive in the subsoil. Paynes has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Pentland association



Pentland soil is a dark reddish brown to dark brown sandy clay loam grading to earthy red light clay. The landform is level to gently undulating plains with the soil also found on mesa summit surfaces. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, long-fruited grey bloodwood, and yellowjack, while *Acacia* species (lancewood, bendee) may be locally dominant. Quinine bush is common in the mid-stratum. *Aristida* species, golden beard grass, black spear grass and buck spinifex are the locally dominant grass species. Associated soils are: *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; *Rangeside*, a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam; and *Barkla*, a greyish brown sand grading to yellowish brown loamy sand on ferricrete.

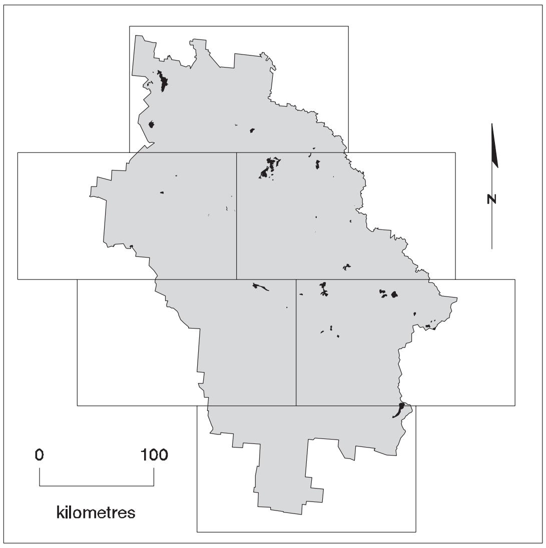


Pentland soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 375 mm of rainfall to fill to one metre and of this 95 mm would be available for plant growth. This soil is generally greater than 3 metres in depth so the soil water store can be considerable on a total profile basis. The soil is weakly dispersive in the surface and not dispersive in the subsoil; there are however alkaline variants which are moderately dispersive. The soil has extremely low bicarbonate phosphorus in the soil surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production. There appears to be no difference in surface phosphorus levels for narrow-leaved ironbark, silver-leaved ironbark, *Acacia* (lancewood. bendee) or yellowjack communities. Phosphorus levels of 12 ppm are necessary for establishment of *Stylosanthes* pastures (Probert and Williams 1985).

Pin Gin association

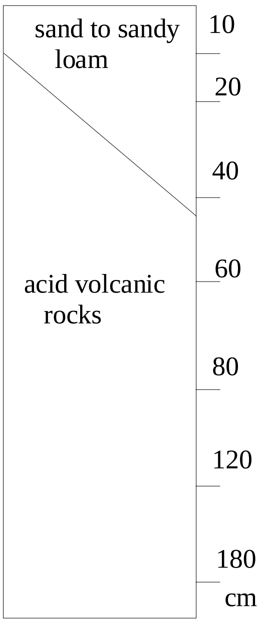
Pin Gin soil is a dark reddish brown clay loam grading to strongly structured red medium clay. This soil is found within the rainforest areas near Mount Fox. The vegetation is rainforest with a fringing sclerophyll forest and, being located predominantly within the World Heritage Estate, they are not generally accessible for agricultural land. Pin Gin and associated soils (unnamed in this report) have been documented in surveys in the tablelands and coastal ranges to the north Laffan (1988), Cannon *et al*. (1992) and Murtha (1986). Pin Gin soil requires 515 mm of rainfall to fill the soil to one metre and of this 90 mm is available for plant growth. This soil is generally greater than 3 metres in depth so on a total soil profile they may have a substantial moisture storage. The soil has high soil phosphorus levels but may have high phosphorus sorption characteristics which lowers the availability. Animal needs are usually sufficient but cropping would need some phosphorus inputs.
[*No profile diagram; no distribution figure*]

Pinnacle association



Pinnacle soil is a dark brown to grey uniform rocky sand to sandy loam. The landform is undulating rises to mountains with rock (acid volcanic origin) outcrops and gravels a common feature. The dominant vegetation is a grassland to mid-high open woodland of narrow-leaved ironbark and silver-leaved ironbark(*E. shirleyi*). The ground layer is dominated by golden beard grass, red natal grass, black spear grass and

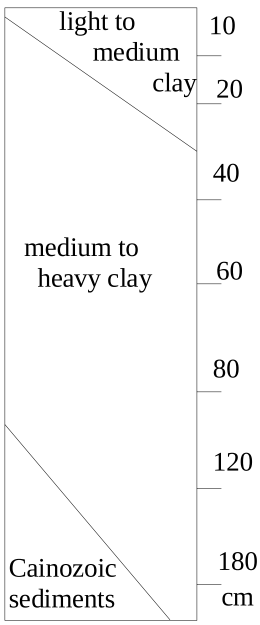
Aristida species. Associated soils are: *Two Creek*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; *Bluff*, a greyish brown sand to sandy loam over alkaline structured yellowish brown clay; and *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay.



Pinnacle soil is formed from acid igneous rocks and generally has low fertility. The soil requires approximately 195 mm of rainfall to fill to a mean maximum depth of 43 cm and of this 50 mm is available for plant growth. There was insufficient data on soil dispersive characteristics. The soil has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

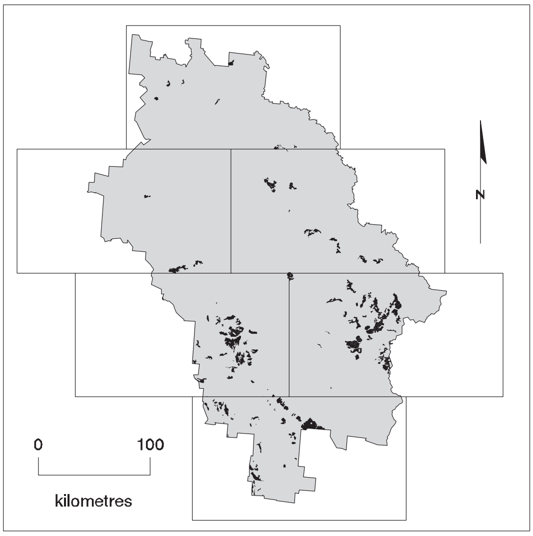
Powlathanga association

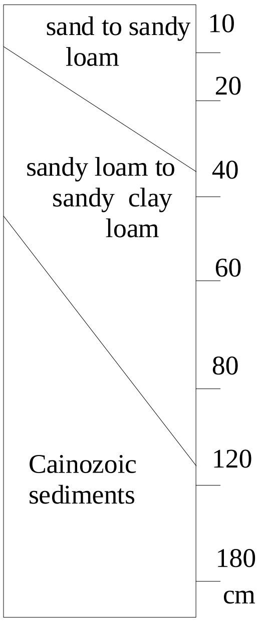
Powlathanga soil is a very dark grey to dark brown clay with a massive to blocky surface over an alkaline upper subsoil and a structured acid lower subsoil. The soil may have surface gravels, commonly rounded quartz. The landform is level alluvial plains where the soil forms subtle drainage lines or swamps. The dominant vegetation is a mid-high woodland of Reid River box with locally blackwood or gidgee forming dense forests. False sandalwood and yellowwood is the dominant mid-stratum. *Aristida* species, golden beard grass, black spear grass and buck spinifex are the locally dominant grass species. Associated soils are: *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; and *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay. In the Cape River area the associated soils are: *Liontown*, a dark brown to greyish brown sandy loam to sandy clay loam with bleached A2 over alkaline structured dark brown to yellowish brown and grey clay; and *Victoria Downs*, a uniform clay soil with a massive to blocky structured dark grey to greyish brown surface grading to alkaline structured dark grey to yellowish brown subsoil.



Powlathanga soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 380 mm of rainfall to fill to one metre and of this 105 mm is available for plant growth. The soil is weakly dispersive in the surface and moderate to highly dispersive in the subsoil. Powlathanga has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* suited to this soil at present. Buffel grass and urochloa are suitable introduced species. There appears to be no difference in phosphorus levels under grassland or woodlands.

Rangeside association

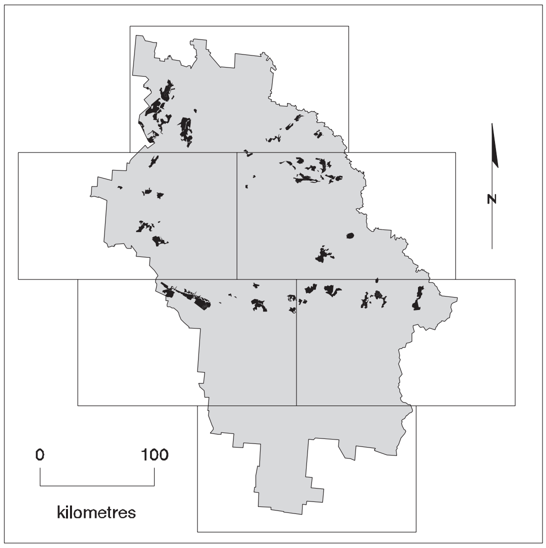




Rangeside soil is a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam. There may be considerable amounts of ferruginous gravels in the profile which is quarried for road base material. The landform is level to gently undulating plains with the soil also found on mesa summit surfaces. The dominant vegetation is a mid-high woodland of silver and/or narrow-leaved ironbark and less commonly Reid River box while *Acacia* species (lancewood, bendee) may be locally dominant. Quinine bush is common in the mid-stratum. *Aristida* species, golden beard grass, black spear grass and buck spinifex are the locally dominant grass species. Associated soils are: *Pentland*, a dark reddish brown to dark brown sandy clay loam grading to earthy red light clay; *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay; *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam; *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; and *Rishton*, a uniform sand often with a bleached A2 horizon, typically with a dark brown loose to soft surface with yellowish brown subsoil.

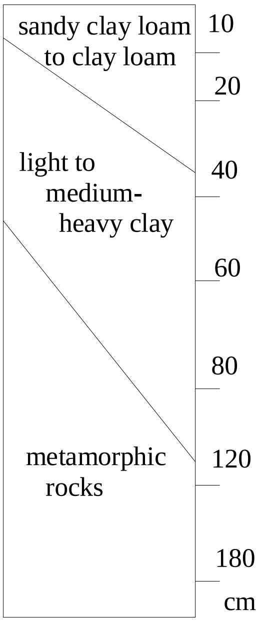
Rangeside soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 435 mm of rainfall to fill to one metre and of this 50 mm is available for plant growth. The soil is naturally very deep (greater than 3 metres) so the total soil moisture store may be considerable. The soil is not dispersive in the surface or subsoil. Rangeside has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Rangeview association



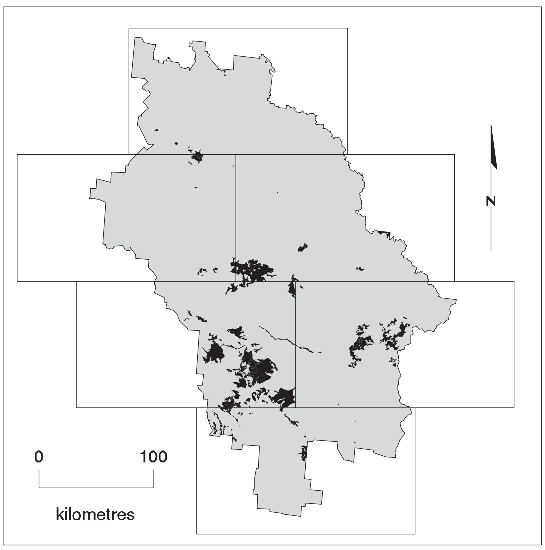
Rangeview soil is a dark reddish brown sandy clay loam to clay loam over structured red to yellowish red clay. Quartz gravels and mica flecks are a common feature throughout the profile. The landform is gentle slopes to gently undulating rises to ranges, quartz veins and exposed metamorphic rocks are a common surface feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark and grey box with a mid-stratum of *Acacia* species. The ground cover is dominated by kangaroo grass, wire grasses, bluegrasses, golden beard grass and black spear grass.

The most commonly associated soils are: *Paynes*, a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay; *Argentine*, a dark brown sandy clay loam to clay loam, often gravely over alkaline, structured red clay; *Ewan*, a shallow massive brown sandy loam over metamorphic rock; and *Warawee*, a dark brown clay loam over alkaline structured yellowish brown clay.

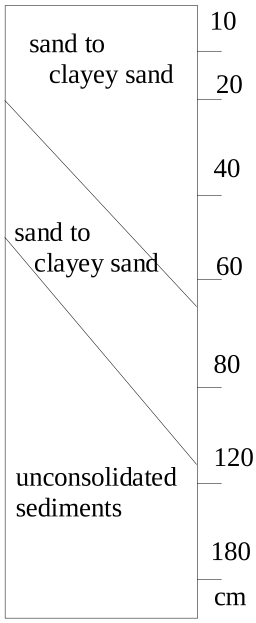


Rangeview soil is formed from metamorphosed sediments and may have inclusions of sedimentary soils, fertility is generally low. The soil requires approximately 355 mm rainfall to fill to a mean maximum depth of 76 cm and of this 85 mm is available for plant growth. The soil is not dispersive in the surface or subsoil. Rangeview has very low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser may be necessary if *Stylosanthes* pastures are to reach optimum production.

