LANDS OF THE BALONNE–MARANOA AREA, QUEENSLAND

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Lands of the Balonne–Maranoa Area, Queensland

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MAPS

PART I. INTRODUCTION

By R. W. GALLOWAY*

I. LOCATION AND EXTENT

The Balonne–Maranoa area occupies 110,000 km² almost entirely in southern Queensland (Fig. 1). It extends northwards from the New South Wales border between longitudes 147° and 150°E. The northern border is the Great Dividing Range where the survey area abuts onto the southern end of three areas of east-central Queensland already surveyed (Nogoa–Belyando, Isaac–Comet, and Dawson–Fitzroy areas). It includes all or significant parts of the shires of Booringa, Bungil, Bendemere, Waggamba, Balonne, Warroo, and Tara in Queensland and Boomi in New South Wales. The entire area drains to the Darling River system.

Roma, which is the most important centre in the area, lies some 500 km west of Brisbane.

II. HISTORY, SETTLEMENT, AND COMMUNICATIONS

Settlement of the area commenced in 1847 and continued rapidly for several decades, particularly after the separation of Queensland from New South Wales in 1859 and despite set-backs of drought and financial crises. Roma was founded in 1862. However, a policy of closer settlement in the period 1884–1902 had little success and under the combined effects of drought, debt, pasture deterioration, and low wool prices, stock numbers declined and reached their lowest recorded level in 1902. From then until 1945 there was a gradual but very erratic recovery punctuated by droughts and periods of low wool prices. Since 1945 there have been substantial developments in clearing land by heavy machinery and in major expansion of the cropped area. Fluctuating wool prices and droughts have continued to be problems. An irrigation scheme was started at St. George in 1957, initially covering about 2200 ha.

The total population is about 25,000 people of whom 6000 are in Roma and 1400 in Mitchell. Lesser centres include St. George, Mungindi, Dirranbandi, and Surat. Outside of these centres and some smaller settlements the population is sparsely distributed and lives on extensive cattle- and sheep-raising properties. In recent years the population has declined in all parts of the area.

The main routes are the Warrego Highway and the Western Railway which runs east to west through Roma, the Moonie Highway which runs east to west to St. George, and the Carnarvon Highway which runs from north to south through the centre of the area. The Southern Railway from Brisbane terminates at Dirranbandi, and Mungindi in the extreme south-east is linked to the New South Wales railway system.

Away from the major routes there is a fair network of secondary roads and station tracks, many of which are impassable at times in the wet season.

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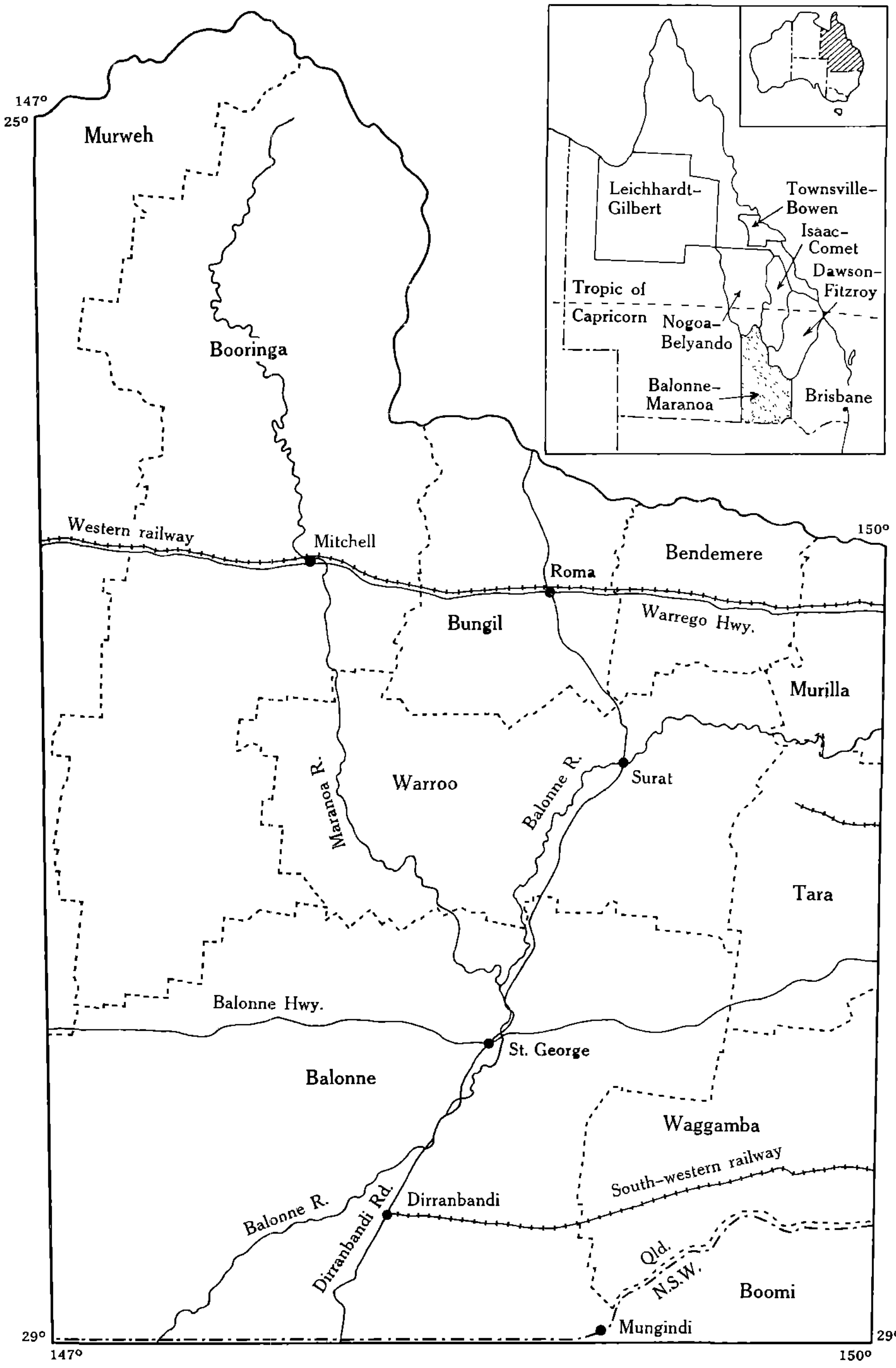

Fig. 1.—Location, settlement, and communications of the Balonne–Maranoa area.

III. Survey Methods

The survey followed the lines of previous investigations by the Division of Land Use Research. Major patterns were delineated on the air photographs and observation sites were selected where these patterns could be examined in the field. Traverses were planned to link these sites and to see as much of the area as possible. Field work was carried out in three periods totalling 15 weeks between April and October 1970. A total of 962 sites were examined in the course of traverses totalling some 12,000 km (Fig. 2). Altogether, some 2–3% of the area was seen during the survey.

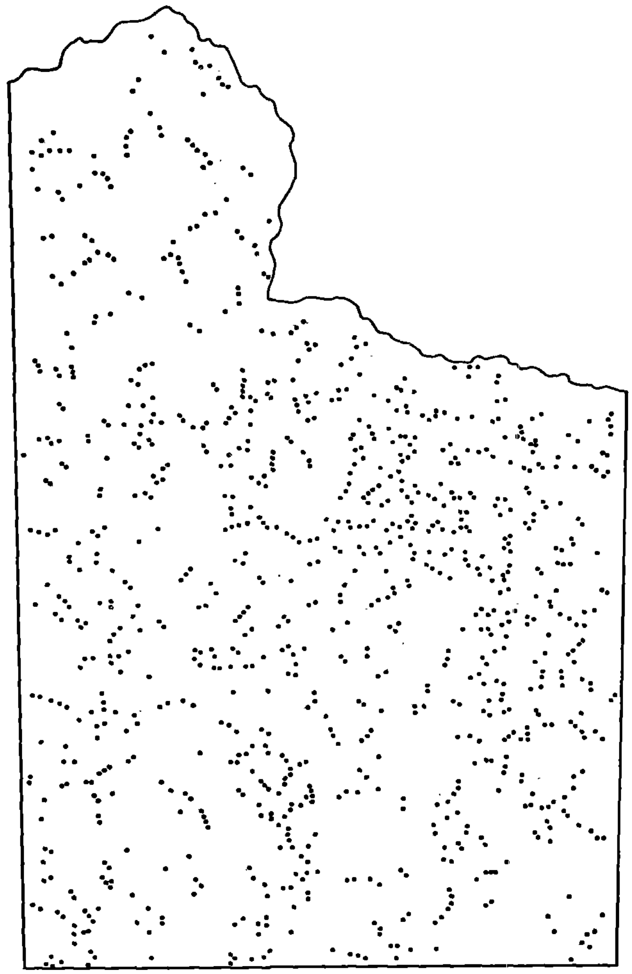

Fig. 2.—Distribution of observation sites.

From field observations, traverse notes, and photo interpretation 76 homogeneous types of country known as land units were identified and described. For mapping purposes these were grouped into 33 land systems.

The presentation of the data differs somewhat from that of previous surveys. It is discussed more fully in Part III of this report.

IV. Acknowledgments

The Queensland Department of Primary Industries assisted in several ways; their officers in Roma, particularly Mr. J. Shaw, kindly provided much information. The Queensland Herbarium made available the services of Mr. L. Pedley as botanist to the survey. Mr. F. Chippendale, Assistant Director of the Agricultural Chemistry Laboratory, carried out many of the soil analyses.

The Queensland Department of Forestry supplied information on timber economics. Hydrologic information was made available by officers of the Irrigation and Water Supply Commission of Queensland at St. George and Brisbane.

The following Commonwealth organizations provided data on the area: Bureau of Agricultural Economics, Bureau of Census and Statistics, Bureau of Meteorology, Department of Civil Aviation, and the Bureau of Mineral Resources, Geology and Geophysics. The Division of National Mapping supplied the topographic base for the land system map. The air-photo stereo pairs are Crown Copyright and have been made available by courtesy of the Director of National Mapping, Department of Minerals and Energy, Canberra.

In preparing the account of the climate there was close cooperation and helpful discussion with Mr. H. A. Nix and Mr. J. R. McAlpine. Miss K. Short, Mrs. G. Keig, and Mrs. A. Komarowski were responsible for most of the computational work. Dr. M. P. Austin provided valuable help in the field and in computer analysis of the vegetation.

PART II. SUMMARY DESCRIPTION

By R. W. GALLOWAY*

I. INTRODUCTION

This Part gives a brief general description of the area followed by summary accounts of the major features of the environment. Parts of the general description are illustrated by Plates 1–6 and references are made to most of the land systems.

II. GENERAL DESCRIPTION

The Balonne–Maranoa area can be split into six main regions (Fig. 3).

(a) *Northern Sandstone Country*

In the extreme north of the area there is a rugged zone of hills and mountains on quartz sandstone, capped along the Great Divide by up to several hundred metres of Tertiary basalt. This region is dominated by dissected tablelands (Plate 1, Fig. 1) with shrubby mixed layered eucalypt woodland and shallow stony soils (QhMe land system). The wider valleys between the dissected tablelands have undulating floors with uniform sandy soils supporting open-woodland and open-forest of apple and cypress pine (QuA land system). The basalt mountains have stony, shallow, clayey soils and open-woodland of mountain coolibah or ironbark (Plate 1, Fig. 2; BhMc land system) together with small high tablelands with deeper soil and stringybark forest (BtS land system). This is the wettest part of the area with mean annual precipitation of 500–800 mm and a strong summer maximum.

Fringing the southern side of the rugged sandstone country is an arcuate belt of undulating and rolling sandy country with rather uniform cypress pine open-forest on deep texture-contrast soils (QrCp land system).