Rishton association

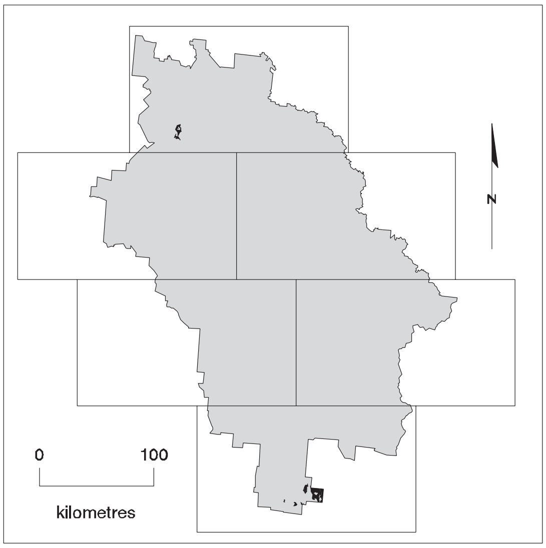


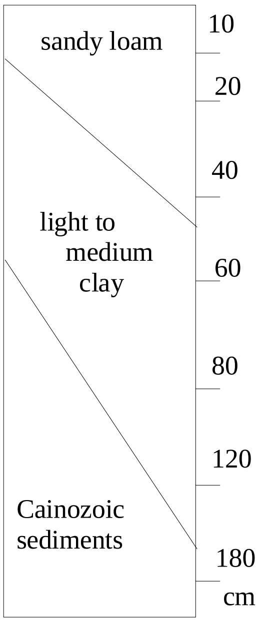
Rishton soil is a uniform sand often with a bleached A2 horizon, typically they have a dark brown loose to soft surface with yellowish brown subsoil. The landform is level to gently undulating plains and footslopes and summit surfaces of mesas. The dominant vegetation is a mid-high to tall woodland of long-fruited grey bloodwood, narrow-leaved ironbark, silver-leaved ironbark (*E. melanopholia*) and yellowjack with *Acacia* species (lancewood, bendee) locally dominant. Quinine bush is common in the mid-stratum. wire grasses, golden beard grass, black spear grass and buck spinifex are the dominant grass species. Associated soils are: *Rangeside*, a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam; *Wattle Vale*, a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loams; and *Flagstone*, a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock.



Rishton soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 345 mm of rainfall to fill to a mean maximum depth of 82 cm and of this 45 mm is available for plant growth. Rishton is not dispersive in the surface and weak to moderately dispersive in the subsoil. The soil has extremely low to very low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary in the majority of cases if *Stylosanthes* pastures are to reach optimum production.

Rolston association

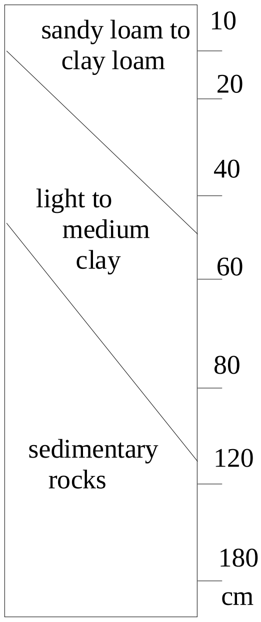




Rolston soil is a dark reddish brown sandy loam over structured red to yellowish red clay. The landform is level to gently undulating plains with occasional mesas. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, long-fruited grey bloodwood and yellowjack with *Acacia* species (lancewood, bendee) locally dominant. Quinine bush is common in the mid-stratum. wire grasses, golden beard grass, black spear grass and buck spinifex are the locally dominant grass species. Associated soils are: *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; *Rangeside*, a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam; and *Pentland*, a dark reddish brown to dark brown sandy clay loam grading to earthy red light clay.

Rolston soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 320 mm of rainfall to fill to one metre and of this 80 mm is available for plant growth. The soil is not dispersive in the surface and weak to moderate in the subsoil. The soil has extremely low to low bicarbonate phosphorus in the surface and cattle grazing on this soil will require phosphorus supplementation. Phosphorus fertiliser may be necessary if *Stylosanthes* pastures are to reach optimum production.

Scartwater association



Scartwater soil is a dark grey to dark brown sandy loam to clay loam with a bleached A2 horizon, over alkaline structured dark greyish brown clay. The landform is gently undulating plains to undulating rises with surface stone and sedimentary rock exposures a common feature. The dominant vegetation is a mid-high woodland of Reid River box, narrow-leaved ironbark with locally dominant blackwood closed forests. The mid-stratum may have false sandalwood, bauhinia and *Acacia* species with some areas heavily infested with the native woody weed currant bush. The ground layer is dominated by wire grasses, blue grass, black spear grass, love grasses and buck spinifex. Associated soils are: *Dotswood*, a dark brown to yellowish brown sandy loam over alkaline structured brown to yellowish brown clay;

Flagstone, a very dark greyish brown to yellowish brown sand to sandy loam over sandstone rock; *Greenvale*, a dark greyish brown to brown sand to sandy loam over structured dark yellowish brown to brownish yellow clay; and occasionally *Myrtlevale*, a very dark greyish brown to dark brown light clay grading to alkaline structured dark brown to yellowish brown medium heavy clay.

Scartwater soil is formed from coarse (sandstone, conglomerate) and fine (siltstone, mudstone) sedimentary rock but all weather to soils which have low fertility. The soil requires approximately 315 mm of rainfall to fill to a mean maximum depth of 80 cm and of this 80 mm is available for plant growth. The soil is weakly dispersive in surface and moderate to highly dispersive in the subsoil. Scartwater has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production. Gillard (1979) demonstrated that *Stylosanthes* pastures could be established on this soil however fertiliser is needed for optimum growth.

Severin association

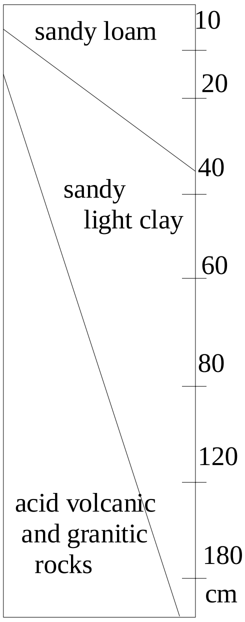
Severin soil is a very dark greyish brown sandy clay loam overlying brownish yellow sandy clay or light medium clay. The landform is steep slopes with rainforest and sclerophyll forest located predominantly within the World Heritage Estate and generally not accessible for agricultural land uses. Severin requires approximately 370 mm of rainfall to fill a metre of soil profile and of this 90 mm is available for plant growth. The soil is not dispersive in the surface or subsoils. The soil has very low levels of bicarbonate phosphorus in the surface and cattle will require phosphorus supplementation. Phosphatic fertilisers would enhance *Stylosanthes* establishment. Associated soils (unnamed in this report) have been documented in larger scale surveys in the tablelands and coastal ranges to the north, Laffan (1988), Cannon *et al*. (1992) and Murtha (1986).
[*No profile diagram; no distribution figure*]

Star association

Star soil is a very dark grey to black self mulching to blocky clay with an alkaline subsoil. Quartz gravels and mica flecks are common throughout the profile. The landform is gentle slopes to gently undulating rises, quartz veins and exposed metamorphic rocks are a common surface feature. A grassland of bluegrasses, golden beard grass and black spear grass is the most common vegetation cover but there are also mid-high woodlands or individual trees of narrow-leaved ironbark and red barked bloodwood. The most commonly associated soils: are *Rangeview*, a dark reddish brown sandy clay loam over structured red to yellowish red clay; *Argentine*, a dark brown sandy clay loam to clay loam, often gravely, over alkaline structured red clay; and *Ewan*, a shallow, massive, brown sandy loam over metamorphic rock.

Star soil is formed from metamorphosed sediments and the association may have inclusions of sedimentary soils. The soil has moderate to high fertility. The soil requires approximately 435 mm rainfall to fill to a mean maximum depth of 79 cm and of this 85 mm is available for plant growth. Star is not dispersive in either the surface or subsoil and has moderate to high levels of phosphorous in the surface making them highly suited to most introduced pasture species. There are no *Stylosanthes* cultivars suitable for this soil at present. [*No profile diagram*]

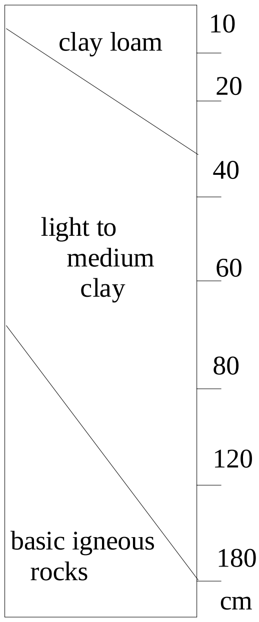
Thorpe association



Thorpe soil is a dark grey sandy loam grading to yellow sandy light clay. The landform is gentle slopes and undulating rises with granite boulders or outcrop a common feature. The dominant vegetation is a tall woodland of narrow-leaved ironbark and popular gum. The ground layer is dominated by black spear grass, blady grass and kangaroo grass. Associated soils are: *Hillview*, a grey brown loamy sand to sandy loam grading to red sandy clay; *Two Creek*, a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay; and *Conolly*, a grey, brown and yellowish brown sand.

Thorpe soil is formed from coarse grained granitic rocks and generally has low fertility. The soil requires approximately 360 mm of rainfall to fill to one metre and of this 90 mm is available for plant growth. The soil is not dispersive in the surface or subsoil and has extremely low bicarbonate phosphorus in the surface. Cattle grazing of pastures on this soil will require phosphorus supplementation and phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production. Dark surface variants of Thorpe may have high phosphorus sorption requiring significantly more phosphorus fertiliser for optimum growth of crops.

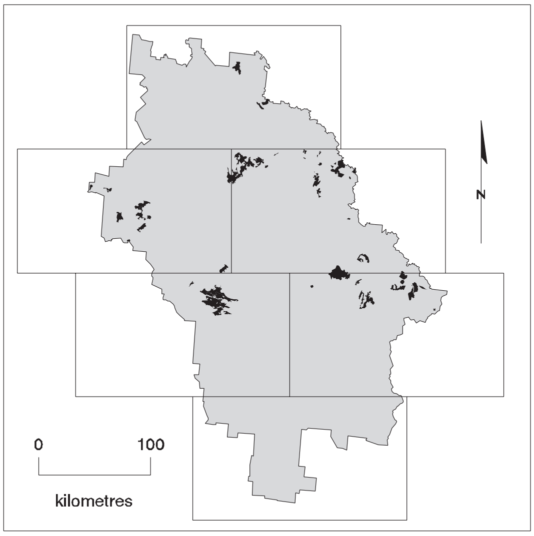
Tuckers association

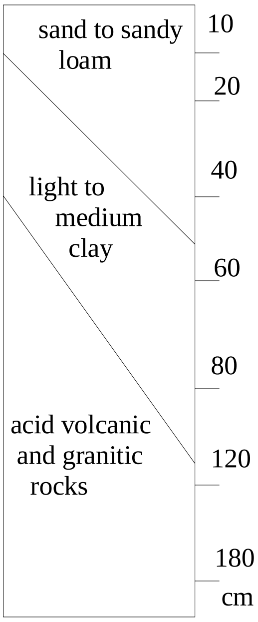


Tuckers soil is a moderately structured reddish brown to dark brown clay loam grading to structured dark reddish brown to yellowish red clay. Red and brown cracking clay variants occur commonly in the association. The landform is gently undulating plains. Dominant vegetation is a grassland to mid-high open woodland of red barked bloodwood and narrow-leaved ironbark. The grassland is dominated locally by Indian couch, black spear grass and desert bluegrass with buffel grass the dominant introduced species. Associated soils are: *Dalrymple*, a reddish brown to dark brown loamy sand to sandy loam over structured red to reddish brown clay; and *Amity*, a self mulching black clay with an alkaline structured subsoil, often with free lime.

Tuckers soil is formed from basic rocks and has moderate to high fertility. The soil requires approximately 515 mm of rainfall to fill to one metre and of this 95 mm is available for plant growth. The surface horizons range in dispersion from nil to moderate and the subsoil is nil to weakly dispersive. Tuckers has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Two Creek association

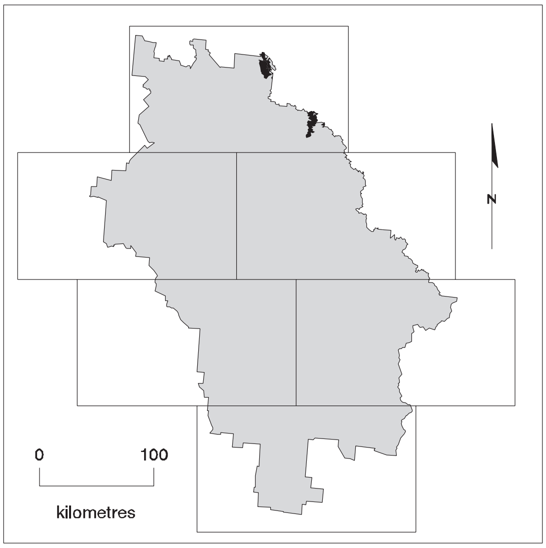




Two Creek soil is a very dark greyish brown sand to sandy loam over structured mottled yellowish brown clay. The landform is undulating rises with granite outcrops a common feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, *Melaleuca* species, Reid River box and poplar gum. The ground layer is dominated by golden beard grass, black spear grass and wire grasses. Associated soils are: *Bluff*, a greyish brown sand to sandy loam over alkaline structured yellowish brown clay; *Conolly*, a grey, brown and yellowish brown sand; and *Carse O' Gowrie*, a dark brown sand over yellowish brown sand.

Two Creek soil is formed from coarse grained granitic rocks and has low fertility. The soil requires approximately 310 mm of rainfall to fill to a mean maximum depth of 77 cm and of this 70 mm is available for plant growth. The soil is not dispersive in the surface, is weakly to moderately dispersive in the subsoil and has extremely low bicarbonate phosphorus in the soil surface. Cattle grazing of pastures on this soil will require phosphorus supplementation and phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

Umala association

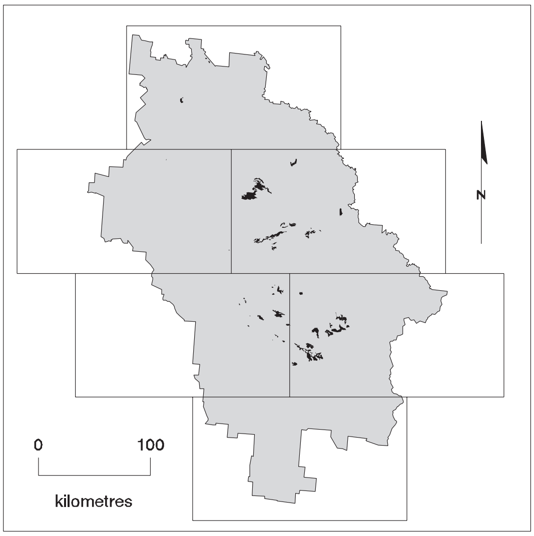


Umala soil is a dark brown clay loam over structured yellowish red to red clay. The landform is steep slopes and ranges. Vegetation is rainforest and sclerophyll forest which is located predominantly within the World Heritage Estate and is generally not accessible for agricultural land uses. Umala soil requires approximately 370 mm of rainfall to fill the soil profile to one metre and of this 90 mm is available for plant growth. The soil does not disperse in the surface or subsoil horizons, has low bicarbonate phosphorus in the surface and in the subsoils and may have high phosphorus retention properties. Cattle grazing of pastures on this soil may require supplement and phosphorus fertiliser would be necessary for optimum pasture production. Umala has been described with associated soils (unnamed in this report), in a larger scale survey to the north, Laffan (1988). [*No profile diagram*]

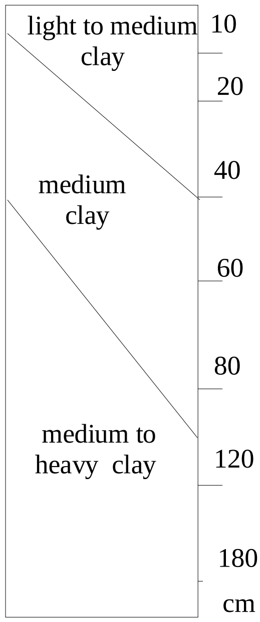
Utchee association

Utchee soil is a dark reddish brown clay loam grading to structured red medium clay. The landform is low hills to steep slopes and ranges with vegetation of rainforest and sclerophyll forest. The soil is located predominantly within the World Heritage Estate and is generally not accessible for agricultural land use. Utchee soil requires approximately 370 mm of rainfall to fill the soil profile to one metre and of this 90 mm is available for plant growth. The soil may be several meters deep and have a substantial water storage capacity. The soil does not disperse in the surface or subsoil horizons and has low bicarbonate phosphorus in the surface. The soil is described with associated soils (unnamed in this report), in larger scale surveys to the north, Laffan (1988), Cannon *et al*. (1992) and Murtha (1986).
[*No profile diagram; no distribution figure*]

Victoria Downs association

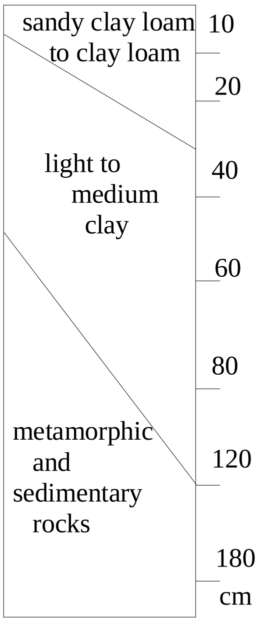


Victoria Downs soil is a uniform clay profile with a massive to blocky structured dark grey to greyish brown surface grading to an alkaline structured dark grey to yellowish brown subsoil. The soil may have surface gravels, commonly rounded quartz. The landform is level to gently undulating alluvial plains. The dominant vegetation is a grassland to mid-high woodland of Reid River box with locally dense woodlands of blackwood and gidgee. False sandalwood and yellowwood may also occur. The grassland is bluegrasses, love grasses, wire grasses and silky brown-top grass. Associated soils are: *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; and *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay. In the Cape River area: *Liontown*, a dark brown to greyish brown sandy clay loam with bleached A2 over alkaline structured dark brown to yellowish brown and grey clay; and *Powlathanga*, a very dark grey to dark brown clay with a massive to blocky surface over an alkaline upper subsoil and a structured acid lower subsoil.



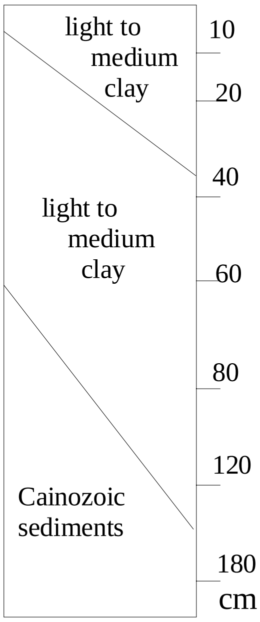
Victoria Downs soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 345 mm of rainfall to fill to one metre and of this 95 mm is available for plant growth. The soil has low to moderate dispersion in the surface and is moderately to highly dispersive in the subsoil. Victoria Downs soil has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* suited to this soil at present however Urochloa may be a suitable introduced species for this soil. There appears to be no difference in phosphorus levels in grassland or woodlands.

Wairuna association



Wairuna soil is a dark reddish brown to dark brown sandy clay loam to clay loam over structured dark red to yellowish red clay. Quartz gravels and mica flecks are common indicators of this soil. The landform is gentle slopes to gently undulating rises, quartz veins and exposed metamorphic rocks are a common surface feature. The dominant vegetation is a mid-high woodland of narrow-leaved ironbark, red barked bloodwood and grey box with an mid-stratum of *Acacia* species. Grass cover is dominated by kangaroo grass, wire grasses, bluegrasses, golden beard grass and black spear grass. Associated soils are: *Rangeview*, a dark reddish brown sandy clay loam over structured red to yellowish red clay; *Paynes*, a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay; *Argentine*, a dark brown sandy clay loam to clay loam, often gravely, over alkaline structured red clay; *Ewan*, a shallow massive brown sandy loam over metamorphic rock; and *Warawee*, a dark brown clay loam over alkaline structured yellowish brown clays. Wairuna soil is formed from metamorphosed sediments and the association may have inclusions of sedimentary soils. Fertility is generally low. The soil requires approximately 410 mm rainfall to fill to a mean maximum depth of 86 cm and of this 95 mm is available for plant growth. Wairuna is weak to moderately dispersive in the surface horizons and moderate to highly dispersive in the subsoil. Although no profiles were sampled for full chemical analysis in this survey, data presented by Grundy and Bryde (1989) on a similar soil shows extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

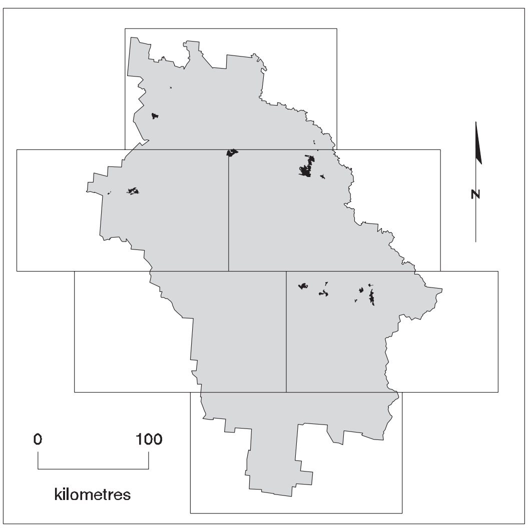
Wambiana association

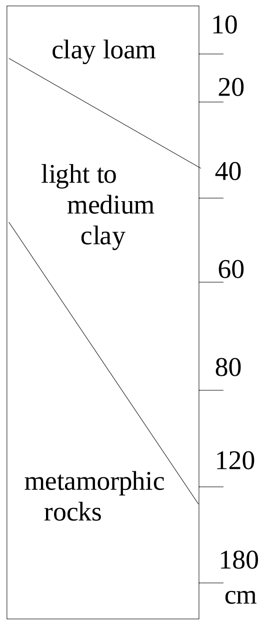


Wambiana soil is a uniform clay, structured dark grey to greyish brown with a neutral pH profile. The landform is level to gently undulating plains. Dominant vegetation is a grassland or mid-high woodland to dense forest of blackwood, gidgee and brigalow with yellowwood locally dominant. Bauhinia and false sandalwood may be present in the mid-stratum. The grassland is predominantly blue grasses (*Bothriochloa* or *Dicanthium* species) and silky brown-top grass. Buffel grass is the dominant introduced grass and would appear to be well established. Associated soils are: *Egera*, a grey self mulching clay often with free lime in subsoil; *Victoria Downs*, a uniform clay of massive to blocky structured dark grey to greyish brown surface grading to alkaline structured dark grey to yellowish brown subsoil; and *Powlathanga*, a very dark grey to dark brown clay with a massive to blocky surface over an alkaline upper subsoil and a structured acid lower subsoil.

Wambiana soil is formed from Cainozoic sediments and generally has moderately high fertility, especially nitrogen when covered with *Acacia* species. The soil requires approximately 555 mm of rainfall to fill to one metre and of this 115 mm is available for plant growth. Wambiana is weak to moderately dispersive in the surface horizons and moderate to highly dispersive in the subsoil. The soil has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. *Stylosanthes* is not suited to this soil at present however buffel grass and urochloa are suitable introduced species. There appears to be no difference in phosphorus levels in grassland or woodland for this soil, including the gidgee and brigalow scrub communities.

Warawee association

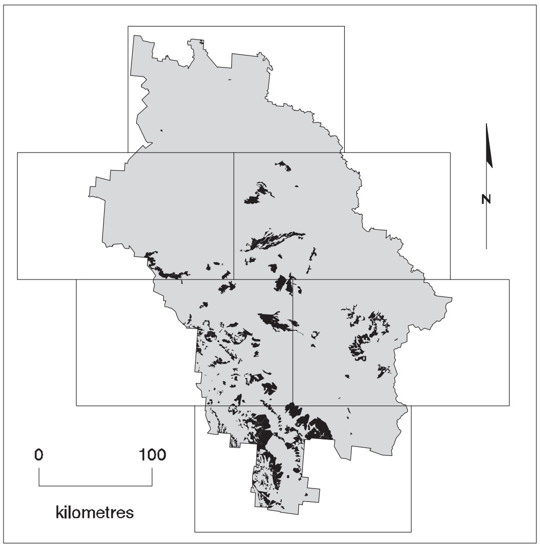


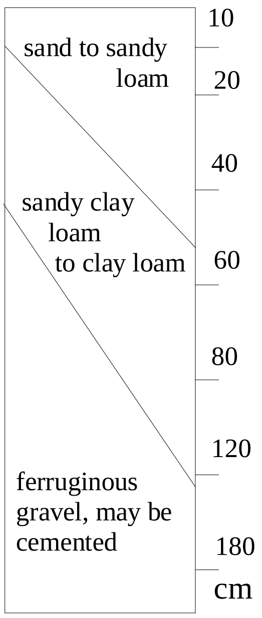


Warawee soil is a dark brown clay loam over alkaline structured yellowish brown clays. Quartz gravels and mica flecks are common indicators of this soil. The landform is chiefly gentle slopes to gently undulating rises and lower slopes of mesas with quartz veins and exposed metamorphic rocks a common surface feature. Dominant vegetation is a mid-high woodland of narrow-leaved ironbark, Reid River box and grey box with an mid-stratum of false sandalwood and *Acacia* species. The grass cover comprises kangaroo grass, wire grasses, bluegrasses, golden beard grass and black spear grass. Associated soils are: *Paynes*, a very dark greyish brown to yellowish brown sand to sandy loam over structured yellowish brown clay; *Argentine*, a dark brown sandy clay loam to clay loam, often gravely over alkaline, structured red clay; *Rangeview*, a dark reddish brown loam over structured red to yellowish red clay; and *Ewan*, a shallow massive brown sandy loams over metamorphic rock.

Warawee soil is formed from metamorphosed sediments and the association may have inclusions of sedimentary soils. The soil is generally low in fertility and requires approximately 330 mm rainfall to fill to a mean maximum depth of 85 cm and of this 90 mm is available for plant growth. The soil is weak to moderately dispersive in the surface horizons and moderate to highly dispersive in the subsoil. Warawee has extremely low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *stylosanthes* pastures are to reach optimum production.

Wattle Vale association





Wattle Vale soil is a dark greyish brown loose to firm loamy sand to sandy loam grading to yellowish brown to yellow sandy clay loam. The soil may have considerable amounts of ferruginous gravel in the profile and is often quarried for road base. The landform is level to gently undulating plains with occasional mesas. Dominant vegetation is a mid-high woodland of silver and/or narrow-leaved ironbark, long-fruited grey bloodwood and less commonly Reid River box with *Acacia* species (lancewood, bendee) locally dominant. Tea tree and quinine bush are common in the mid-stratum. wire grasses, golden beard grass, black spear grass and buck spinifex are the locally dominant grass species. Associated soils are: *Rangeside*, a dark reddish brown to dark brown sand to sandy loam grading to earthy red to yellowish red sandy loam to clay loam; *Corea*, a very dark grey to dark brown sand to sandy loam over massive to structured yellowish brown clay; *Boston*, a dark greyish brown sandy loam to sandy clay loam grading to yellowish brown clay; and *Rishton*, a uniform sand often with a bleached A2 horizon, typically with a dark brown loose to soft surface with yellowish brown subsoil.

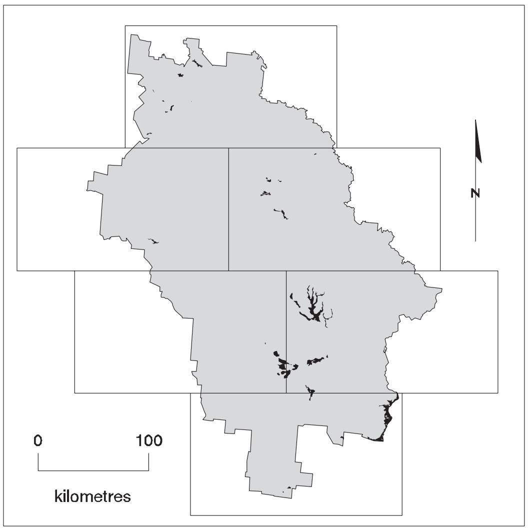
Wattle Vale soil is formed from Cainozoic sediments and has low fertility. The soil requires approximately 380 mm of rainfall to fill to a mean maximum depth of 88 cm and of this 70 mm is available for plant growth. The soil does not disperse or is weakly dispersive in the surface and the subsoil, and has extremely low bicarbonate phosphorus in the surface. Cattle grazing of pastures on this soil will require phosphorus supplementation. Phosphorus fertiliser will be necessary if *Stylosanthes* pastures are to reach optimum production.