(b) *Central and Eastern Clay Belt*

Running diagonally across the area from south-east to north-west is a complex belt of country mainly consisting of erosional lowlands on soft, fine-textured, deeply weathered rocks interspersed with some low uplands on sandstone beds or where resistant weathered caps have been preserved. The greater part of the belt has deep clayey soils supporting open-forest of belah and brigalow (Plate 2, Fig. 1; (S)uB1, (S)uXB, and (S)uBu land systems). These open-forests have now been extensively cleared for improved pastures and cereal cultivation, especially in the east (Plate 2, Fig. 2). Patches of Mitchell grass downs also occur in the belt (Plate 3, Fig. 1; SuD land system), principally around Mitchell and Roma but with outliers to the west as far as Morven and to the south-east beyond Surat. The downs are on fresh rocks but where traces of former deep weathering survive open-woodland of mountain coolibah occurs (SuMc land system).

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The interspersed uplands rise 20–200 m above their surroundings and generally support cypress pine open-forest, mixed layered eucalypt woodland, or poplar box woodland (QrCp, QhMe, SrX, (S)uX land systems). Where resistant lateritic or siliceous caps are present ironbark woodland occurs on the tops with open-forest of bendee on the eroded margins (Plate 3, Fig. 2; (S)rNi and (S)rBe land systems).

Throughout this belt rainfall is generally between 500 and 600 mm per annum.

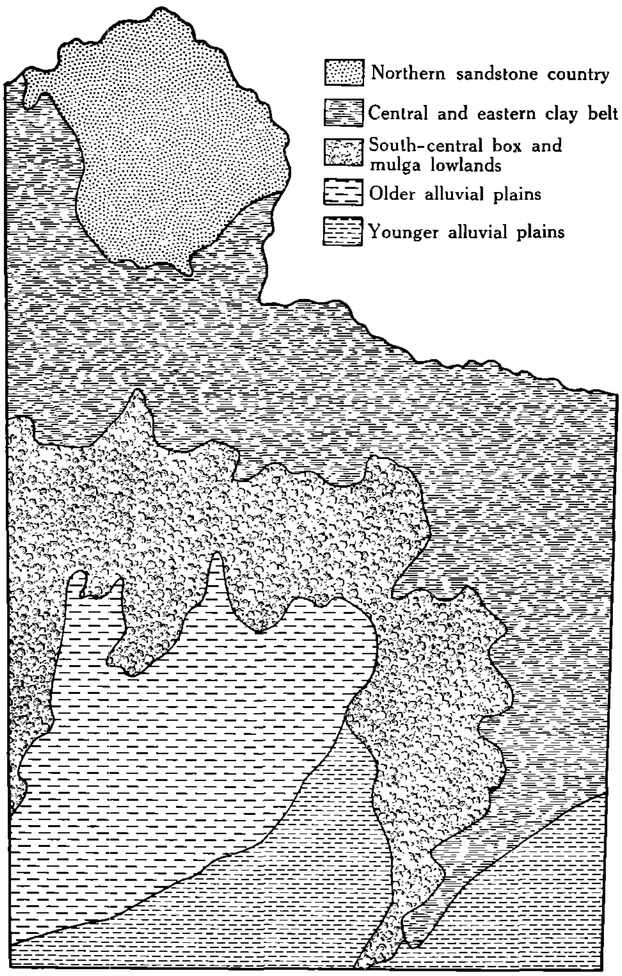


Fig. 3.—Major regions of the Balonne–Maranoa area.

(c) *South-central Box and Mulga Lowlands*

An arcuate belt of gently undulating lowlands extends from north to Bollon in the west through Talwood in the east to Mungindi in the south. This entire belt is characterized by box woodland in the east and mulga open-forest or woodland in the drier western portion (Plate 4, Fig. 1) where precipitation is 400–450 mm. It consists mainly of (S)uX, (S)uIX, (S)uXM, and (S)uM land systems. The soils are mainly red earths with some texture-contrast types and moderate amounts of ironstone gravel are consistently present. The soils are shallower and more subject to sheet erosion in the west.

(d) *Older Alluvial Plains*

Partially enclosed by the arcuate belt of box and mulga lowlands is an area of older alluvial plains. An extensive alluvial fan has been laid down by the Maranoa and smaller alluvial spreads are associated with Wallum Creek to the west and with the Balonne River to the east. The Maranoa and Wallum Creek fans are mainly loamy with linear sandy belts and some clay plains and are almost devoid of streams. The less extensive Balonne deposits are entirely clayey. On the loamy sediments red earths support poplar box woodland (Plate 4, Fig. 2) with an increasing proportion of mulga towards the drier western portions (CpXM and CpM land systems). On the sandy rises woodland of cypress pine, box, and apple and some heath predominate (CpCp land system). On the clays (Plate 5, Fig. 1) belah and brigalow open-forests are the rule (CpBl land system) except in the driest parts in the south-west where precipitation falls to below 400 mm and gidgee is the dominant tree (CpG land system).

(e) *Younger Alluvial Plains*

The extreme south of the area is occupied by extensive young alluvial plains, mainly of clay but with silt and sand tracts. The clays form wide plains with coolibah or belah open-woodland (Plate 5, Fig. 2) interspersed with grassland. This country is liable to flooding and forms AC land system.

Slightly higher areas are occupied by complex levee tracts with silts and sands supporting woodlands dominated by cypress pine and poplar box (ACp, AXM, AX land systems; Plate 6, Fig. 1). The texture-contrast soils are liable to severe sheet erosion where over-grazed (Plate 6, Fig. 2).

Precipitation on these younger alluvial plains ranges from less than 400 mm in the west to 500 mm in the south-east, of which fully 40% falls in the winter half-year.

Narrow tracts of alluvium also fringe all the major streams with sandy or loamy textures prevailing along the Maranoa system and clayey material predominating along the Balonne River system which drains fine-textured rocks and mature soils.

III. Major Features of the Environment

(a) *Climate*

The climate of the Balonne–Maranoa area is subhumid to semi-arid warm temperate. Mean annual precipitation ranges from about 600 mm in the north-east to 400 mm in the south-west; on the high ranges in the extreme north it may be as great as 800 mm. Two-thirds of this precipitation falls in the summer half-year. Mean absolute humidity is highest in summer but relative humidity is highest in winter on account of the lower temperatures. January with 60–80 mm mean precipitation is usually the wettest month, though locally February is slightly wetter. August and September are the driest months with most stations recording between 20 and 25 mm precipitation. Variability is somewhat greater in summer than in winter.

Mean daily temperatures range from 27–30°C in early February to 10–14°C in mid July. Temperatures over 40°C are not uncommon in summer and frosts frequently occur in winter, especially in low-lying sites in the south and west. The diurnal temperature range is considerable, being about 15 degC throughout the year.

Pan evaporation is about 2000 mm per year. Calculations indicate that soil moisture conditions are least favourable for crops in spring and improve through summer and autumn to optimal conditions in winter. Droughts are liable to occur at any season and are one of the least favourable aspects of the climate.

(*b*) *Geology*

The area occupies part of the Surat and Eromanga Basins which are subdivisions of the Great Artesian Basin separated by the buried Nebine Ridge. Both basins contain Mesozoic sedimentary rocks dipping gently south or west. Lithologies include quartzose and sublabile sandstones mainly exposed in the north and labile siltstone and shales which are predominantly exposed in the centre of the area. In the south labile fine-textured Mesozoic sedimentary rocks are buried by younger sediments.

Cainozoic rocks are widespread and include small areas of basalt flows and gabbro intrusions in the north and north-east, poorly consolidated sandstones and conglomerates in the centre and locally in the north, and very extensive fluvial deposits ranging from sand to clay mainly in the south. Some of the Mesozoic and Cainozoic rocks are weathered to considerable depths though the intensity of the weathering is usually moderate. Laterite horizons are practically absent but there are extensive areas of silicification, especially in the west.

Natural gas is exploited but the main economic mineral is ground water which flows as artesian bores in the south and west of the area (Plate 8, Fig. 2).

(*c*) *Geomorphology*

The northern part of the area consists of hilly and locally mountainous erosional topography mainly developed on resistant quartz sandstone and some basalt and lying between 400 and 1000 m above sea level. The centre comprises varied topography ranging from low hills and plateaux to plains mostly lying between 200 and 400 m and formed on shales and fairly weak siltstones locally rendered more resistant by the accumulation of silica or iron oxides due to deep weathering. The south is occupied by extensive depositional plains, the older having deep mature soils while the younger, formed by alluvia related to the present stream system, are liable to flooding in many parts.

In mid-Tertiary times the area was reduced to a deeply weathered erosion surface sloping gently southward. This surface was somewhat dissected and then partially buried by basalt which covered extensive areas in the north and flowed down old valleys. Continued erosion in later Tertiary times further dissected the mid-Tertiary landscape. In the centre of the area erosion in places cut completely through the deep weathering profile into the fresh shales beneath, leaving relics of the old surface as low mesas. Elsewhere more resistant members of the Mesozoic rocks formed low scarps and the sandstone hills in the north. The basalt area was considerably reduced and some valley infills were left standing as mesas. Much of the eroded material was deposited as sand, silt, and clay sheets in the south. In Quaternary and Recent times alluvial clay plains were formed in the south and along the Balonne. Minor wind-blown sands accumulated.

The area is drained to the south-west by the Maranoa which rises in the north and by the Balonne which enters from the east. The mean annual discharge of the combined streams at St. George is $1 \cdot 3 \times 10^9$ m^3.

(*d*) *Soils*

Seven major groups of soils have been recognized. The broad distribution of six of these is shown on the accompanying soil map.

(i) *Alluvial Soils.*—These youthful soils occur near present stream channels and have little profile development. Surface textures range from clays to sands. Their occurrences are too small and scattered to be shown on the soil map. They occupy 1% of the area.

(ii) *Brown and Grey-brown Soils.*—Textures of this group are either uniformly fine or gradational. They occur on both weathered and fresh labile sedimentary rocks and on alluvium and cover 8% of the area.

(iii) *Cracking Clay Soils.*—These soils are generally deep clays with marked shrinking and swelling properties. They cover 21% of the area. Where developed on weathered fine-textured rocks or materials derived therefrom, they have strong gilgai microrelief and are generally acid at depth if not throughout. On fresher shales the cracking clays are rather shallower and generally alkaline. On alluvium the clays are poorly drained and alkaline. Minor shallow cracking clays occur on shales and basalt.

(iv) *Duplex Soils.*—A sharp break between sandy or loamy surface horizons and clayey subsoils characterizes this group which occupies 33% of the total area. The soils occur widely on weathered argillaceous sediments where the coarser-textured surface horizons tend to be shallow and on quartzose sediments where the surface horizons are deep. Both alkaline and acid reactions occur and blocky or columnar structures predominate in the subsoils. Duplex soils also occur on alluvium and have been severely eroded in the drier south-west of the area.

(v) *Massive Earths.*—This widespread group covering 22% of the area is characterized by gradational textures, massive structure, and porous or earthy fabric. The soils occur on weathered argillaceous sediments, on reworked material derived therefrom, and sometimes on alluvium. On the weathered sediments they are moderately deep with fine ferruginous gravel, whereas on the reworked material they are very deep and lack gravel. Soil reactions are generally not far from neutral. A strongly alkaline variety occurs on transported material commonly in a mosaic with gilgaied cracking clays.

(vi) *Uniform Sandy Soils.*—These soils occur on sandy levees and quartzose sandstone and occupy 10% of the area. Reactions are neutral to medium acid throughout and single-grain structures becoming somewhat firmer at depth are the rule. On the levees soils are deep, on the sandstone moderately deep to shallow.