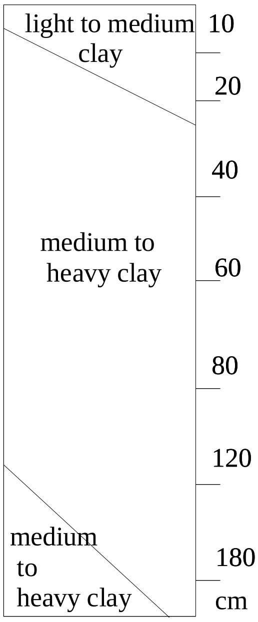
Worsley association

Worsley soil is a very dark brown clay loam grading to structured yellowish brown light clay. The landform is low hills to steep slopes and ranges with vegetation of rainforest and sclerophyll forest located predominantly within the World Heritage Estate and generally not accessible for agricultural land use. Worsley soil requires approximately 370 mm of rainfall to fill the soil profile to one metre and of this 90 mm is available for plant growth. The soil may be several meters deep and have a substantial water storage capacity. The soil does not disperse in the surface or subsoil horizons and has low bicarbonate phosphorus in the surface. Worsley soil has been described with associated soils (unnamed in this report), in a larger scale survey on the Atherton Tablelands, Laffan (1988).

[*No profile diagram; no distribution figure*]

Yarraman association





Yarraman soil is a black, brown or grey clay with a self mulching to blocky surface and an alkaline structured subsoil. The landform is broad gilgai plains away from the major present day streams. Vegetation consists of grasslands and mid-high woodlands of blackwood, brigalow, coolibah, and Reid River box. False sandalwood and saplings of the tallest stratum are the most common mid-stratum. The ground layer is dominated by kangaroo grass, *Bothriochloa* species, bluegrasses and love grasses. Buffel grass has been successfully established along with urochloa on this soil. The depth of gilgai depressions can prevent pasture establishment through wet conditions in the depression of the gilgai. Associated soils are: *Cape*, a very dark greyish brown silty loam to clay loam over alkaline structured dark brownish yellow or brown clay; *Creek*, a dark greyish brown sandy loam to sandy clay loam over structured yellowish brown to grey clay; and *Manoa*, a dark grey to dark yellowish brown clay with structured neutral to alkaline subsoil.

Yarraman soil is formed from alluvium and may have low to high soil nutrient levels depending on the catchment geology. The soil requires approximately 555 mm of rainfall to fill to one metre and of this 110 mm is available for plant growth. The soil is weak to moderately dispersive in the surface soil and moderate to highly dispersive in the subsoil. Yarraman has extremely low to low bicarbonate phosphorus in the surface and cattle grazing of pastures on this soil will generally require phosphorus supplementation. Phosphorus fertiliser may be necessary if improved pasture is to reach optimum production. There are no *Stylosanthes* suited to this soil at present with buffel grass and urochloa the suitable introduced species for this soil. There appears to be no difference in phosphorus levels in grassland or woodland for this soil, including the brigalow, blackwood and gidgee scrub communities.

DATA SUMMARIES

Degradation

Indicators of degradation were assessed by visual estimates for dimensions of soil erosion (sheet, rill, gully and scald), for native and exotic weed occurrence and extent, and for grass basal area % (GBA). The geological landscapes and the Order level of the Australian Classification have been ranked for degradation by summing the percentage of sites where an occurrence of any indicator has been recorded. The degradation rank is derived from the sum of the percentages of sites with degradation occurring for each of the soil types. For example, Argentine soil in the metamorphic landscape has 73% of sites with sheet erosion, 18% with rill erosion, 36% with gully erosion, 27% with scald erosion, 64% with grass basal area ≤1.5%, 18% with exotic weeds and 73% of sites with native weeds. Other soils are assessed likewise to derive a simple degradation rank. A list of soil types and percentage of sites with various forms of degradation is listed in Table 15.

Table 13. Generalised degradation rank for the geological landscapes

Geological landscape	Degradation ranking
Sedimentary	HIGH
Metamorphic	↓
Granodiorite	
Cainozoic	
Alluvial	
Igneous	
Basalt	LOW

Table 14. Generalised degradation rank for the Orders of Australian Soil Classification

Order	Degradation ranking
Sodosols	HIGH
Chromosols	↓
Rudosols	
Tenosols	
Vertosols	
Dermosols	
Kandosols	
Ferrosols	LOW

Table 15. Percentage of sites were degradation occurs for various degradation categories across soil types

Soil Type*	No. of sites assessed for degradation categories	% of sites with 0 degradation score	Soil erosion occurrence (%)				GBA ≤ 1.5%	exotic weed %	native weed %
			Sheet	Rill	Gully	Scalds			
Argentine	11	0	73	18	36	27	64	18	73
Amity	26	12	12	0	23	0	22	41	52
Barkla	8	0	25	0	0	0	43	13	63
Bluff	29	10	72	34	62	28	52	17	55
Boston	127	14	34	6	5	21	43	3	60
Burra	24	21	17	0	8	38	22	0	50
Burdekin	47	11	19	0	4	23	36	35	63
Bulliwallah	6	0	83	17	33	83	67	0	50
Conjuboy	43	26	14	0	5	42	32	9	16
Ceaser	25	4	64	4	24	44	48	0	36
Carse O’Gowrie	53	17	51	4	9	13	33	19	9
Creek	51	25	24	0	12	20	37	18	61
Conolly	28	7	57	11	21	21	54	43	21
Cape	70	11	20	6	9	36	52	20	70
Corea	100	12	35	6	8	19	42	11	63
Charters Towers	43	7	28	16	14	30	3	61	61

Table 15. continued

Soil Type*	No. of sites assessed for degradation categories	% of sites with 0 degradation score	Soil erosion occurrence (%)				GBA ≤ 1.5%	exotic weed %	native weed %
			Sheet	Rill	Gully	Scalds			
Dotswood	63	3	60	17	30	30	62	6	77
Egera	47	4	2	2	0	32	64	20	72
Ewan	15	0	73	20	27	53	67	0	53
Flagstone	13	8	54	8	0	38	53	6	50
Fanning River	36	11	19	6	6	19	42	30	70
Felspar	14	14	21	0	0	50	36	29	7
Gainsford	21	19	19	5	5	14	32	24	57
Glencoe	29	31	17	0	3	21	18	14	21
Greenvale	56	11	64	20	30	29	54	2	58
Hillgrove	41	44	17	0	2	34	15	7	20
Hillview	6	17	33	0	0	33	33	17	50
Lime View	14	0	21	7	14	7	42	57	64
Lolworth	58	28	3	2	21	9	44	18	28
Liontown	73	3	30	14	0	32	52	12	89
Maryvale	30	37	0	3	10	10	30	29	28
Mingela	18	11	44	17	28	22	47	67	72
Manoa	29	14	21	0	14	34	50	10	52
Mount Ravenswood	17	18	24	6	18	18	18	53	65
Myrtlevale	37	5	35	16	16	41	74	18	73
Nial	21	10	52	19	10	33	52	5	67
Nosnillor	54	4	43	13	17	35	61	18	76
Pandanus	39	18	13	3	0	10	48	20	55
Pentland	99	19	40	3	3	36	37	3	40
Pinnacle	9	0	44	0	11	11	83	22	22
Pallamana	44	11	45	7	9	30	44	13	58
Paynes	27	0	63	22	26	30	46	4	59
Powlathanga	30	0	10	3	0	30	64	23	83
Rangeview	49	16	69	10	22	24	30	4	53
Rishton	86	14	21	2	3	12	46	7	48
Rolston	26	8	46	15	23	38	48	23	58
Rangeside	39	15	33	8	3	33	49	5	40
Scartwater	32	3	66	9	9	38	81	6	84
Star	8	25	0	0	0	38	50	0	63
Two Creek	76	17	43	14	14	16	34	26	32
Thorpe	7	14	29	14	14	29	43	0	29
Tuckers	27	15	41	19	4	26	32	32	29
Victoria Downs	46	4	13	0	2	41	49	22	78
Warawee	24	13	63	38	58	25	67	0	75
Wambiana	37	5	11	3	0	24	43	11	58
Wairuna	30	0	77	17	37	27	50	3	71
Wattle Vale	67	16	22	6	3	13	38	3	55
Yarraman	24	8	4	0	8	21	58	24	52

* Only soils with greater than five sites assessed are listed.

Infiltration

Water is the major limitation to plant growth in the Dalrymple Shire. The rainfall is highly seasonal and occurs mostly as storms over the summer months when evaporation rates are high. The growing season for pastures is limited to those times when rainfall exceeds evapotranspiration and when the pastures can access stored soil moisture. Infiltration rates and soil moisture characteristics were estimated for the soil types using fifteen representative sites. The infiltration rates were determined for a falling head of 56 mm (approx. 2 inches) using a 30 cm diameter ring pushed 10 cm into the soil. Rates were measured under the canopy of trees, on and around clumps of grass, on bare areas of soil and on the top of the subsoil (see Photos 8 to 11). Intact 2 inch soil cores were taken todetermine bulk density, air dry moisture and available water at 10 and 1500 kpa suctions for surface and subsoils. The following data are based on infiltration rates averaged over the first five minutes of water application. Five minutes was chosen as infiltration rates began to level off from initial high values at this time. The most obvious difference across treatments averaged over all sites was the increase in infiltration rates from the top of the B horizon and bare topsoil (similar rates) to rates for the grassed treatment (increase of 80%) and rates for under trees (increase of 150% over bare topsoil or B horizon and 40% increase over grassed areas). This effect was observed as a flush of new grass growth under trees after light falls of rain. The effect was more pronounced on sandy soils as moisture is readily available and less water is required to wet up the topsoil.

Table 16. Cumulative infiltration for 15 soil types

Soil Type	Order Classification	Geological landscape	Cumulative infiltration after 5 min (mm)			
			Under tree	Grassed surface	Bare top soil	Top of subsoil
Burdekin	Tenosol	Alluvial	39	19	15	20
Conjuboy	Ferrosol	Basalt	34	17	10	8
Hillgrove	Ferrosol	Basalt	23	21	6	14
Lolworth	Vertosol	Basalt	*	30	35	46
Corea	Chromosol	Cainozoic	34	35	16	16
Boston	Kandosol	Cainozoic	35	15	10	18
Pentland	Kandosol	Cainozoic	23	24	8	7
Pallamana	Sodosol	Cainozoic	21	18	9	1
Rishton	Tenosol	Cainozoic	*	*	*	*
Victoria Downs	Vertosol	Cainozoic	21	13	9	8
Dalrymple	Chromosol	Granodiorite	28	20	12	10
Conolly	Rudosol	Igneous	36	17	18	29
Bluff	Sodosol	Igneous	31	32	15	12
Paynes	Chromosol	Metamorphic	26	24	9	9
Rangeview	Chromosol	Metamorphic	22	14	7	9

* All water infiltrated before 5 min (high infiltration rates)

Photo 8. Infiltration on surface soil under grass cover

Photo 9. Infiltration on bare topsoil

Photo 10. Infiltration on top of B horizon

Photo 11. Infiltration on soil surface under tree canopy

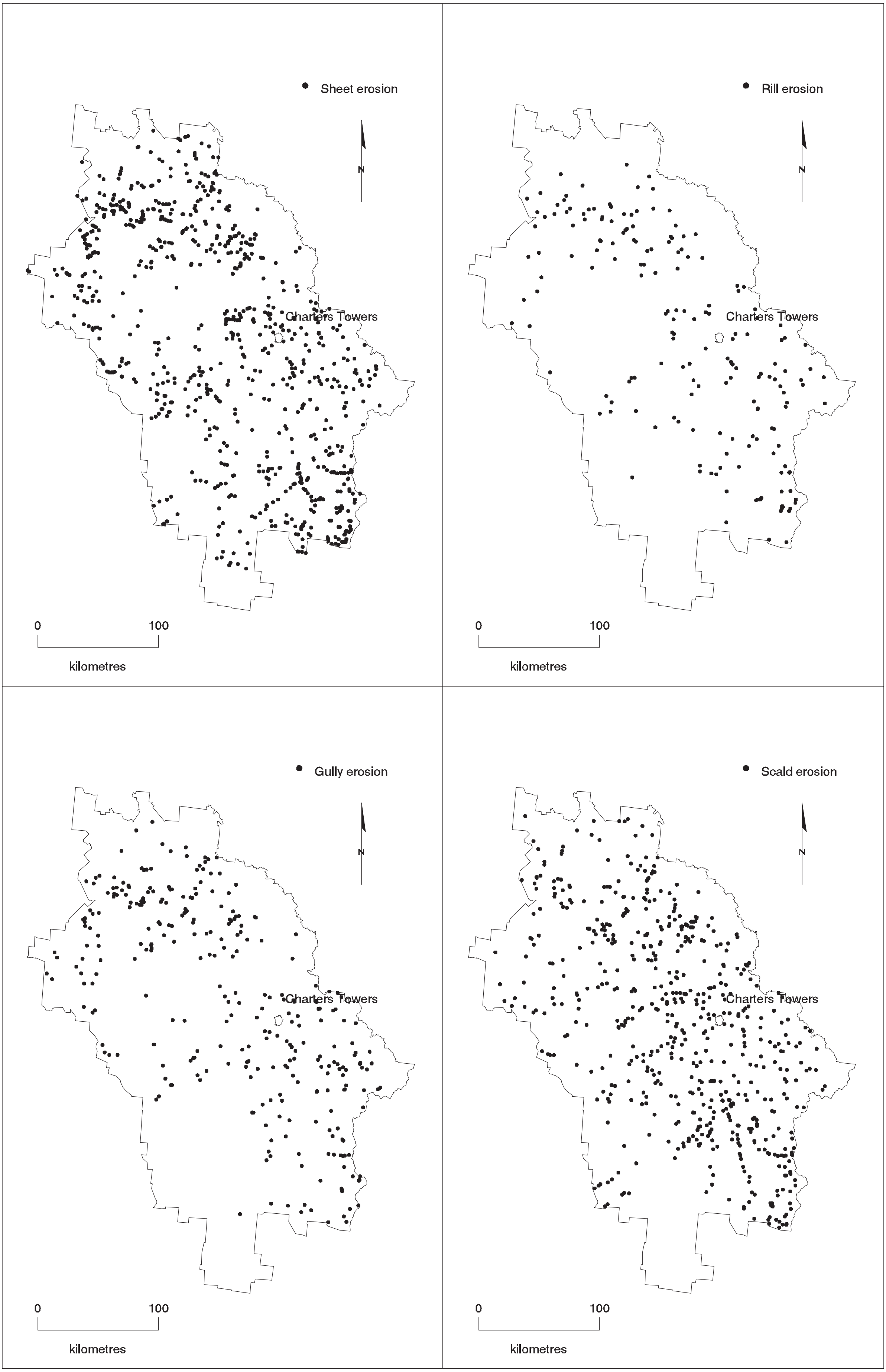


Figure 13. Survey sites where soil erosion was recorded

Dispersion data

Dispersion is the separation and suspension of clay particles from a clod of soil in water. A dispersive soil will erode and runoff water will remain cloudy. A dispersion test was carried out to determine an index of erodability for the soil types. Samples of the topsoil (A horizon) and top of the subsoil (B horizon) from 937 profiles were tested to obtain a dispersion score using a modified method of Loveday and Pyle (1973). Details of the procedure are listed in the methods section. Dispersive soils are generally prone to erosion and have a score of 8 or greater. Table 17 shows the average dispersion scores for the soil types. Figure 14 shows the low exchangeable sodium percente (ESP) values and dominance of low dispersion scores for a Chromosol vs the higher ESP and dispersion scores of a Sodosol. Sodosols typically have dispersive erodable subsoils.

Table 17. Average dispersion score for A and B horizons of soil type

Soil Type	Average score A horizon	Average score B horizon
Argentine	1	2
Amity	2	1
Bluff	3	9
Boston	3	2
Burra	3	3
Burdekin	2	4
Conjuboy	3	1
Ceaser	4	2
Carse O'Gowrie	0	2
Creek	4	6
Conolly	1	0
Cape	4	11
Corea	3	6
Charters Towers	3	2
Dalrymple	4	1
Dotswood	5	9
Egera	3	6
Ewan	4	14
Flagstone	5	0
Fanning River	5	7
Felspar	3	0
Gainsford	4	5
Glencoe	3	2
Greenvale	5	4
Hillgrove	3	0
Hillview	6	0
Limestone	2	0
Lolworth	3	2

Soil Type	Average score A horizon	Average score B horizon
Liontown	4	13
Maryvale	3	2
Mingela	3	8
Manoa	6	11
Mount Ravenswood	2	1
Myrtlevale	6	6
Nial	5	6
Nosnillor	3	9
Pandanus	1	4
Pentland	4	2
Pallamana	1	1
Paynes	4	4
Powlathanga	7	8
Rangeview	3	1
Rishton	1	3
Rolston	3	1
Rangeside	2	2
Scartwater	4	11
Star	2	2
Two Creek	3	4
Thorpe	1	0
Tuckers	6	3
Victoria Downs	4	6
Warawee	5	7
Wambiana	5	7
Wairuna	6	2
Wattle Vale	3	2
Yarraman	4	5

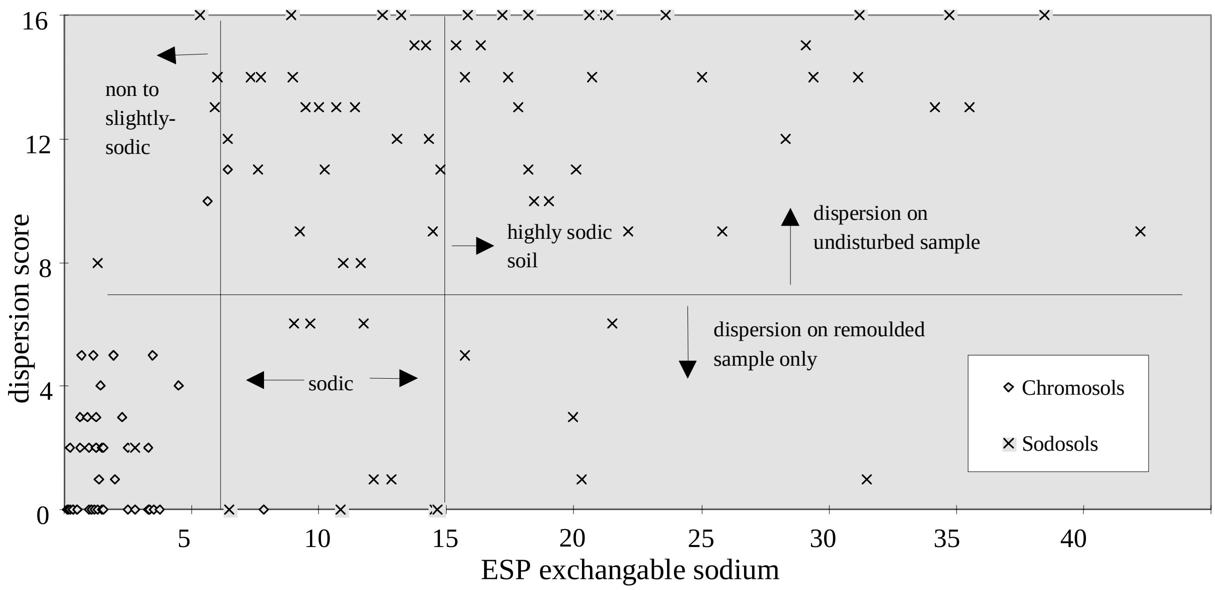


Figure 14. Dispersion score vs exchangeable sodium percentage for two classification Orders (Chromosols and Sodosols)

Grass and tree basal area

Grass basal area (GBA) was recorded as the growing points of a perennial tussock or hummock grass. Using this method the condition of the pasture could be assessed independent of grazing pressure or occurrence of fire. Sedges and forbs were not assessed as many are annuals, however while they may make up only 3–8% of the pasture composition they can contribute up to 30 to 40% to the diet of beef cattle at selected times of the year (Ash, *pers. comm*.). Grass basal area recordings were undertaken at each site using visual estimates. Figure 16 shows data for all sites of grass basal area against tree basal area. A grass basal area of less than or equal to 1.5 % was considered to determine pastures in a degraded state.

Trials by Pressland (1994) showed that 40% ground cover was required to significantly reduce soil erosion. Data over four dry seasons of the survey show that pastures with a GBA greater than or equal to 2.0% could achieve a ground cover class of 30 to 70 % under grazed conditions. All the grass species recorded required a minimum GBA of 2.0% to achieve a mid-dense ground cover class (30–70% cover). A small number of sites had a GBA less than 2.0% and a ground cover greater than 30% where cattle had been mostly excluded. Figure 15 shows the distribution of GBA data.

Tree basal area (TBA) was assessed by using a modified method of Grosenbaugh (1952). Using this method, 10 counts approximate to 2.29 m^2/ha. A summary of grass and tree basal area data for soil associations is presented in Table 18.

The average grass basal area across all soils in the Shire was 1.8% (average for soil types, 0.9 to 3.2%) and for tree basal area 3.7 m^2/ha (average for soils types 1.4 to 6.2 m^2/ha). In general terms the data show that as tree basal area increases, grass basal area decreases. The line drawn at the top of the data points is what might be best achieved (highest GBA given set TBA) using conservative grazing pressures. The slope of the line will change for different soil, climate and vegetation combinations with higher grass and tree basal areas supported on more fertile soils and where moisture is more available. An example is shown in Figure 17 of grass and tree basal area data for a yellow earth on Tertiary surface (Kandosol, Boston soil) and a loamy texture contrast soil on sediments (Sodosol, Scartwater soil). Grass cover was recorded at each site by visual estimate and ranked in the classes shown in Table 19. The highest cover class was dominated by *Bothriochloa pertusa* (Indian couch) which increases the number of growing points under grazing pressure due to its stoloniferous habit.

Table 18. Average grass and tree basal area for the soil types

Soil Type	Av. GBA %	Av. TBA (m^2/ha)
Argentine	1.3	5.0
Amity	3.1	1.6
Barkla	1.4	3.9
Bluff	1.7	3.9
Boston	1.8	3.7
Burra	2.2	2.7
Burdekin	1.8	4.4
Bulliwallah	0.9	2.3
Conjuboy	1.8	4.4
Ceaser	1.6	3.2
Carse O'Gowrie	1.9	3.9
Creek	1.9	5.0
Conolly	1.7	3.0
Cape	1.7	4.8
Corea	1.8	3.9
Charters Towers	3.2	2.7
Dalrymple	2.6	3.4
Dotswood	1.4	5.0
Egera	1.4	2.7
Ewan	1.2	2.7
Flagstone	1.5	3.2
Fanning River	1.9	4.4
Felspar	2.2	3.9
Gainsford	1.8	5.5
Glencoe	2.3	3.0
Greenvale	1.5	4.4
Hillgrove	2.8	3.7
Hillview	1.5	6.2
Limestone	2.3	3.2
Lolworth	1.9	1.4
Liontown	1.5	3.9
Maryvale	1.9	2.7
Mingela	2.4	2.7
Manoa	1.6	4.1
Mount Ravenswood	2.3	2.7
Myrtlevale	1.2	2.7
Nial	1.6	3.9
Nosnillor	1.3	3.2
Pandanus	1.8	5.0
Pentland	1.9	3.7
Pinnacle	1.1	2.1
Pallamana	1.8	3.9
Paynes	1.6	4.6
Powlathanga	1.3	3.4
Rangeview	2.0	4.4
Rishton	1.6	3.7
Rolston	1.8	4.4
Rangeside	1.6	4.1
Scartwater	0.9	4.8
Star	1.8	1.8
Two Creek	2.0	4.6
Thorpe	2.0	4.8
Tuckers	2.6	3.0
Victoria Downs	1.8	3.0
Warawee	1.5	5.0
Wambiana	1.5	2.1
Wairuna	1.6	4.1
Wattle Vale	1.8	4.4
Yarraman	1.3	3.9
Average	**1.8 %**	**3.7 m^2/ha**