(vii) *Skeletal Soils.*—Stony shallow soils with little profile development occur in hilly terrain. Textures are sandy on sandstone and loamy or clayey on finer-textured rocks. These soils occupy 5% of the area—a low figure in comparison to most regions of Australia.

(*e*) *Vegetation*

The vegetation consists predominantly of grassland, low open-woodland, open-woodland, woodland, and open-forest. These formations can be split into various communities which have been impossible to map because of problems of scale and complexity. However, the land system map shows the generalized distribution of 23 of the major communities.

(i) *Grassland.*—This formation is dominantly Mitchell grass, though white spear grass is widespread and has increased as a result of grazing. It occurs on fairly fresh base-rich sediments and fine-textured alluvial flats; it is often interspersed with open-woodland of poplar box and coolibah. Fairly small areas of open-grassland occur in the south-west.

(ii) *Low Open-woodland.*—This relatively minor formation includes leopardwood, whitewood, and some brigalow. The leopardwood grows on alluvial soils in the south-west, the whitewood (sometimes associated with bauhinia) is dominantly on slightly weathered sedimentary rocks on the margins of the downs, while the low open-woodland of brigalow is a minor occurrence on the clay soils in the extreme south-west.

(iii) *Open-woodland.*—Coolibah woodland is widespread on alluvial clays in the south of the area; shrubs, mainly river myall and creek wilga, occur only in wetter situations. Mountain coolibah and silver-leaved ironbark woodland are restricted to basalts and limited shale areas in the north-east and gravelly undulating country in the extreme north. The widespread poplar box communities are on texture-contrast soils derived from shales or alluvium; an associated shrub layer is common. Apple woodlands are extensive on sandy soils in the north, often being severely modified by fire. Carbeen occupies sandy levees and minor dunes.

(iv) *Woodland.*—This is the dominant vegetation formation and occupies more than half the area. Considerable intergrading exists between the various communities recognized. Poplar box woodland is the most widespread and includes types with understoreys of cypress pine, bull oak, mulga, belah, brigalow, and sandalwood. Silver-leaved ironbark communities resembling the box communities are widespread and, in addition, grassy woodland, uncommon with poplar box, is common with this ironbark. In the north-east of the area the narrow-leaved rather than the silver-leaved ironbark predominates. Belah woodland, often associated with brigalow or bauhinia, occurs on fine-textured soils near Surat and Roma but most belah occurs as forest rather than woodland. Yapunyah and green-leaved box occur as relatively small patches on scarps of weathered rocks.

(v) *Open-forests.*—Cypress pine open-forests are widespread on sandy soils in the north, mulga dominates extensive loamy red earth areas in the west, and belah

Fig. 1.—Steep hills on quartz sandstone in the north of the area form the scenically attractive QhMe land system.

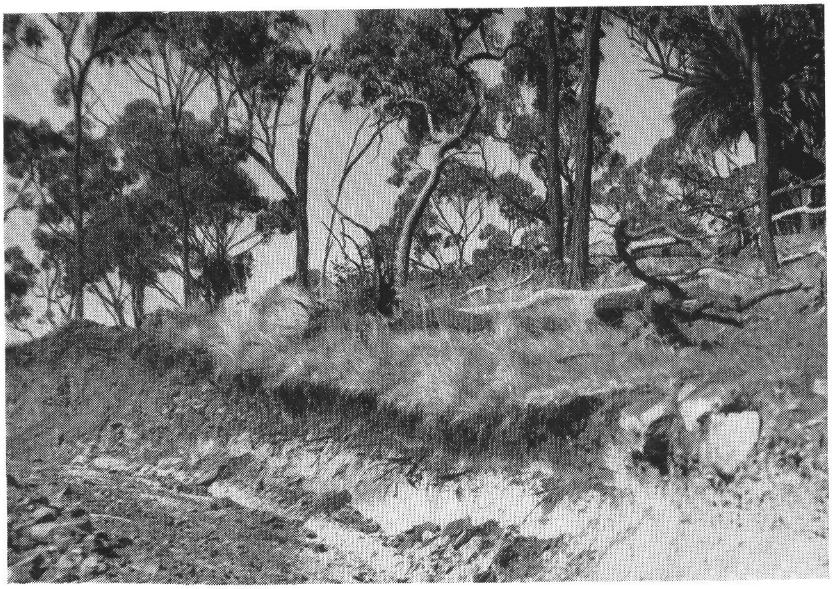


Fig. 2.—Basalt caps the Great Divide in the extreme north of the area and forms the rugged BhMc land system. Very stony soils and steep slopes are the rule.

Fig. 1.—Belah open-forest on clayey soils developed on soft weathered sedimentary rocks is one of the most widespread types of country and dominates the large (S)uBl land system. Gilgai microrelief is a common feature.

Fig. 2.—Most belah forests have now been cleared by pulling followed by burning. The cleared land is devoted to improved pastures dominantly sown with Rhodes grass or to cereal cropping in the east. Gilgai microrelief can be a severe handicap.

Fig. 1.—Undulating grassland with cracking clay soils forming SuD land system is developed on base-rich sedimentary rocks where erosion has removed the former overlying deep weathered zone. Where remnants of this zone survive there are open-woodlands of mountain coolibah, poplar box, or bauhinia.

Fig. 2.—Where resistant weathered layers cap low hills and rises, bendee open forest occurs on extremely shallow skeletal soils subject to severe sheet erosion.

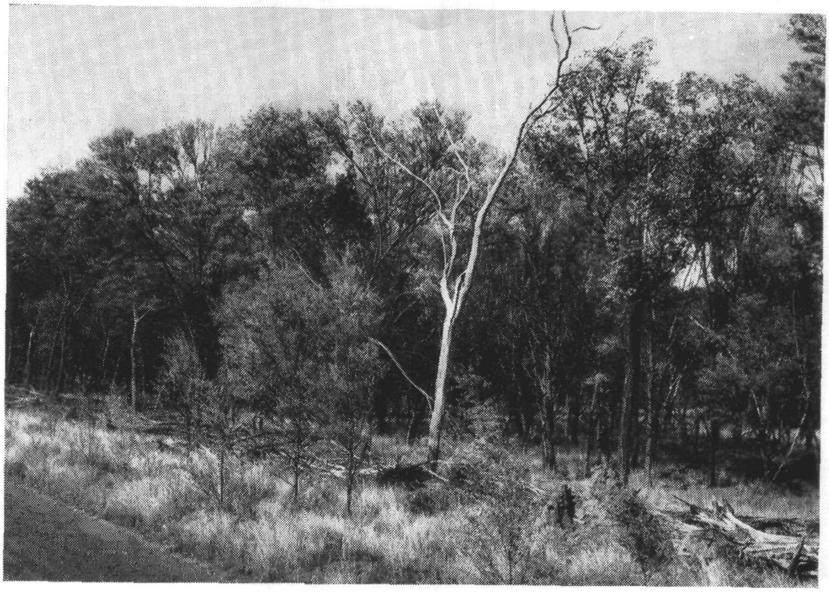


Fig. 1.—Mulga open-forest with varying proportions of poplar box and silver-leaved ironbark occupy extensive areas of red earths, especially in the west. This relatively simple homogeneous type of country predominates in (S)uM, (S)uXM, and (S)rXM land systems.

Fig. 2.—Poplar box woodland occupies extensive plains on Cainozoic sands and silts in CpXM land system. The tree and shrub communities are relatively simple and uniform but density and species composition of the grasses vary according to grazing pressures and the impact of fire. Note the contrast in grass cover along the fence.

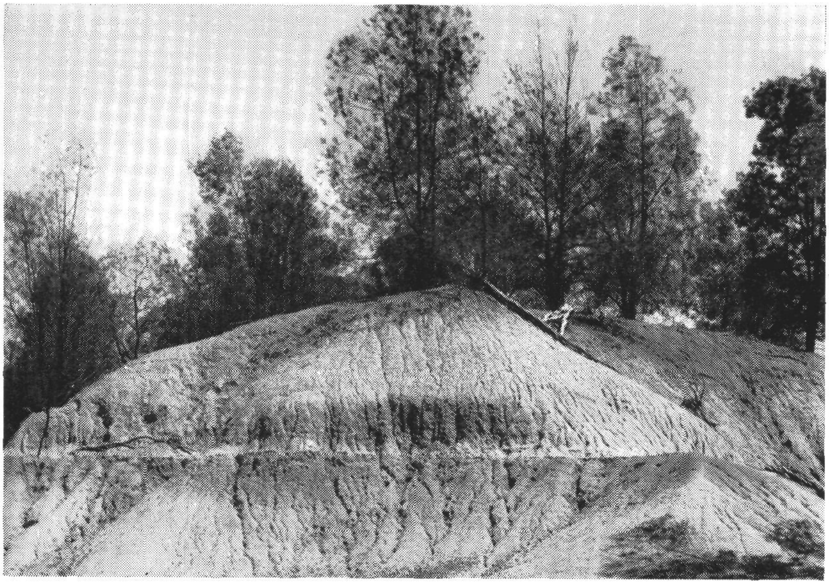


Fig. 1.—Cainozoic stone-free clays supporting belah or gidgee forests form extensive plains in the south and south-west and make up CpBl and CpG land systems. In this photograph a creek bank exposure shows about 4 m of this clay overlying similar material formed *in situ* by weathering of Cretaceous shale or mudstone.

Fig. 2.—Young alluvial clay forms extensive plains in the south-west with open-woodland of coolibah or belah interspersed with grassland. This country comprises AC land system and is liable to flooding.

Fig. 1.—Woodlands dominated by poplar box are common on levees and medium-textured alluvial plains throughout the area. They are especially significant in AX land system.

Fig. 2.—In the drier south-west, levees have locally suffered severe sheet erosion in cleared and over-grazed portions of AX land system.

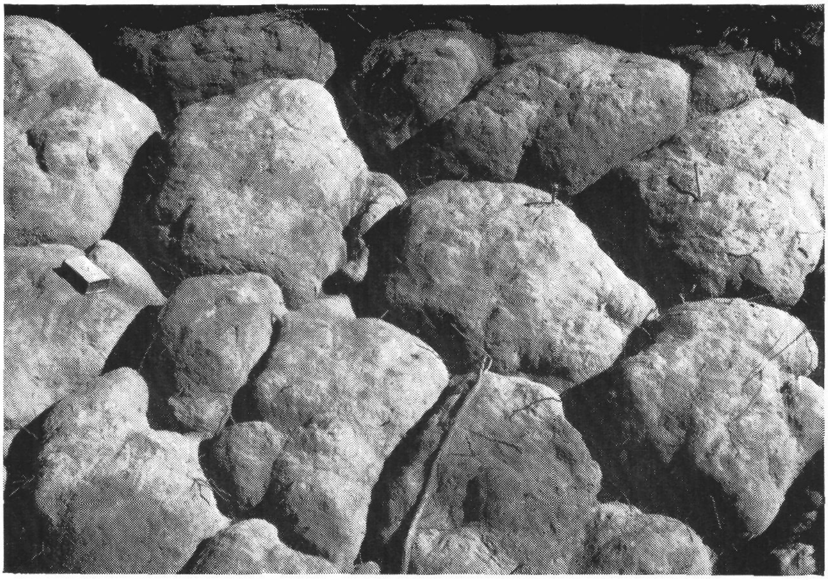


Fig. 1.—Dense clay columns are a feature of the B horizon of duplex soils in (S)uBu land system in the north-east. These poor soils support bull oak and restrict more intensive development.

Fig. 2.—Drought is a major hazard in the area and the edible foliage of mulga provides a valuable reserve of feed in the dry western portion. Mulga regenerates readily, provided seed trees are left when cutting for fodder and seedlings are not too heavily grazed.