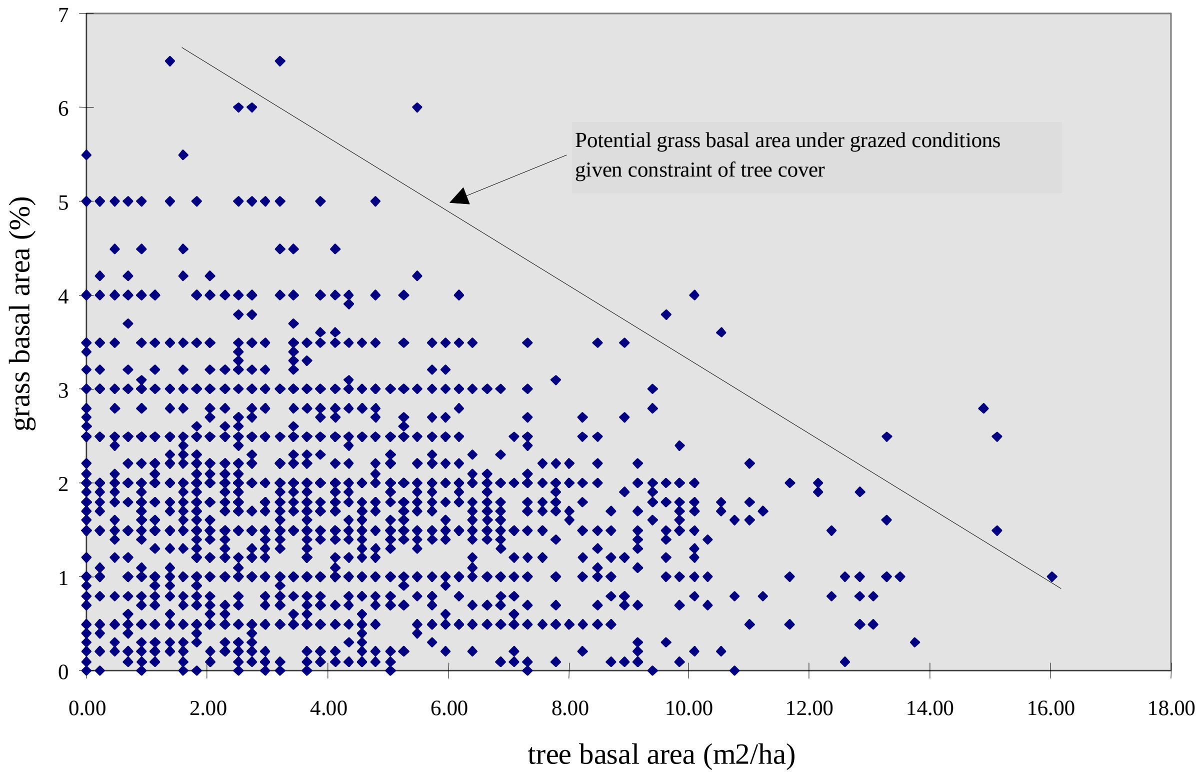


Figure 15. Grass basal area vs Tree basal area for all sites

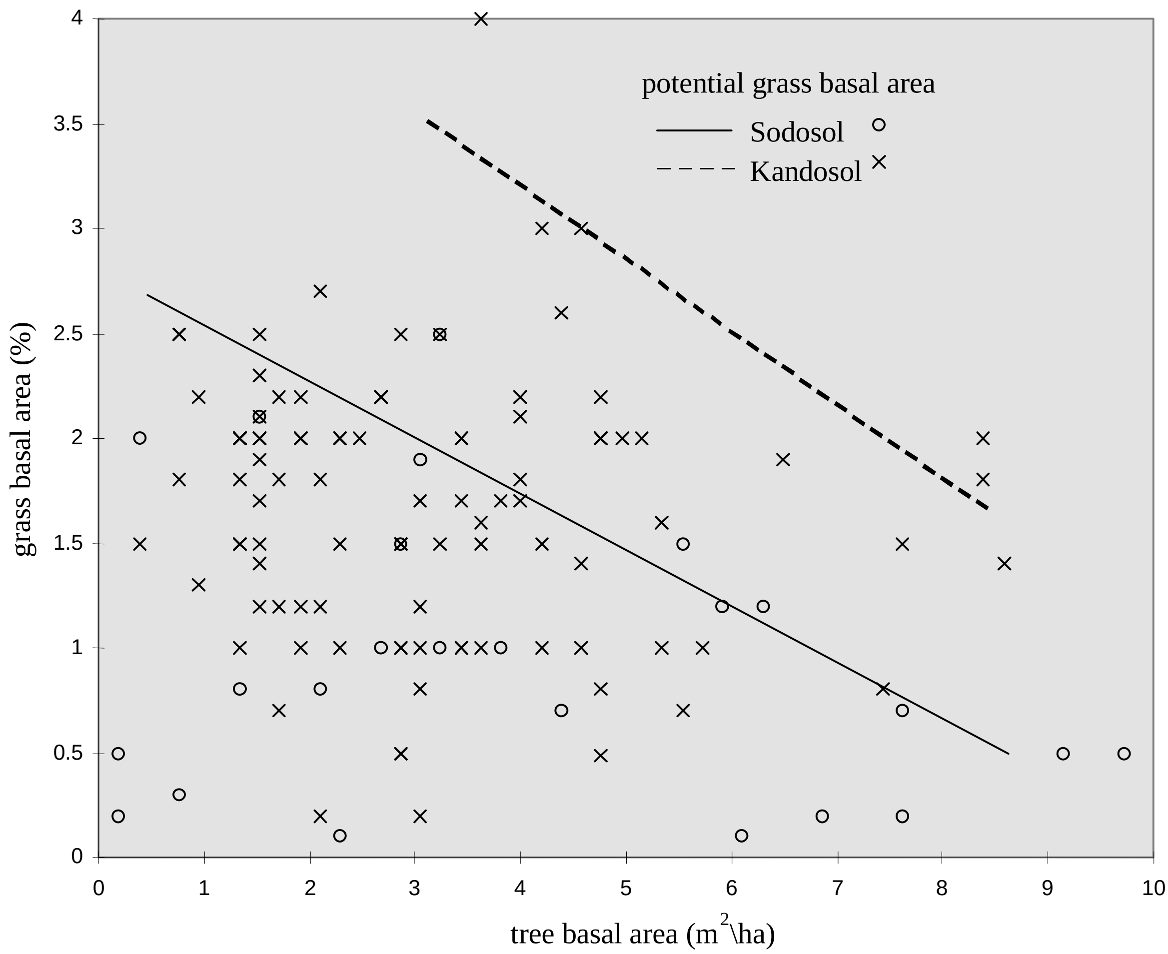


Figure 16. Grass basal area vs Tree basal area for two selected soil types

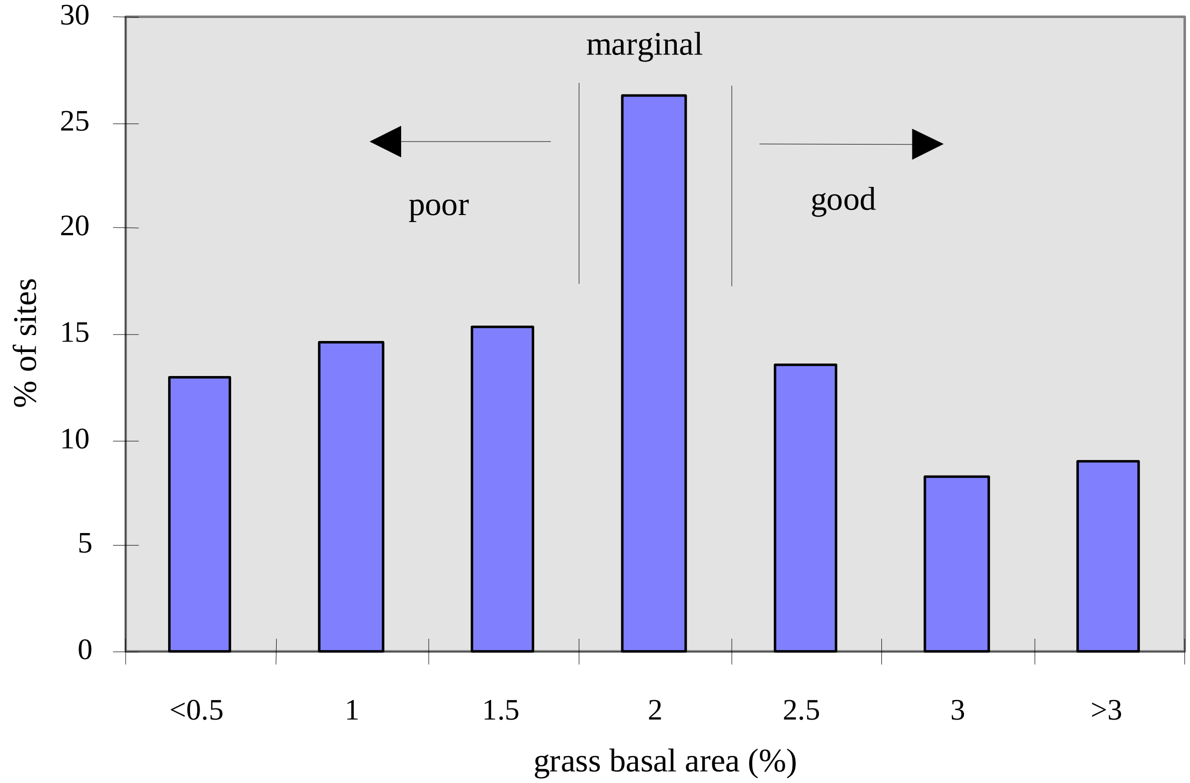


Figure 17. Grass basal area for all sites showing classes of poor, marginal and good pasture condition

Studies of runoff and erosion on grazing lands in the study area by Pressland *et al*. (1991) indicate that a grass and litter cover of 30–40% is required to reduce runoff and erosion rates to low levels. A number of grasses comprised the dominant number of occurrences where cover classes were mid-dense to dense (greater than 30% cover), these are listed in Table 20. All grass species required a GBA of 2.0% or greater to achieve the mid-dense to dense cover class.

Table 19 Percentage distribution of grass cover classes

Cover class	% cover	% sites
Closed or dense	>70%	1.8%
Mid-dense	30-70%	18.3%
Sparse	10-30%	44.6%
Very sparse	<10%	15.5%
Isolated plants	<1%	3.0%
cover class not recorded *		16.8%

* most of these sites were heavily grazed and grass species could not be identified

Table 20. Percentage occurrence of dominant grasses for mid-dense to dense cover class and as percentage occurrence in the site database

Grass species	% of species in mid-dense to dense class	% of species in database
black spear grass	19	15.4
Indian couch	15	8.4
kangaroo grass	13	7.3
desert bluegrass	7	4.3
wire grasses	6	15.5
golden beard grass	6	4.3
pitted bluegrass	4	4.0
buck spinifex	4	5.0

Native weeds

The most prevalent weed in the Shire was currant bush (*Carissa lanceolata* and C. *ovata*, Photo 12), which occurred at 47% of sites, with none recorded at 42% of sites and the remainder (11%) of sites not assessed. Assuming the sites are equally distributed across the Shire, the approximate ground area covered by *Carissa* species canopy is 220 000 ha. (Average extent of

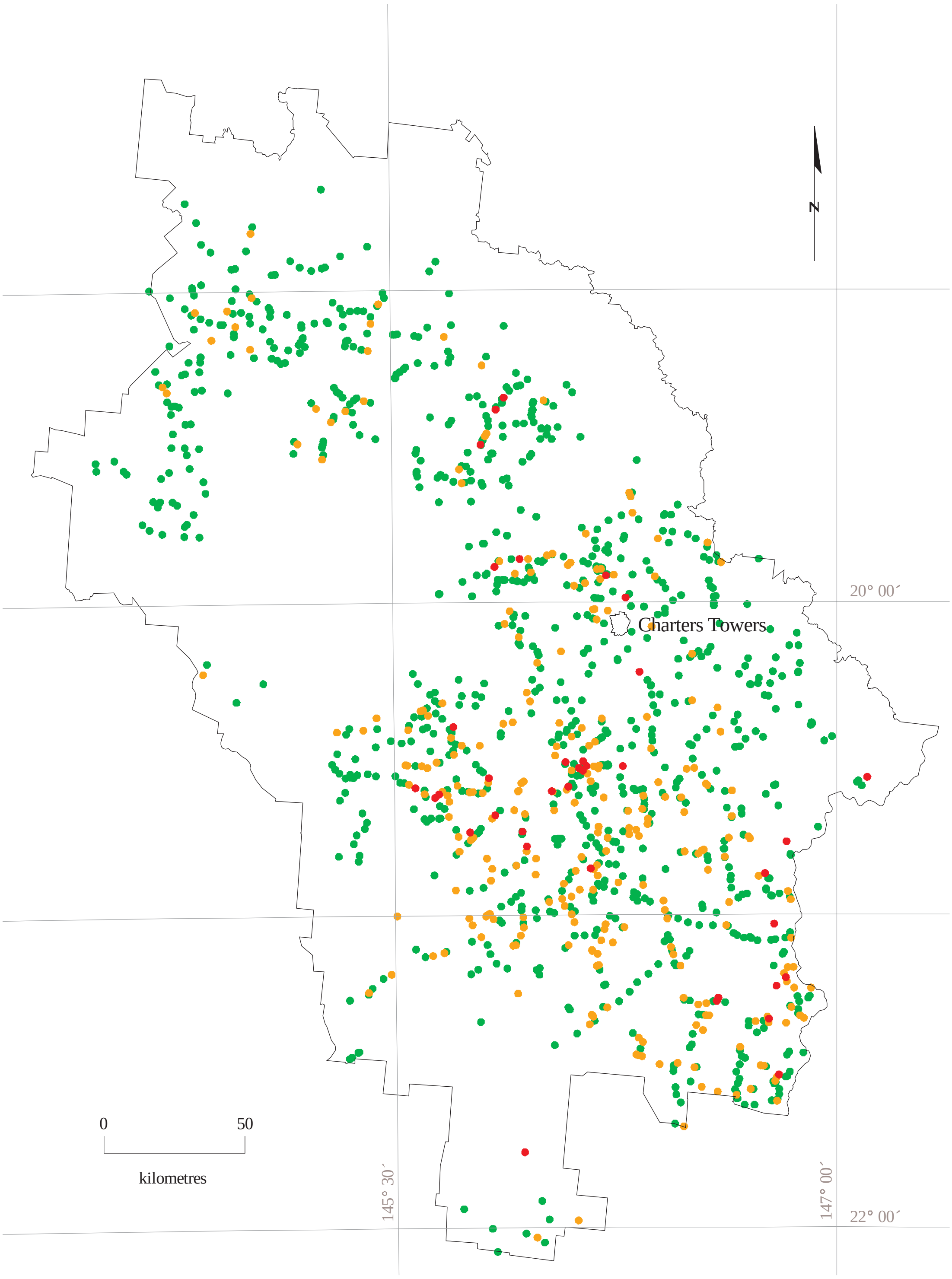
Carissa spp. per soil type times extent of soil across Shire). This represents a significant loss in annual beef production.

Metamorphic, Sedimentary, Cainozoic and Alluvial geological landscapes had approximately 60% of sites with currant bush, Granodiorite landscapes had 43% and Basalt landscapes 17%. Currant bush was more common on Sodosols (73% of sites average occurrence), with Chromosols 56%, Dermosols, Kandosols, Tenosols and Vertosols approx. 50%, Rudosols 36% and Ferrosols 15%. See Table 15 for % occurrence of native weeds for each soil type. Mimosa bush (*Acacia farnesiana*) was the other native weed which was found mainly on clay soils.

Photo 12. Currant bush (*Carissa* spp.) under box trees in a Cainozoic landscape

Table 21. Ground cover classes for currant bush and mimosa bush

Cover class of weed (ground cover)	Number of sites with currant bush and % of total assessed	Number of sites with mimosa bush and % of total assessed
0–10%	588 (24%)	44 (1.4%)
10–20%	341 (15%)	11 (0.4)
20–30%	170 (7.4%)	6 (0.2)
30–40%	67 (2.9%)	2 (0.1)
40–50%	34 (1.5%)	
50–60%	9 (0.4%)	
60–70%	12 (0.5%)	
70–80%	10 (0.4%)	
80–90%	5 (0.2%)	
90–100%	2 (0.1%)	



LEGEND

- 0-20% ground cover
- 21-50% ground cover
- 51-100% ground cover

Figure 18. Survey sites with currant bush *(Carissa* spp.*)*

Exotic weeds

Up to four weed species and associated extent codes are recorded for each site. No exotic weeds were found at 83% of sites. Weed species that follow watercourses may be under-represented as the sampling technique generally went across watercourses rather than along them. A distribution of exotic weeds for soil types is presented in Table 15. A dense stand of chinee apple in the Granodiorite landscape is shown in Photo 13.

Table 22. Number and percentage of survey sites with exotic weeds

Weed species	Number of sites and % of total assessed.	Weed species	Number of sites and % of total assessed.
Rubber vine *Cryptostegia grandiflora*	178 (7.6%)	Lantana *Lantana camara*	19 (0.8%)
Chinee Apple *Ziziphus mauritiana*	119 (5.1%)	Sicklepod *Cassia obtusifolia*	2 (0.1%)
Prickly Acacia *Acacia nilotica*	33 (1.4%)	Calotropis *Calotropis procera*	4 (0.2%)
Parthenium *Parthenium hysterophorus*	6 (0.3%)	Belly ache *Jatropha gossypifolia*	3 (0.1%)
Parkinsonia *Parkinsonia aculeata*	19 (0.8%)	Prickly pear *Opuntia* species	4 (0.2%)
Harrisia cactus *Eriocereus martinii*	4 (0.2%)		

Photo 13. Chinee apple infestation on a black clay in the Granodiorite landscape

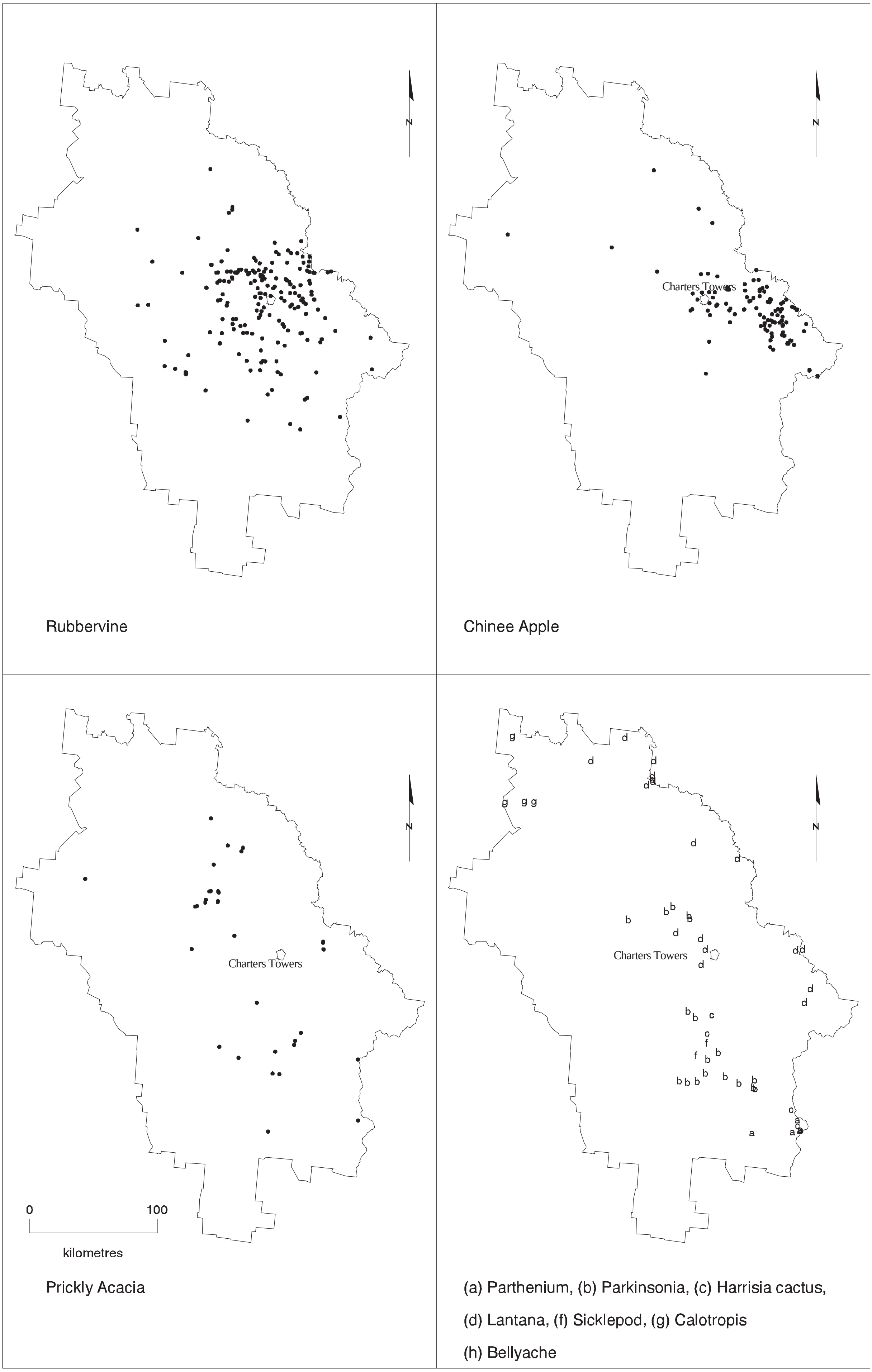


Figure 19. Survey sites with exotic weeds

Salinity

Electrical conductivity measurements were determined on samples from 1637 sites throughout the Shire (see methods section - chemical and physical analysis). Saline profiles were found at 4.7% of sites (% total soluble salts > 0.25).

EC values for topsoil (A horizon) and subsoils (B horizon) are listed for the Australian Soil Classification Orders in Figure 20. Subsoils of Sodosols and Vertosols show accumulation of salts due to generally low permeability of these soils.

Using salinity data from this survey, Bui *et. al*. (1996) assessed the risk of salinisation for the Dalrymple Shire using the integration of topographical, hydrological, hydrogeological and soils data on a geographic information system (GIS). Recharge and discharge areas were identified from the Atlas of Australian Soils (1:2 000 000, Isbell *et al*. 1967, 1968) and the following areas were identified for any given catchment (Figure 21).

- If a recharge area is present and % TSS (total soluble salts) > 0.25 and depth to groundwater < 6 m, then risk of salinisation after tree clearing is HIGH
- If a recharge area is present and % TSS > 0.25 and depth to groundwater >6 m but < 20 m, then risk of salinisation after tree clearing is MEDIUM
- If a recharge area is present and % TSS < 0.25 and depth to groundwater < 6 m, then risk of salinisation after tree clearing is MEDIUM
- If a recharge area is present and % TSS < 0.25 and depth to groundwater > 20 m, then risk of salinisation after tree clearing is LOW

Bui recommended that to lessen the risk of salinisation, recharge areas should not be cleared in watersheds where shallow unconfined aquifers are present and where soils with % TSS > 0.25 occur.

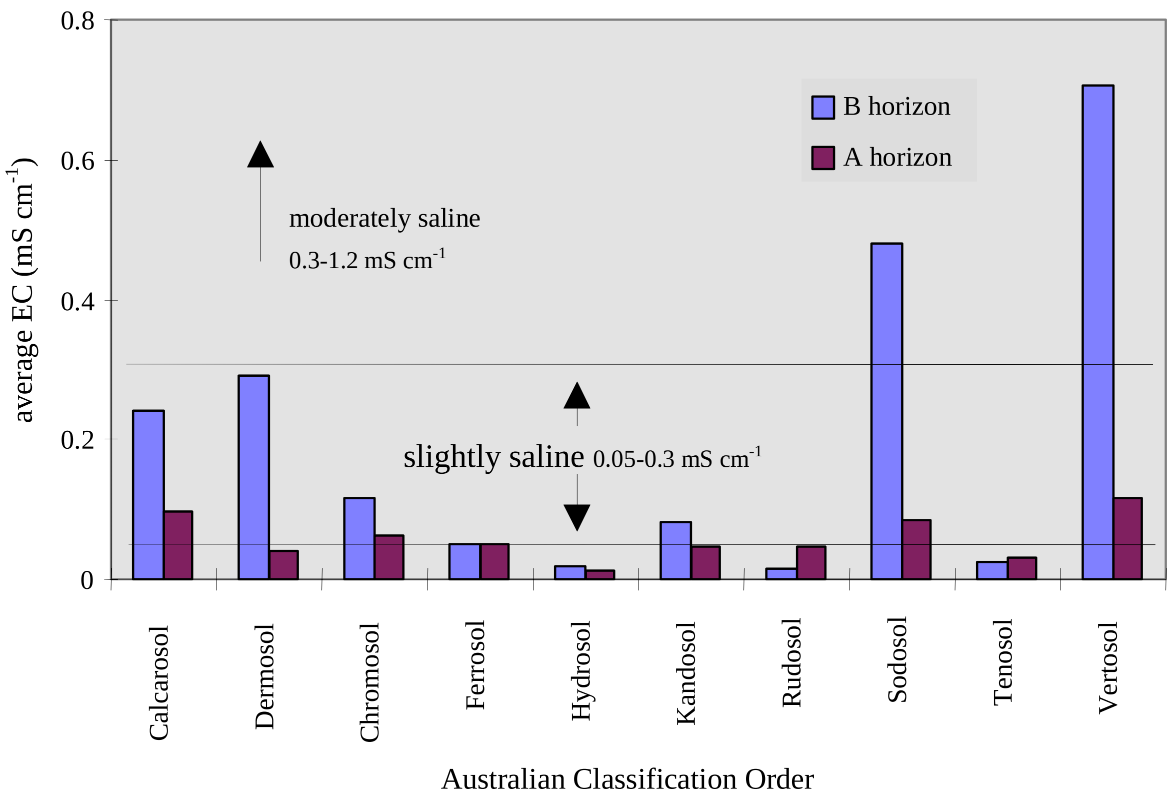
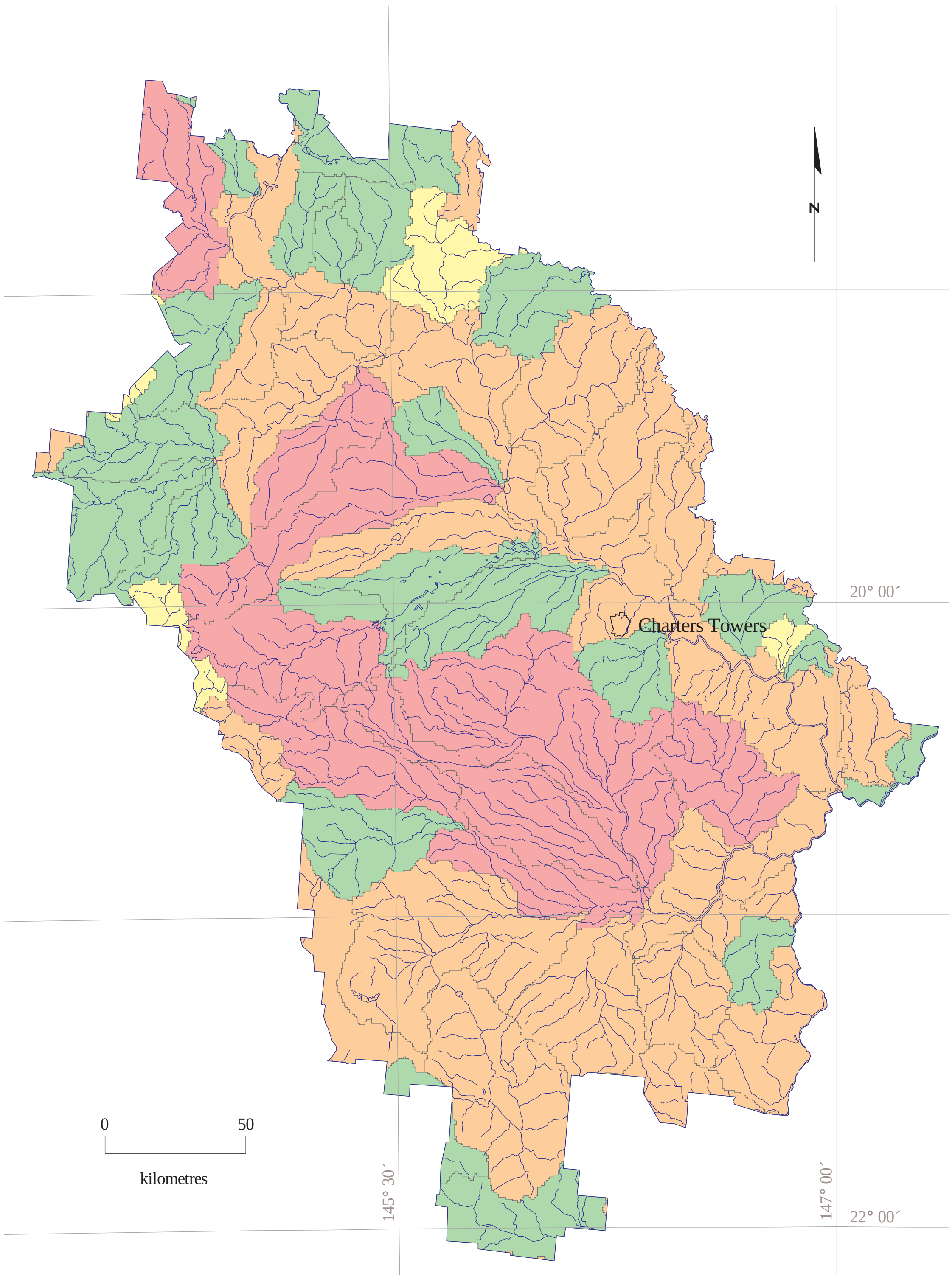


Figure 20. Average electrical conductivity (EC) for A and B horizons for all sites grouped by Orders of the Australian Soil Classification



LEGEND

- High Risk: Groundwater depth <=6m and TSS >=0.25%
- Moderate Risk: TSS >=0.25%, Groundwater depth 6m to 20m
- Moderate Risk: TSS < 0.25%, Groundwater depth < 6m
- Low Risk: Groundwater depth > 6m and TSS < 0.25%

Drainage

Sub-catchment boundaries

TSS = Total soluble salts

Figure 21. Salinity risks for catchments in the Dalrymple Shire (Bui,1996)

Electrical conductivity was measured for most horizons at ~63% of sites. These data give an indication of salt content of the soil types. Classes shown in Table 23 match those recorded in the UMA listing in Volume 2.