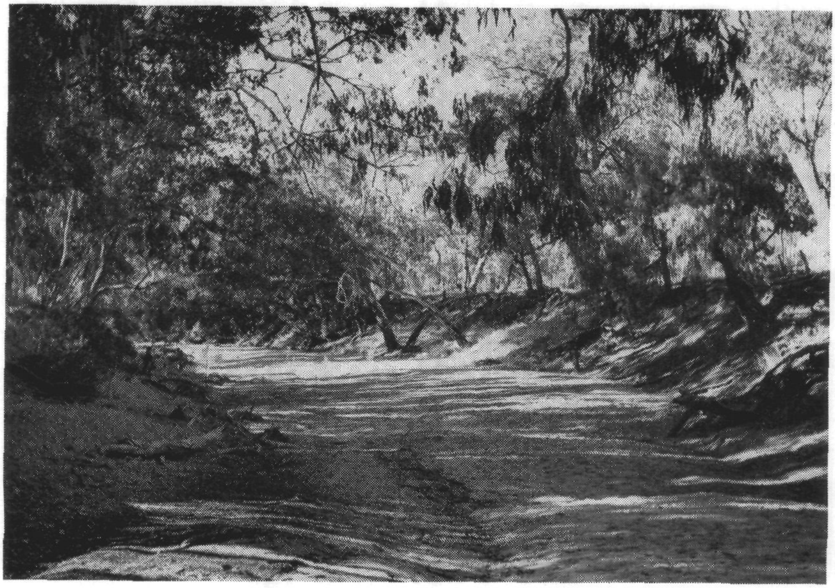


Fig. 1.—During the dry season even the biggest rivers, such as the Maranoa shown here, cease flowing. On the other hand, at the height of the wet season extensive flooding can occur on the clay plains in the south of the area.

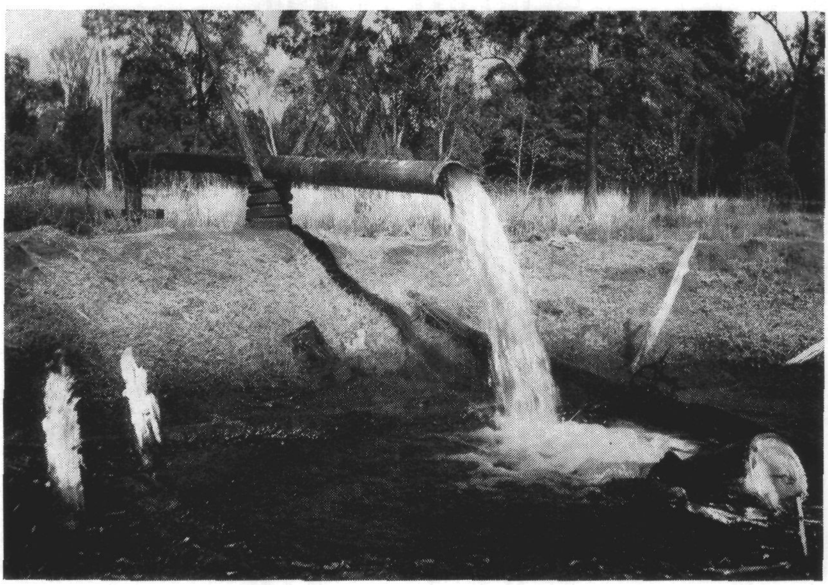


Fig. 2.—Artesian bores are a valuable source of stock water in the south-western third of the area. From the bores water is distributed to the paddocks by ditches ('bore drains').

occurs widely on fine-textured soils mainly in the east and centre. Shrubs are sparse in these communities but various eucalypts are often interspersed. Brigalow open-forest is found on predominantly clay soils and often has a shrub layer of wilga and false sandalwood, and there is usually an intermixture of belah or eucalypts. Gidgee forms minor open-forests in the extreme south-west. Bendee, lancewood, and bowyakka form forests on scarps with shallow soils on weathered rock.

Other minor vegetation elements include patches of softwood scrub (semi-evergreen vine thicket) on hills in the north-east, tall open-forest on the Carnarvon Range, and fringing communities of coolibah, river red gum, and blue gum along most channels.

IV. Land Use

In the rugged isolated north of the area cattle-breeding is by far the dominant occupation, with large holdings running up to 25,000 ha. Despite the relatively good rainfall of this part the poor soils and rough topography make it unlikely that other forms of agricultural production will be introduced. Forestry is an important additional resource with considerable potential.

Holdings are nearly as large in the dry western part of the area which has been almost wholly devoted to the production of wool. Here the use of mulga for drought feed (Plate 7, Fig. 2) and artesian water (Plate 8, Fig. 2) have been important aids.

Throughout the centre of the area the properties are generally 4000–8000 ha and combine both sheep and cattle production in varying proportions. Cereal production is minor but increasing, especially on the better soils in the wetter eastern part of this area.

In the east holdings are mainly 1000–4000 ha, occasionally falling below 1000 ha in places along the railway. Cattle, sheep, and cereal production are all important enterprises.

Over most of the area stock are grazed on natural pastures and improvement is confined to ring-barking and clearing, operations which are held to improve the carrying capacity significantly. In pulled belah country, which is mainly in the moister east, pasture improvement with exotic species is practised (Plate 2, Fig. 2) and there is a moderate use of fodder crops as well as other supplements to tide over the low value of winter pastures. Sheet erosion is widespread on alluvial duplex soils in the south-west and on massive red earths in the west.

Cereal production has increased rapidly in recent years though it is still a relatively minor feature of the economy of the region as a whole. It is concentrated on the cracking clays and texture-contrast soils of downs and pulled belah–brigalow country. Yields are low and variable according to the rainfall. Apart from a little grain sorghum the cereals are winter crops; grain wheat predominates but both wheat and oats are also grown as fodder. Little fertilizer is used and there are problems of erosion, especially on weakly structured red-brown earths, of gilgai microrelief, and of flooding on alluvium.

Extensive forest reserves exist in the north and north-east where natural stands of cypress pine on sandy soils are exploited. There is also some minor use of eucalypt timber in the extreme north-east.

An irrigation scheme at St. George provides water to some 20 farms, totalling 4800 ha. Lucerne, fat lambs, and cereals have been the main products but there has recently been a significant increase in cotton. Because rainfall and river regimes are both highly seasonal and erratic (Plate 8, Fig. 1), extensive water storage is required in relation to the extent of irrigated areas.

If price trends of the late 1960s continue it seems likely that there will be a considerable reduction in the emphasis on wool, a substantial increase in cattle production (restricted perhaps by availability of capital and store cattle), and some moderate growth in cereal production.*

The extreme north of the area abuts on the Carnarvon National Park and this district has some potential for recreational development. A tourist access road has been built to the top of the Carnarvon Range.

*Since this account was written wool prices have in fact recovered remarkably.

PART III. LAND UNITS, MAPPING UNITS, AND LAND SYSTEMS OF THE BALONNE–MARANOA AREA

By R. W. Galloway,* R. H. Gunn,* and L. Pedley†

I. Introduction

Information on the lands of the Balonne–Maranoa area has been collated at three different levels of detail: land unit, mapping unit, and land system. Following experience with a re-examination of survey data from three areas immediately to the north (Gunn and Nix, unpublished data) most emphasis has been laid on the land unit level, land systems being regarded as no more than convenient mapping entities.

A small portion of the area in the east has been surveyed by Dawson (1972).‡ The land systems he mapped and described are generally similar to those recognized in this report.

II. Land Units

Land units are tracts of country with a fairly high degree of uniformity in land form, parent material, soil, climate, and vegetation. They are too small and difficult to identify on the available air photographs to be mappable. In this report they have been defined primarily by analysis and classification of the data from 962 field observation sites supplemented by traverse notes and air-photo interpretation. The primary basis of classification has been the arboreal vegetation with supporting evidence from geology, land forms, and soils. The recognition of catenary relationships of soil and vegetation has also helped to define some of the land units, as indicated in Part VII. The natural vegetation is, of course, intimately related to the environment and consequently the identification and description of units refer to uncleared vegetation as far as possible. The plant cover on cleared land is too variable to be useful in defining a basic inventory of the types of country.

In the Balonne–Maranoa area 76 land units have been recognized. Each is described in summary form in this Part and further information is given in the subsequent Parts. The characteristic photo pattern of most units is illustrated by a small stereo pair and the general distribution is shown as a small map. Sketches illustrate the catena relationships between land units. Basic criteria for identification in the field are given. The number of observation sites used in defining each unit serves as a rough guide to the accuracy of the description. There can be no doubt that some of the land units in the area, particularly in the more inaccessible parts, have been missed. The land units are arranged in a sequence from steep country on rocks little affected by Tertiary deep weathering (quartz sandstone, fresh sediments,

*Division of Land Use Research, CSIRO, P.O. Box 1666, Canberra City, A.C.T. 2601.

†Queensland Department of Primary Industries, Brisbane.

‡Dawson, N. M. (1972).—Land inventory and technical guide, Miles area, Queensland. Part 1. Land classification and land use. Qd Dep. Primary Ind., Div. Land Utiliz. tech. Bull. No. 5.

basalt) through weathered rock of decreasing degree of resistance to late Cainozoic unconsolidated deposits and alluvium.

The land units range in size from 6450 km^2 to 14 km^2. The 12 largest units occupy 50% of the area while the 12 smallest cover just over 1% of the area.

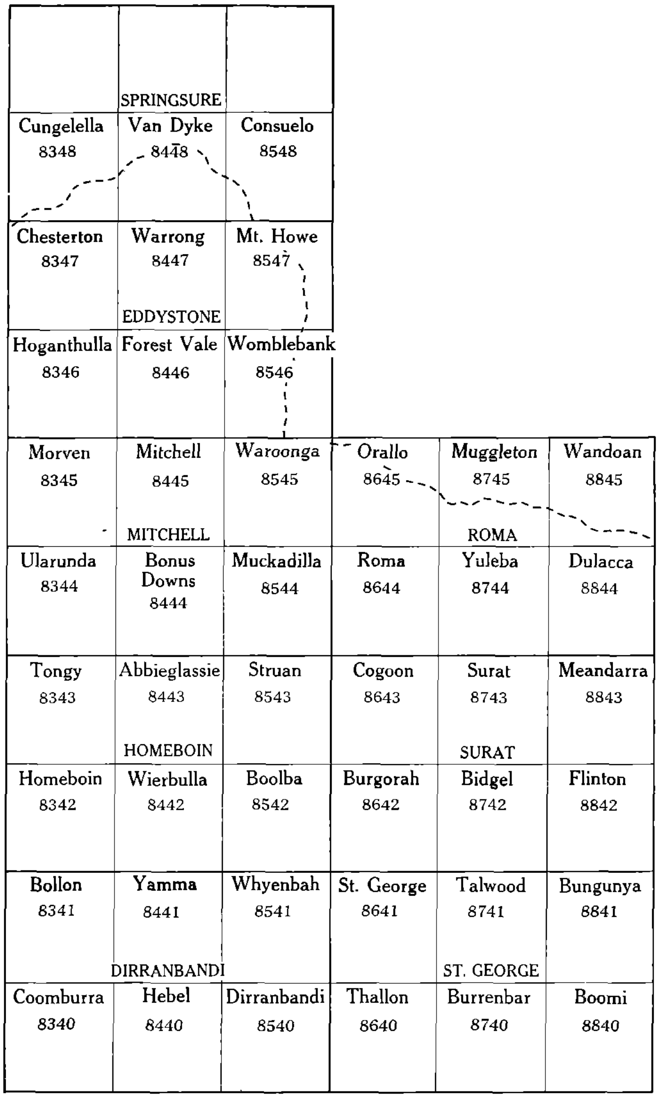


Fig. 4.—Index of 1 : 250,000 maps and 1 : 100,000 mosaics (photo keys).

III. Mapping Units

During air-photo interpretation entities known as "mapping units" were delineated and labelled according to an *ad hoc* system of symbols indicating dominant geology, relief, and vegetation. Mapping units are the smallest patterns that can readily be delineated in the time available on the existing air photographs (1:85,000, black and white, pan minus blue). They are believed to correspond to fairly discrete tracts of country on the ground. The accuracy of labelling is not high since only 2–3% of the area was actually seen on the ground and many vegetation patterns are indistinguishable on the available air photographs. On the other hand, the boundaries seem reasonably accurate since they follow recognizable breaks in photo patterns.

Mapping units are too complex and insufficiently accurate to publish; in this survey about 1000 were recognized. However, transparent overlays showing the mapping units with an explanatory key and the exact location of observation sites for which detailed field data on land form, soil, and vegetation can be supplied, are obtainable on request from the CSIRO Division of Land Use Research, Canberra. These overlays are on the same scale and sheet lines as the 1:100,000 mosaics (photo keys) obtainable from the Division of National Mapping, Department of Minerals and Energy, Canberra (Fig. 4).

TABLE 1

NOMENCLATURE OF LAND SYSTEMS

MATERIAL (Capitals)

Q	Quartz and quartzose sandstone
S	Shale, mudstone, and other labile sediments
B	Basalt
C	Cainozoic deposits. Subdivisible into (*a*) sand–silt–mud and (*b*) clay
A	Alluvium. Subdivisible into (*a*) sand–silt–mud and (*b*) clay. All alluvium is regarded as plains
( )	Deeply weathered rocks. Subdivisible in this area into three classes of varying resistance to erosion

RELIEF (Lower case)

t	Tableland (very restricted extent)	u	Undulating
h	Hilly	p	Plain
r	Rolling	f	Liable to flooding

VEGETATION (First letter in capitals, second letter lower case)

Me	Mixed eucalypt	Be	Bendee
A	Apple	Bu	Bull oak
Cp	Cypress pine	M	Mulga
Sw	Softwood scrub	Y	Yapunyah
X	Poplar box	B	Brigalow
Mc	Mountain coolibah	Bl	Belah
D	Downs (i.e. grassland)	G	Gidgee
S	Stringybark	C	Coolibah
I	Silver-leaved ironbark	Bb	Black box
Ni	Narrow-leaved ironbark		

Examples.—QrCp land system is rolling country on quartzose sandstone dominated by cypress pine. (S)hY land system is hilly country on weathered labile sedimentary rocks dominated by yapunyah. AC land system is alluvial plains with coolibah.

IV. LAND SYSTEMS

The land units and mapping units have been grouped into 33 land systems in order to provide a practical map of the types of country. Reflecting this dual derivation the land systems can be defined as both readily identifiable photo patterns and

TABLE 2

OCCURRENCE OF LAND UNITS IN LAND SYSTEMS

A, unit occupies > 30% of land system; C, unit occupies 10–30% of land system; O, unit occupies < 10% of land system

Land unit	QhMe	QuA	QrCp	ShSw	SrX	SuMc	SuD	BtS	BhMc	BuI	(S)rNi	(S)rBe	(S)rXM	(S)uM	(S)uXM	(S)uX	(S)uIX	(S)uBu	(S)hY	(S)uXB	(S)uBI	CpCp	CpXM	CpM	CpBXM	CpBI	CpG	ACp	AXM	AX	AC	ABb	Af
1	A																																
2	O																																
3	C																																
4	C																																
5	O	A	O															O															
6			O																														
7	C	C	C									O			O			C															
8		C	A												O	O	C	O															
9				A					O																								
10					C																												
11					A																												
12						A	C														O												
13						A	C																										
14							A																										
15								A																									
16								C																									
17									A																								
18									C	A																							
19									O	A																							
20											A	C							O														
21											C																						
22											C	A	C	O					O														
23													A																				
24													C	A	A												O						
25		O	O								C	O	O			C	O	C			O												
26													O	C	O	A	O																
27													O				A																
28											O	O							C														
29			O													O				O													
30			O								O					O		O															
31																O		A															
32													O		C																		
33			O										O		C	C	C	O		C	O												
34															O		C																
35																			A														
36												O							C		O												
37															O	O				A	C		O			O							
38																					C					O							
39																				C	O												
40																					O												
41						O	O														O												
42																					O												
43																			C	O	O					O							
44																				O	C					O							
45																						A											
46																						A	C	O									
47																						O	O	C									
48																O							O	O									
49																						O	A	A									
50																									A								
51			O																				C	C									
52																									A								
53																				O						C							
54																											C						
55																				O	O					C							
56																									O		C						

TABLE 2 (*Continued*)

Land unit	Land system																																
	QhMe	QuA	QrCp	ShSw	SrX	SuMc	SuD	BtS	BhMc	Bul	(S)rNi	(S)rBe	(S)rXM	(S)uM	(S)uXM	(S)uX	(S)uIX	(S)uBu	(S)hY	(S)uXB	(S)uBl	CpCp	CpXM	CpM	CpBXM	CpBl	CpG	ACp	AXM	AX	AC	ABb	Af
57																									O		C						
58																					O					A							
59																										O	C						
60																												A	O	O			
61																						O						O					
62																												O	A				
63	O																					O						C	C	O			
64		O	O			O							O		O	O	O	O		O	O					O		C	C	A	O		O
65																								O					O				
66																													O	C	O	O	
67		O							O	O																				O			
68							O																							O			
69																														O	C		
70																															C	O	O
71																														O	A	C	C
72																									O							A	
73																											C		O	O		O	
74																															O		A
75																													O	O			
76																															O		O

as tracts of relatively uniform country. Grouping was carried out according to 10 types of material and 23 dominant classes of vegetation. The types of materials are discussed in Part VI and some examples of the landscapes developed on them are illustrated in the plates. Use of vegetation in defining land systems in this area implies that account is taken of climatic factors and the 1:500,000 land system map doubles as a map of dominant vegetation types. It should be pointed out that estimates of the relative proportions of different units within each land system are only rough approximations based on general impressions obtained during field work.

In view of the rather different emphasis and mode of presentation compared to earlier surveys, as well as the differing nature of the land, the colouring of the map is not fully compatible with the colours on the three adjacent survey areas to the north. In line with the reduced emphasis on land systems the practice of assigning them geographic names has been dropped. Instead, land systems have been given simple descriptive key letters related to popular terms for material, relief, and vegetation. The system is explained in Table 1. The arrangement of the land systems follows that of the land units in being a sequence from little-weathered rock through weathered rock to alluvium.

The five largest land systems together cover just over half the area. The five smallest land systems together cover barely 1% of the area.

The land units in each land system are given in the reference to the land system map and in Table 2. The numbers of land units per land system range from one in ShSw (softwood scrub on hills of shale) to 18 in (S)uBl (undulating relief on weathered shales dominated by belah forest). However, this variability is less significant than might at first appear since more than half of every land system is made up of one, two, or at the most three land units. Most of the additional units are minor inclusions of different country too small to be mapped as other land systems.

Generally the more extensive land systems have more units than the smaller ones (Fig. 5), mainly because there were more observations and hence more scope for subdivision.

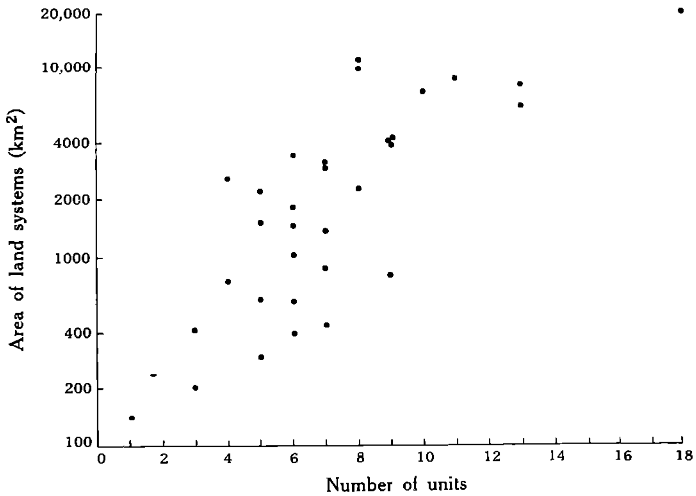


Fig. 5.—Number of units in relation to area of land systems.

The distribution of land units on various materials is shown diagrammatically in Figures 6–9.

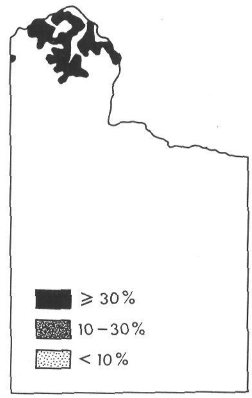
Geomorphic category	Quartz sandstone			Quartzose sandstone		
Land system	QhMe		QuA part	QuA part, QrCp		
Terrain	Hilly dissected	Hilly to rolling	Gently undulating	Rolling to gently undulating		

Soils	Skeletal soils, Ga (Ee); extensive outcrop	Shallow uniform sandy soils, Fc (Fe)	Deep uniform sandy soils, Fe (Fd, Fc)	Deep uniform sandy soils, Fe, Fc	Uniform sandy soils, Fe, Fd, Fc	Sandy duplex soils, Dg (Df, Dd, De)
Vegetation	Mixed eucalypt or *narrow-leaved ironbark* woodland (sandstone forest)	Mixed eucalypt–*rusty gum woodland*	Rusty gum woodland and/or silver-leaved ironbark, tumble-down gum, budgeroo cypress pine woodland	Bloodwood, silver-leaved ironbark, budgeroo woodland	Cypress pine forest with emergent silver- and/or narrow-leaved ironbark, tumble-down gum, or bloodwood	Cypress pine, box, silver-leaved ironbark, tumble-down gum woodland

Land units: 1, 2, 3 — 4 — 5 — 6 — 7 — 8 — ro

Fig. 6.—Distribution of land units on quartzose sediments.

Land Unit 1 (1460 km²)

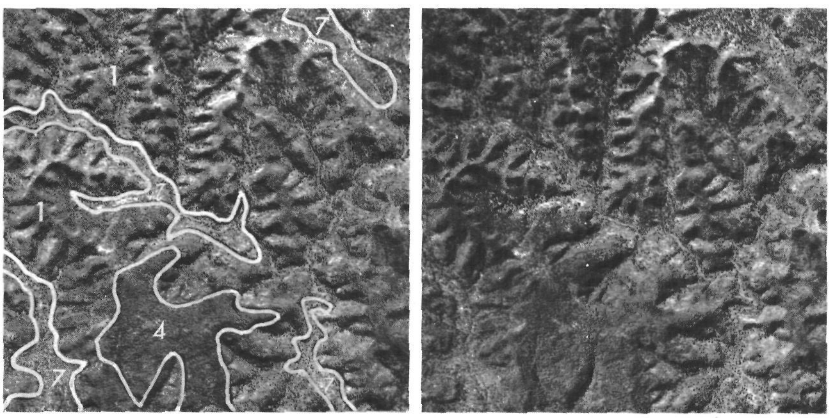


Field Criteria.—Steep, rocky hills, bloodwood–ironbark woodland with shrubs, skeletal soils.

Median Rainfall.—Nov.–Apr.: 400–530 mm. May–Oct.: 170–200 mm.

Material.—Quartz sandstone.

Relief.—Steep hills, dissected plateaux, stony with much outcrop; slopes 10–50% and locally up to vertical.



Position on Slope.—Crests and upper slopes.

Soil.—Skeletal soils: very shallow (< 30 cm) sandy and gravelly, Ga (Uc1.2).