Table 23. Number of sites for various electrical conductivity (EC) classes

Soil type	Number of sites in salinity classes				Number of sites assessed for EC
	Nil EC <0.05 mS cm^{-1}	Slight EC 0.05-<0.3 mS cm^{-1}	Moderate EC 0.3-<1.2 mS cm^{-1}	Severe EC >=1.2 mS cm^{-1}	
Amity	1	18	5		24
Argentine		6	1		7
Barkla	2				2
Bluff	4	11	7	1	23
Boston	44	13	4		61
Bulliwallah	2	1	1		4
Burdekin	27	5	4		36
Burra	6	4	1	1	12
Cape	5	14	31	5	55
Carse O'Gowrie	27	4			31
Ceaser	13	4	1	1	19
Charters Towers	13	15	1		29
Conjuboy	21	13	1		35
Conolly	16	6	1		23
Corea	36	16			52
Creek	22	11	4		37
Dalrymple	39	11			50
Dotswood	3	18	29	2	52
Egera	1	5	17	9	32
Ewan	8	2			10
Fanning River	9	7	7	1	24
Felspar	5	5			10
Flagstone	8	2	1		11
Gainsford	11	3	1		15
Glencoe	10	10	2		22
Greenvale	19	5	6		30
Hillgrove	15	7			22
Hillview	1	1			2
Lime View	1	9	2		12
Liontown	1	19	21	2	43
Lolworth	4	29	16	1	50
Manoa	1	4	15	3	23
Maryvale		10	13	1	24
Mingela	2	4	10		16
Miscellaneous basalt		1			1
Mount Ravenswood	2	12	1		15

Table 23 continued

Soil type	Number of sites in salinity classes				Number of sites assessed for EC
	Nil EC <0.05 mS cm^{-1}	Slight EC 0.05-<0.3 mS cm^{-1}	Moderate EC 0.3-<1.2 mS cm^{-1}	Severe EC >=1.2 mS cm^{-1}	
Myrtlevale	1	11	9	8	29
Nial	4	8	5		17
Nosnillor	3	18	14	1	36
Pallamana	10	9	7	2	28
Pandanus	13	6			19
Paynes	12	6	2		20
Pentland	46	16	1	1	64
Pinnacle	5				5
Powlathanga		1	16	6	23
Rangeside	21	2	1		24
Rangeview	23	5			28
Rishton	31	3	1		35
Rolston	10	5	1	1	17
Scartwater	2	9	17		28
Star		4			4
Thorpe	4		1		5
Tuckers	11	7	1		19
Two Creek	34	15	2		51
Umala	1				1
Utchee	1				1
Victoria Downs		7	23	1	31
Wairuna	6	9	2	1	18
Wambiana	5	6	17	3	31
Warawee	3	7	9	2	21
Wattle Vale	29	7	1		37
Worsley		1			1
Yarraman		2	13	6	21

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GLOSSARY

Adamellite	A form of granite with roughly equal amounts of calcium and potassium bearing minerals.
Alluvial deposits (alluvium)	Material transported by rivers/creeks and deposited on alluvial plains, terraces, swamps etc.
Annual plant	Plant that completes its lifecycle from seed germination to seed production and death in a single season.
Apedal	Soil with no observable peds, see single grained and massive.
Argillaceous sandstone	A term for detrital sedimentary rocks, usually laid down in water.
Basalt	A fine grained, basic igneous rock. Generally low in silica, with high contents of Iron, Maganese and Calcium.
Batholith	Any large intrusive mass of igneous rock.
Cainozoic	That period from 65 m.y. to 2 m.y.
Calcrete	Any cemented terrestrial carbonate accumulation, usually calcium or magnesium carbonate.
Campaspe beds	Tertiary sediments of ‘ Buff argillaceous sandstone; some conglomerate; siltstone and claystone’.
CEC (Cation exchange capacity)	The total amount of exchangeable cations that a soil can absorb being made up of calcium, magnesium, potassium, sodium, aluminium and hydrogen. CEC affects soil properties and behaviour, stability of structure, the availability of some nutrients for plant growth and soil pH.
Clay	Soil particles <0.002 mm.
Coarse fragments	Particles >2 mm, but not segregations of pedogenic origin (formed in soil profile)
Coarse sand	Particles 0.6 to 2.0, has a feel similar to raw sugar.
Coherent	A condition where two-thirds of the soil material, whether or not composed of peds, will remain united at the given moisture state unless force is applied.
Cracking surface condition	Cracks at least 5 mm wide and extending upwards to the surface or to the base of any plough layer or thin (<0.03 m) surface horizon.
Devonian	That period of time 395 m.y. to 345 m.y.
Diorite	A coarse grained plutonic intermediate igneous rock, usually dark grey.
Dolerite	A medium grained basic igneous rock that has crystallised near the surface.

Glossary, continued

Dolomite	Material dominated by magnesium carbonate.
Drainage	How water drains from the soil profile. Rapid drainage will cause water to move past the root zone in a short period limiting water uptake by the plant, while slow drainage will cause the soil profile to become saturated with water. A saturated profile will exclude most of the oxygen from the soil which leads to root cell death and greatly reduced uptake of moisture by the plant. Drainage is dependent on landscape position (controls external drainage and run-on), permeability of soil (texture, structure and distribution of pore spaces) and impediments in the profile to water movement such as hardpan and rock. • Very poorly drained: Water is removed soil so slowly that the watertable remains at or near the surface for most of the year. • Poorly drained: Water is removed very slowly in relation to supply, all horizons remain wet for several months. • Imperfectly drained: Water is removed slowly in relation to supply. Some horizons may be mottled and remain wet for several weeks. • Moderately well drained: Water is removed from the soil somewhat slowly in relation to supply. Some horizons may remain wet for one week after water addition. • Well drained: Water is removed from the soil readily but not rapidly. The soils are often medium in texture with some horizons remaining wet for several days. • Rapidly drained: Water is removed from the soil rapidly in relation to supply. Soils are usually coarse textured or shallow and no horizon is normally wet for more than several hours.
Duplex	Term defined in Northcote (1979), also known as texture contrast soils, i.e. profiles in which the clay content increases significantly between the surface and subsoils over a boundary of less than 5 cm.
Earthy fabric	The soil material is coherent and characterised by the presence of pores and few if any peds.
EC	Electrical conductivity (mS cm^{-1}). Indicates level of salt (sodium and others) in soil/ water, the higher the salt content the higher the conductivity.
Fabric	Describes the appearance of the soil material (under x10 hand lens). See Earthy fabric, Sandy fabric.
Ferricrete	Indurated (cemented) layer of material dominated by hydrated oxides of iron (usually goethite and haematite), usually in the form of cemented iron nodules or as massive sheets. Also known as laterite, duricrust or ironstone.
Ferruginous gravel	Gravel which is dominantly composed of iron-rich materials; also known as ironstone and laterite gravel.
Fine sand	Particles 0.06 to 0.1 mm, just visible with the naked eye and which feel similar to coarse flour or table salt.
Firm surface condition	Coherent mass of individual particles or aggregates. Surface disturbed or indented by moderate pressure of forefinger.

Glossary, continued

Fluvial deposits	Sedimentary material deposited in shallow fresh water bodies, rivers, lakes etc.
Gabbro	A coarse grained basic igneous rock.
Gilgai microrelief	Associated with soils with shrink-swell characteristics. Consists of mounds and depressions.
Gneiss	Banded rocks formed through high grade regional metamorphism.
Gradational	Term defined in Northcote (1979), used to describe those profiles where the clay content increases gradually with depth
Granodiorite	A coarse grained acid igneous consisting of quartz (20–40%), calc-alkali feldspar and various ferromagnesian minerals (usually hornblende and biotite).
Great Soil Group	A soil classification by Stace et al. (1968).
Greywacke	Sedimentary rock that consists of fine to coarse, angular to sub-angular fragments cemented with finer material.
Gully erosion	A channel in soil more than 0.3 m deep. Formed by the action of water moving over bare soil washing away soil material.
Hardsetting	Compact, hard, apparently apedal condition formed on drying but which softens on wetting. When dry, the material is hard below any surface crust or flake, and is not disturbed or indented by pressure of the forefinger.
Holocene	Period of time from the last ice age to the present.
Horizons	Layers within a soil profile which have morphological properties different from those above and below (Northcote 1979).
Hummock grass	Coarse xeromorphic (able to withstand dry conditions) grass with a mound like form often dead in the middle.
Igneous rock	Broad group of rocks, usually crystalline formed from magma.
Incoherent	A condition where less than two-thirds of the soil material, whether composed of peds or not, will remain united at the given moisture state without significant force.
Laterite	Residual deposits formed in past tropical environments under climatic extremes of wet and dry seasons throughout the year. Leaching of the profile removes sodium, potassium, calcium and magnesium ions. Iron oxides remain to form a hardened and cemented layer.
Loam	A medium textured soil of approximate composition 10 to 25% clay, 25 to 50% silt and <50% sand.
Loose	Incoherent mass of individual particles or aggregates. Surface easily disturbed by pressure of forefinger.

Massive	Apedal coherent soil. When disturbed, soil separates into fragments which may be crushed to ultimate particles.
Medium sand	Particles 0.2 to 0.6 mm, which can be seen easily and feel similar to white sugar.
Mesozoic	That period of time 230 m.y. to 70 m.y. comprising Triassic, Jurassic, Cretaceous systems
Meta-sedimentary rocks	Rocks of sedimentary origin that have undergone varying grades of heating and pressure to form metamorphic type rocks.
Metamorphic rocks	Material (usually sedimentary) altered by heat and pressure and chemically active fluids.
Miocene	Epoch of the Tertiary between Oligocene and the Pliocene epochs.
Moisture availability	This is a measure or rating of the amount of moisture held in the soil which is available to the plant. It is defined as the difference between the field capacity of the soil and the wilting point. Field capacity occurs when the soils large pores (>30 microns) have drained but when all the small pores and capillary channels are still filled with water. Wilting point occurs when the soil is dry to the point where the plants can extract no more water. Soil texture has the greatest effect on availability of water to the plant.
Palaeozoic	The era ranging in time from 600–230 m.y. Preceded by Precambrian and followed by Mesozoic.
Perennial plant	Plant that continues growth from year to year. Herbaceous or woody.
Permian	Period of time from 280–225 m.y. at end of Palaeozoic Era.
pH	Soil pH is a measure of the acidity or alkalinity. A pH of 7.0 denotes a neutral soil with a log scale of increasing alkalinity of pH 7 to 14 and a log scale of increasing acidity of pH 7 to 1 (most soils have a pH range of 4 to 10). Each unit change in pH doubles the acidity or alkalinity.
PPF (Principal Profile Form)	The term given to the end point in the Northcote factual key soil classification.
Syenite	Coarse grained intermediate igneous rocks dominated by alkali feldspars.
Quaternary	The period of time from the present to 2 m.y. Continues from top of Pliocene.
Rhyolite	Fine grained to glassy acid volcanic rock.
Rill erosion	A small channel up to 0.3 m deep which can be largely obliterated by tillage operations.
Salinity	Salinity is the build-up of soluble salts, especially sodium chloride within the profile. High salt levels in the soil water increase the osmotic pressure and the plant's ability to take up moisture. Salinity in the soil profile can come from rising saline groundwaters and by addition of water which has generally low to moderate levels of salt, which is concentrated as the water evaporates.

Sandy fabric	The soil material is coherent, with few if any peds. The closely packed sand grains provide the characteristic appearance of the soil mass.
Saprolite	A form of decomposed rock. Characterised by the preservation of structures that were present in the unweathered rock.
Scald erosion	Removal of soil by water/wind, often exposing more clayey subsoil which is devoid of vegetation and relatively impermeable to water.
Schist	A regionally metamorphosed rock characterised by parallel arrangement of the bulk of the constituent minerals.
Sedimentary rocks	Rocks formed from material derived from pre-existing rocks by processes of denudation (weathering, transport, erosion) together with material of organic origin.
Self mulching surface	Strongly pedal loose surface mulch forms on wetting and drying. Peds commonly <5 mm in least dimension.
Shale	A group of sedimentary rocks formed in water environment which have bedding planes and a particle size <1/16 mm.
Sheet erosion	The relatively uniform removal of soil from an area without the development of conspicuous channels.
Silcrete	Strongly indurated (cemented) siliceous material.
Siltstone	A group of sedimentary rocks formed in water which have a silt sized particle range.
Silurian	The period of time 435 m.y. to 395 m.y. Named from the Silures, an ancient Celtic tribe of the Welsh Borderland.
Soft surface condition	Coherent mass of individual particles of aggregates. Surface easily disturbed by pressure of forefinger.
Soil Association	A mapping unit consisting of two or more soil types.
Structure	Soil structure refers to the distinctness, size and shape of peds. A ped is an individual natural soil aggregate consisting of a cluster of primary particles, and separated from adjoining peds by surfaces of weakness which are recognisable as natural voids or by the occurrence of cutans A soil has either no structure (i.e. apedal) or a grade of pedality listed below: • Weak: Peds indistinct and barely observable in undisplaced soil. When displaced, up to one-third of the soil material consists of peds. • Moderate: Peds well formed and evident but not distinct in undisplaced soil. Adhesion between peds is moderate to strong. When displaced, more than one-thirds of the soil material consists of peds. • Strong: Peds quite distinct in undisplaced soil. Adhesion between peds is moderate to weak. When displaced more than two thirds of the soil material consists of peds.

Glossary, continued

Surface condition	Describes the natural surface condition of the topsoil as listed. See self mulching, loose, soft, firm, hardsetting.
Tertiary	The period of time from 65 m.y. to 0 m.y.
Texture contrast	see Duplex
Tonalite	General term for Diorite: a coarse grained plutonic intermediate igneous rock.
Tussock grass	Grass that forms discrete but open tussocks usually with distinct individual shoots, or if not, then not forming a hummock.
UMA	Unique mapping area or discrete polygon (mapping unit) on a map.
Uniform	Term defined in Northcote (1979), used to describe those profiles where the clay content does not increase with depth.
WARIS	Worldwide Applicable Resource Inventory System Computer database for storage of site descriptions and data on each UMA. Rosenthal *et al*. (1986).