Vegetation.—Mixed layered eucalypt woodland; *Eucalyptus decorticans* usually predominant, *E. trachyphloia*, *E. bloxsomei*, and *Angophora costata* often conspicuous; low trees and shrubs of *Lysicarpus angustifolius*, *Acacia pustula*, *Casuarina inophloia*, *Hovea longifolia*, etc.; ground cover sparse, mainly *Aristida muricata*, *Cleistochloa subjuncea*, and *Dianella* sp.

Land Capability.—VII–VIIIt$_{7-8}$, r$_{7-8}$. **No. of Observations.**—1.

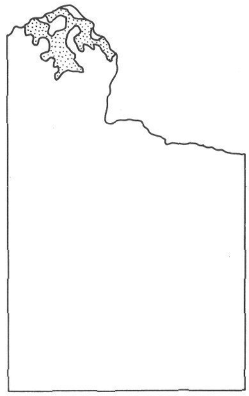
LAND UNIT 2 (120 KM^2)

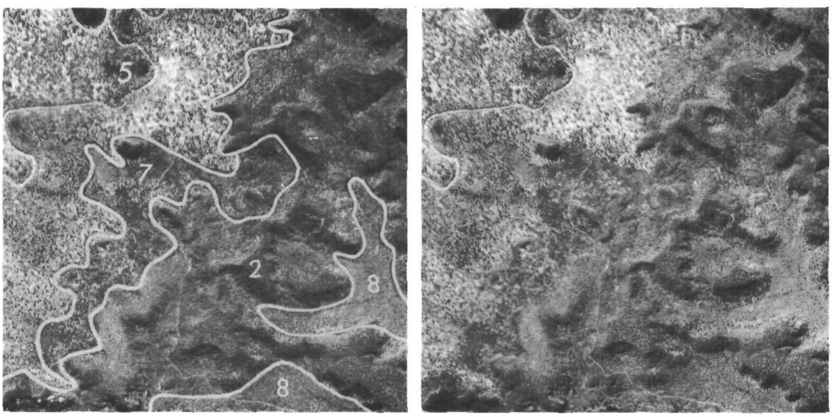
Field Criteria.—Steep sandstone hills, narrow-leaved ironbark woodland with wattles, massive earths.

Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 170–200 mm.

Material.—Quartz sandstone and siltstone.

Relief.—Hills, dissected plateaux; slopes 5–20%.





Position on Slope.—Benches on mid slopes, lower slopes.

Soil.—Massive earths: moderately shallow (60–90 cm), Ee (Gn2.81, 2.41); medium acid throughout; extensive outcrop.

Vegetation.—Woodland of *Eucalyptus drepanophylla*, occasionally *E. decorticans*, sometimes with lower *E. trachyphloia* and *Acacia longispicata* and shrub layer of *A. bancroftii*, *A. complanata*, *Dodonaea* spp., and *Leptospermum*; ground cover sparse, usually *Cleistochloa subjuncea* and *Amphipogon caricinus*, occasionally *Arundinella nepalensis*, or *Eremochloa bimaculata*.

Land Capability.—IV or VIt_{4-6}, m_4. **No. of Observations.**—2.

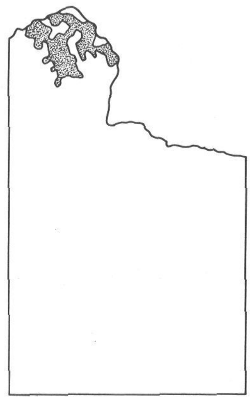
Land Unit 3 (290 km²)

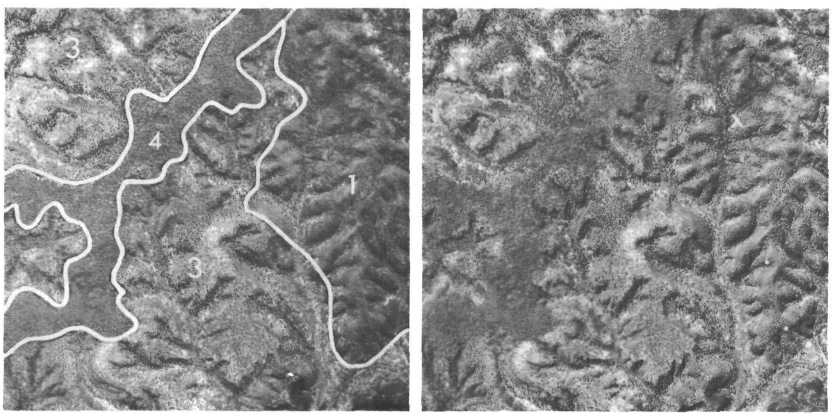
Field Criteria.—Low sandstone hills, poplar box woodland, skeletal soils.

Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 170–200 mm.

Material.—Quartz sandstone.

Relief.—Hills and rolling country with sharply incised valleys; slopes 5–20%.





Position on Slope.—Lower slopes, benches.

Soil.—Skeletal soils: very shallow (< 30 cm) sandy and gravelly, Ga (Uc1.21); minor shallow texture-contrast soils on some lower slopes, Dc (Db2.22).

Vegetation.—Woodland of *Eucalyptus populnea*; shrubs absent; ground cover sparse, *Eremochloa bimaculata* common, with *Bothriochloa decipiens* and *Aristida ramosa* occasional.

Land Capability.—VIt_6, d_6. **No. of Observations.**—1.

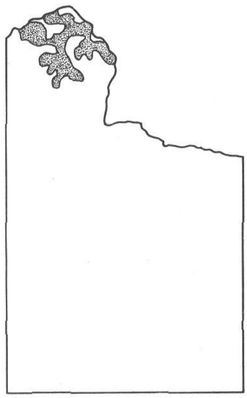
LAND UNIT 4 (555 KM^2)

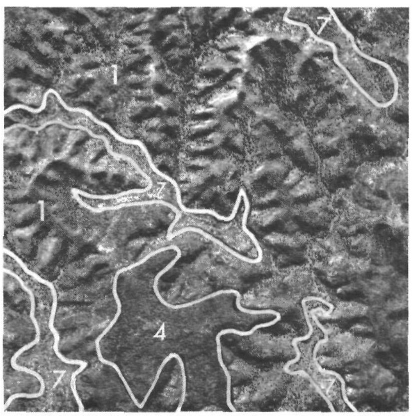
Field Criteria.—Sandstone rises and low hills, stringybark or ironbark woodland and shrubs on sand.

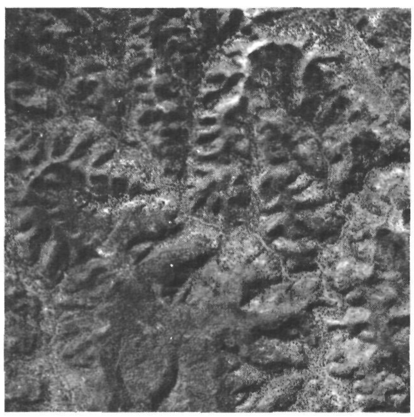
Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 170–200 mm.

Material.—Quartz sandstone.

Relief.—Rolling to hilly; slopes 5–20%; frequently stony.







Position on Slope.—Mainly crests and upper slopes.

Soil.—Uniform sandy soils: mainly shallow (< 60 cm), Fc (Uc1.21, 1.23); some deep soils (> 90 cm), Fe (Uc5.11, 4.2), medium acid throughout.

Vegetation.—Mixed layered eucalypt woodland; *Eucalyptus bloxsomei*, *E. major*, *E. umbra*, and *Angophora costata*, sometimes, however, mainly *E. fibrosa* subsp. *nubila* or less frequently *E. drepanophylla*; lower tree layer sometimes dense of *Callitris columellaris*, *Lysicarpus angustifolius*, *Petalostigma pubescens*, and *E. trachyphloia*; shrub layer floristically diverse, mainly *Acacia* spp., *Leptospermum sericatum*, and *Hovea pannosa*, and *Pultenaea* spp.; ground cover sparse, *Aristida echinata*, *A. browniana*, *Cymbopogon refractus*, *Cleistochloa subjuncea*, and *Entolasia stricta*.

Land Capability.—VIt_6, d_{4-6}. **No. of Observations.**—5.

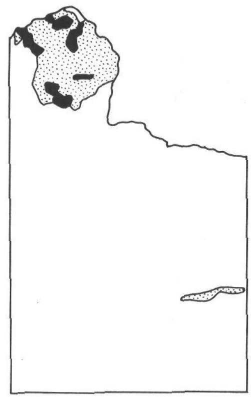
Land Unit 5 (1800 km²)

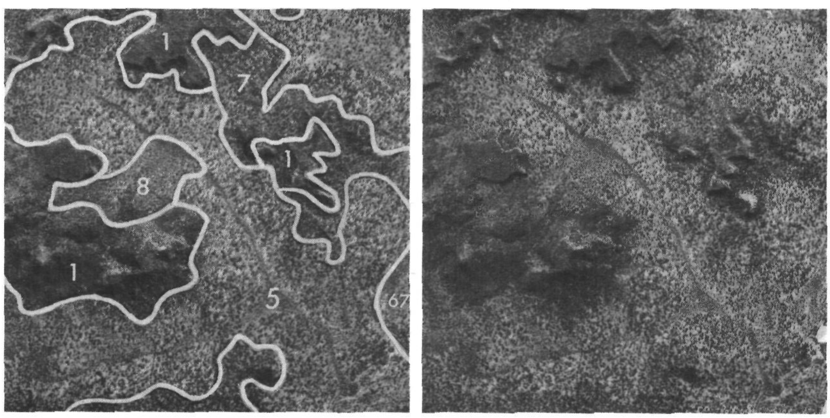
Field Criteria.—Wide valleys in sandstone country, open-woodland of rusty gum or budgeroo with cypress pine understorey, sandy soils.

Median Rainfall.—Nov.–Apr.: 360–480 mm. May–Oct.: 160–220 mm.

Material.—Sandy colluvium, minor quartz sandstone.

Relief.—Wide valley floors in dissected sandstone hills; mainly undulating, some rolling; slopes 2–5%.





Position on Slope.—Mainly colluvial aprons, minor lower slopes.

Soil.—Uniform sandy soils: mainly >150 cm deep, yellowish brown to brown, Fe (Uc4.2, 5.11); less commonly red, Fd (Uc1.23); occasionally shallow, Fc (Uc1.21).

Vegetation.—Open-woodland of *Angophora costata*, occasionally with *Eucalyptus melanophloia*, *E. dealbata*, and rarely in the north *E. bloxsomei*, *E. punctata*, *E. trachyphloia*, and *E. phaeotricha*; with dense lower tree layer of *Callitris columellaris* or open *Lysicarpus angustifolius*; shrub layer rich and varied, dense when taller layers are open, mainly *Xanthorrhoea* spp., *Acacia gnidium*, *A. macradenia*, *Leucopogon biflorus*, *L. mitchellii*, *Aotus subglabra*, *Ricinocarpos bowmanii*, and *Dodonaea* spp.; ground cover usually open *Triodia mitchellii* and/or *Aristida muricata*, *A. jerichoensis*, *Chrysopogon fallax*, *Eragrostis lacunaria*, *Panicum effusum*, and in the north-west *Eremochloa bimaculata*.

Land Capability.—IVm$_4$, c$_{3-4}$. **No. of Observations.**—9.

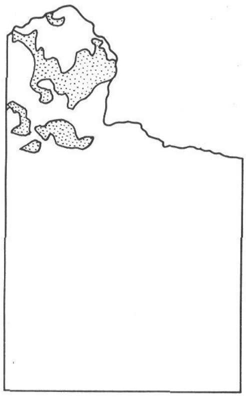
LAND UNIT 6 (175 KM^2)

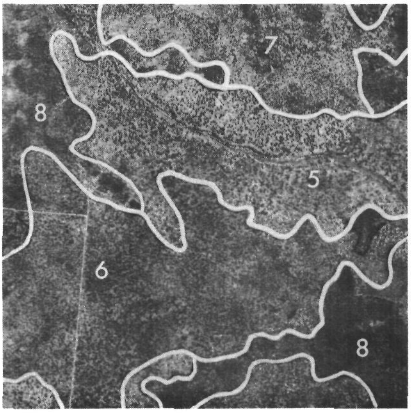
Field Criteria.—Undulating sandy country, bloodwood and silver-leaved ironbark woodland, sandy soils.

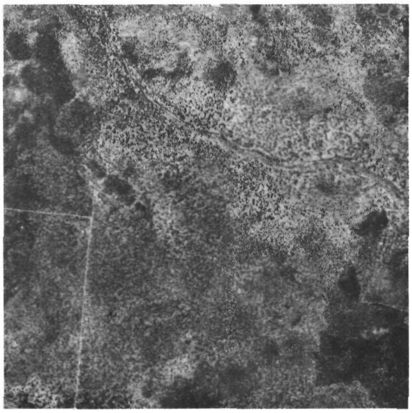
Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 170–200 mm.

Material.—Quartz sand.

Relief.—Undulating sandy colluvial aprons; slopes probably 0·5–2%.







Position on Slope.—Probably crests and upper slopes.

Soil.—Uniform sandy soils: medium sands 75–150 cm deep, slightly to medium acid, Fe and Fc (Uc5.11).

Vegetation.—Open-woodland of *Eucalyptus trachyphloia* with a high proportion of *E. melanophloia*, *Xylomelum pyriforme*, *Lysicarpus angustifolius*, and occasional *Acacia longispicata* and *Callitris columellaris*; varied shrub layer often very dense of *Grevillea parallela*, *Acacia leptostachya*, *Calytrix tetragona*, *Dodonaea* spp.. *Cassinia laevis*, and *Xanthorrhoea* sp.; sparse ground cover of *Triodia mitchellii*, *Aristida echinata*, *A. muricata*, and *Eriachne mucronata*.

Land Capability.—IVm$_4$, c$_{3-4}$. **No. of Observations.**—2.

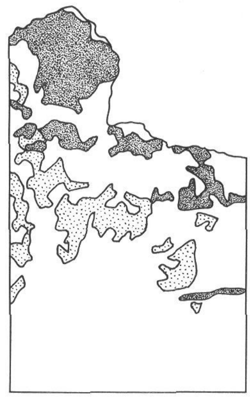
LAND UNIT 7 (3455 KM²)

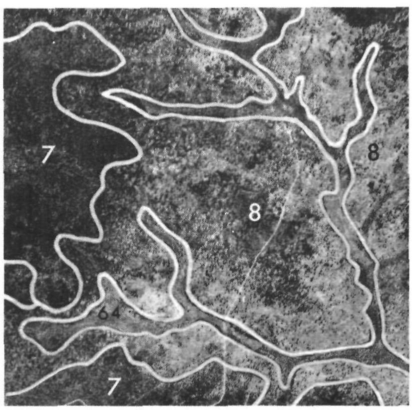
Field Criteria.—Undulating country, open-forest of cypress pine, uniform sandy soils.

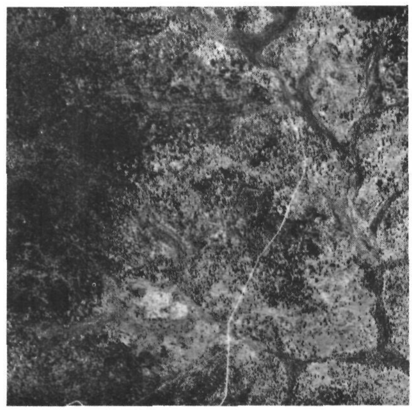
Median Rainfall.—Nov.–Apr.: 250–450 mm. May–Oct.: 150–220 mm.

Material.—Quartzose sandstone and siltstone, minor sandy colluvium.

Relief.—Undulating and rolling; slopes 1–5 %.







Position on Slope.—Occurs on all parts of slopes.

Soil.—Uniform sandy soils: generally more than 120 cm deep; underlain by hard rock at 60–90 cm in places; reddish brown to yellowish brown sands to sandy loams, Fd, Fe, Fc (Uc5.11, 1.23, 1.21); medium acid to neutral reaction throughout.

Vegetation.—Usually open-forest of *Callitris columellaris* with scattered *Eucalyptus dealbata*, or less commonly *E. melanophloia*, *E. polycarpa*, *E. tessellaris*, or *Angophora costata*; sometimes woodland of *E. melanophloia* or *E. drepanophylla* (rarely *E. populnea*) with lower tree layer of *Callitris columellaris*, sometimes with some *Casuarina luehmannii* or *Acacia burrowii*; scattered low trees or shrubs of *A. longispicata*, *A. cunninghamii*, *Alphitonia excelsa*, *Lysicarpus angustifolius*, *Geijera parviflora*, or *Monotoca scoparia*; ground cover extremely open, mainly *Aristida echinata*, *A. jerichoensis*, *A. ingrata*, *A. muricata*, or *A. caput-medusae* with lesser *Bothriochloa decipiens*, *Eriachne mucronata*, *Enneapogon* spp., and (west of Westmar) *Triodia mitchellii* and *Neurachne mitchelliana*.

Land Capability.—IVm$_4$, c$_{3-4}$. **No. of Observations.**—22.

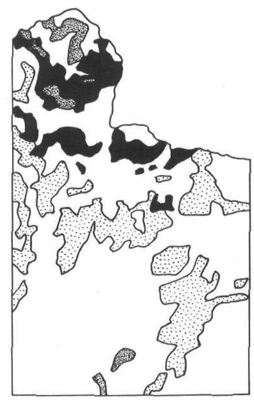
Land Unit 8 (4310 km²)

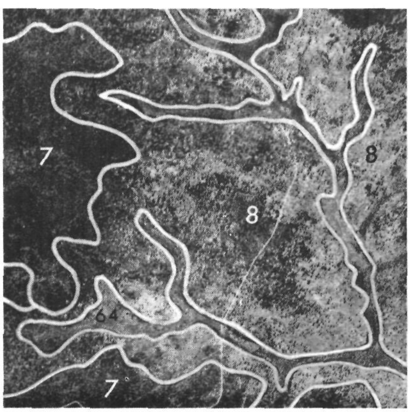
Field Criteria.—Undulating country, poplar box, ironbark, or tumble-down gum woodland with cypress pine understorey, deep texture-contrast soils.

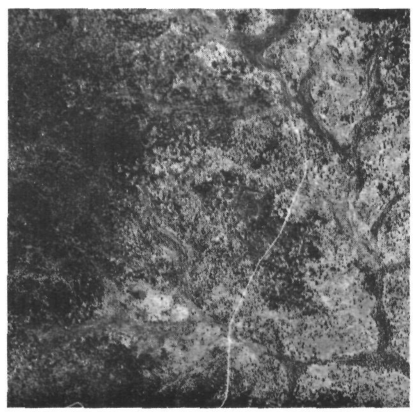
Median Rainfall.—Nov.–Apr.: 300–450 mm. May–Oct.: 150–250 mm.

Material.—Quartzose sandstone and conglomerate, sublabile sandstone and siltstone.

Relief.—Mainly undulating and rolling lowlands; slopes 1·5–4·5%.







Position on Slope.—Occurs on all parts of slopes.

Soil.—Deep texture-contrast soils: thick (56 cm average) sandy surface horizons over neutral to acid, mainly yellow, mottled subsoils, Dg (Dy3.42, 3.82, 3.41); minor Df (Dy3.23, Dr3.23), Dd (Dy 3.23), and De (Dy3.41).

Vegetation.—Woodland of *Eucalyptus populnea*, or occasionally of *E. melanophloia* with *E. dealbata* often conspicuous, or (in the east) of *E. drepanophylla*, all with lower tree layer of *Callitris columellaris* sometimes with considerable *Casuarina luehmannii* and *Acacia* spp.; sometimes open-forest of *Callitris columellaris* with scattered eucalypts or *Angophora costata;* shrub layer absent or of scattered *Eremophila mitchellii* or *Dodonaea* spp.; ground cover sparse, variable in composition, mainly *Aristida* spp. (*A. echinata*, *A. jerichoensis*, *A. muricata*, and *A. ingrata*) with *Cymbopogon refractus*, *Digitaria ammophila*, *Eragrostis lacunaria*, and *Panicum effusum*.

Land Capability.—IVp_{3-4}. m_{3-4}, c_{3-4}. **No. of Observations.**—38.

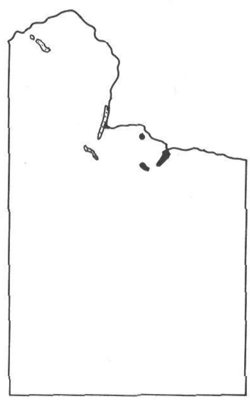
Land Unit 9 (140 km²)

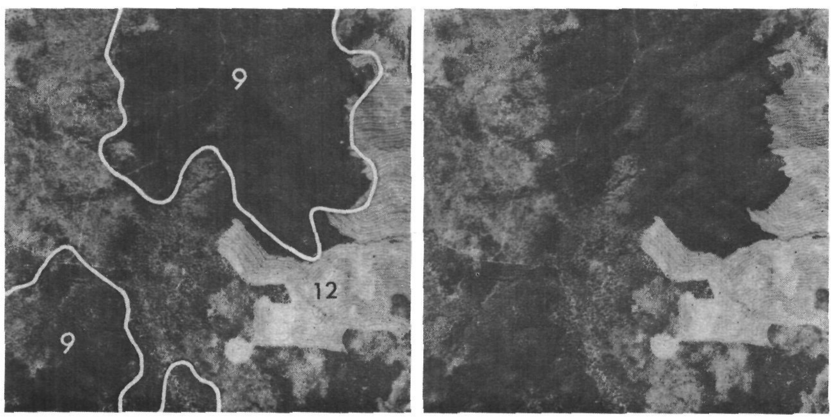
Field Criteria.—Steep slopes with softwood scrub, shallow brown soils.

Median Rainfall.—Nov.–Apr.: 380–450 mm. May–Oct.: 160–220 mm.

Material.—Slightly weathered labile fine-textured sediments; basalt; coarse lag gravel of silcrete.

Relief.—Hills and escarpments; slopes 5–50%.





Position on Slope.—Middle and upper slopes.

Soil.—Shallow brown and grey-brown soils: loams or light clays grading to medium or heavy clays, commonly with soft carbonate accumulations at shallow depth (15–45 cm), Bf (Gn3.13, 3.23, Uf6.12); generally neutral reaction at surface grading to strongly alkaline; occasionally strongly alkaline and calcareous throughout.

Vegetation.—Semi-evergreen vine thicket (softwood scrub); *Geijera parviflora, Ventilago viminalis, Atalaya hemiglauca, Capparis lasiantha, Carissa ovata, Planchonella cotinifolia, Eremophila mitchellii, Croton phebalioides, Citriobatus spinescens, Heterocalymnantha minutifolia*, sometimes with emergent *Eucalyptus orgadophila*, with sparse ground cover usually *Chloris acicularis, C. unispicea*, and *Eragrostis megalosperma.*

Land Capability.—VI–VIIt$_{6-7}$, d$_{6-7}$. **No. of Observations.**—5.

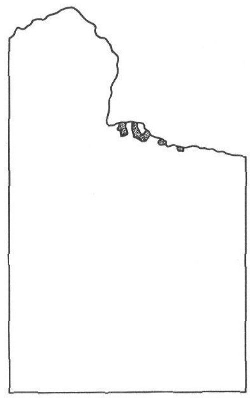
Land Unit 10 (90 km^2)

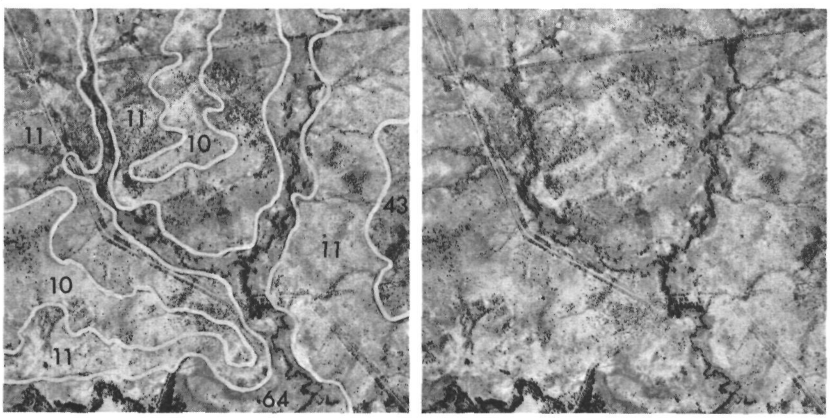
Field Criteria.—Upper slopes of rolling country, ironbark or box woodland and shrubs, shallow soils.

Median Rainfall.—Nov.–Apr.: 400–450 mm. May–Oct.: 180–220 mm.

Material.—Mudstone, labile sandstone, and siltstone; minor gravel.

Relief.—Rolling; slopes 3–12%.





Position on Slope.—Crests and upper slopes.

Soil.—Shallow soils: cracking clay soils, Cf (Ug5.23), and dark brown and grey-brown soils, Bf (Gn3.53), underlain by calcareous strongly alkaline weathered rock materials at less than 60 cm depth; minor skeletal soils, Ga (Uc1), underlain by calcareous rocks; stony surface strew common; severe sheet erosion at some localities.

Vegetation.—Woodland of *Eucalyptus melanophloia* or *E. populnea*; shrub layer, sometimes dense, of *Eremophila mitchellii*; moderately dense ground cover of *Chloris acicularis*, *Aristida ramosa*, and *Bothriochloa decipiens*.

Land Capability.—IV or VId$_{4-6}$, e$_{3-4}$. **No. of Observations.**—3.

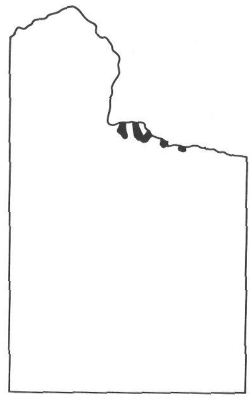
LAND UNIT 11 (200 km^2)

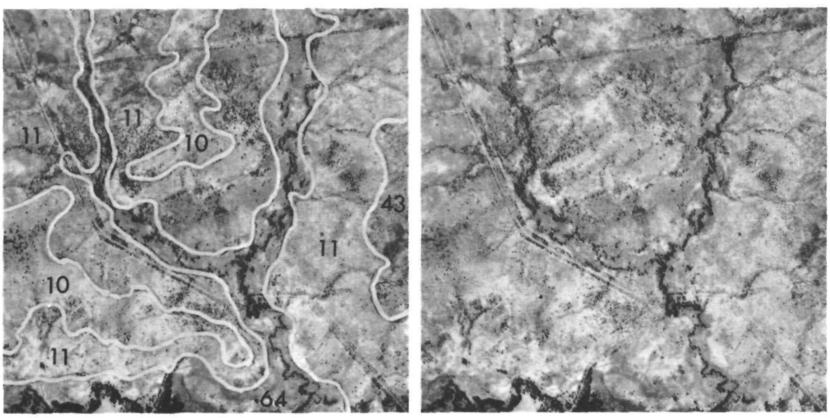
Field Criteria.—Lower slopes of rolling country, ironbark or box woodland and shrubs, brown soils.

Median Rainfall.—Nov.–Apr.: 400–450 mm. May–Oct.: 180–220 mm.

Material.—Mudstone, labile sandstone, and siltstone; minor gravel.

Relief.—Rolling; slopes 2–8%.





Position on Slope.—Middle and lower slopes.

Soil.—Dark brown and grey-brown soils: shallow to moderately deep (40–90 cm) uniform light to heavy clay soils, Bf (Uf6.31, 6.32) and Bd (Uf6.33); generally with strongly alkaline calcareous subsoils; moderate to severe sheet erosion (5–10 cm of surface soil removed) in places.

Vegetation.—Woodland of *Eucalyptus populnea* sometimes with occasional *E. melanophloia*; shrub layer mainly of *Eremophila mitchellii*; ground cover sparse, mainly *Aristida* spp.

Land Capability.—IVd_{3-4}, e_{3-4}. **No. of Observations.**—3.

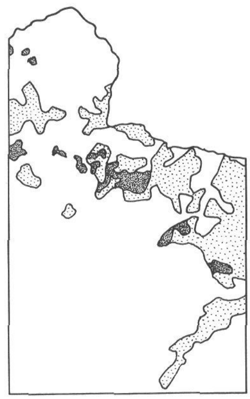
LAND UNIT 12 (845 KM²)

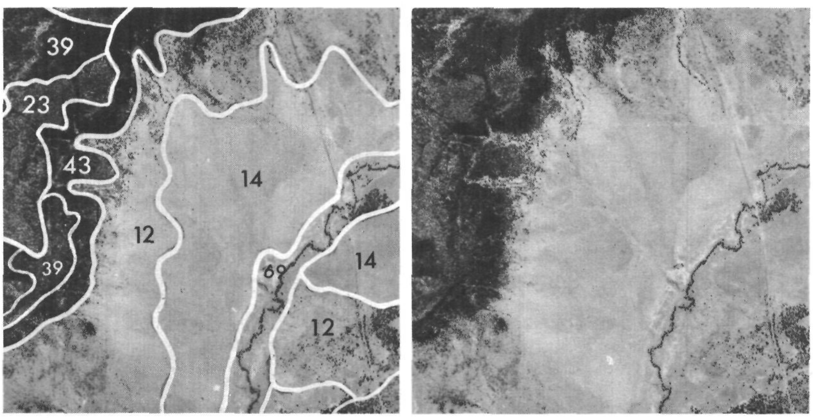
Field Criteria.—Rises with open woodland of box, silver-leaved iron-bark, or mountain coolibah, non-cracking calcareous clay soils.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–230 mm.

Material.—Labile siltstone or mudstone slightly affected by Tertiary deep weathering.

Relief.—Undulating, sometimes rolling; slopes 1–4%.





Position on Slope.—Crests and upper slopes.

Soil.—Brown and grey-brown soils: shallow to moderately deep uniform clays or loams grading to clays, Bf (Uf6.31, Gn3.13) and Bd (Uf6.31), generally with strongly alkaline calcareous subsoils; minor occurrences of texture-contrast soils, Da (Db1.33) and Dc (Dr2.12).

Vegetation.—Open-woodland of *Eucalyptus populnea*, *E. melanophloia*, or *E. orgadophila*, the latter sometimes with lower tree layer of *Acacia harpophylla* or *Casuarina cristata*, sometimes dense; shrubs absent or scattered, usually *Eremophila mitchellii* or *Geijera parviflora*; moderately dense ground cover of *Aristida latifolia*, *A. platychaeta*, *A. jerichoensis*, *Sporobolus actinocladus*, occasional *Astrebla* sp., and, where taller strata are dense, *Chloris acicularis* and *Paspalidium* spp.

Land Capability.—IVd_{3-4}, e_{3-4}, c_{3-4}. **No. of Observations.**—13.

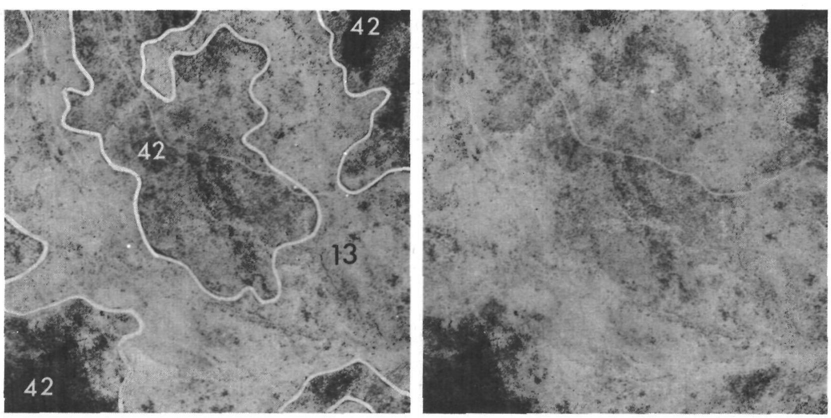
LAND UNIT 13 (720 KM²)

Field Criteria.—Rises with open-woodland of box, silver-leaved ironbark, or mountain coolibah, cracking calcareous clay soils.

Median Rainfall.—Nov.–Apr.: 350–400 mm. May–Oct.: 150–220 mm.

Material.—Labile siltstone and mudstone slightly affected by Tertiary deep weathering.

Relief.—Undulating, sometimes rolling; slopes 1–4%.



Position on Slope.—Crests and upper slopes.

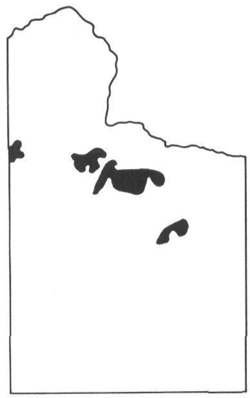
Soil.—Cracking clay soils: brown and grey, 75–105 cm deep, Cc (Ug5.32, 5.22, 5.12); minor shallow dark clay soils, Cf (Ug5.12), underlain by soft carbonate; generally neutral reaction at surface becoming strongly alkaline and calcareous; small to moderate accumulation (3–20%) of soft carbonate and/or gypsum in lower profiles.

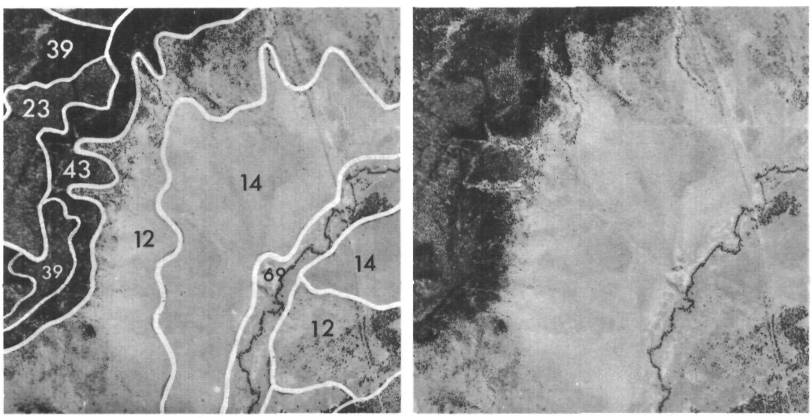
Vegetation.—Open-woodland of *Eucalyptus orgadophila*, *E. melanophloia*, or *E. populnea*, the first rarely with lower *Acacia harpophylla*, *Casuarina cristata*; shrubs absent or scattered, mainly *Eremophila mitchellii*, *Geijera parviflora*, *Atalaya hemiglauca*, or *Acacia victoriae*; ground cover sparse to dense (largely determined by grazing pressure), *Astrebla* spp., *Aristida leptopoda*, *A. latifolia*, *Malvastrum spicatum*, and occasional *Aristida platychaeta*, *Thellungia advena*, *Dichanthium* sp., and *Bassia quinquecuspis*.

Land Capability.—III–IVc_{3-4}, d_{2-3}, e_{2-3}. **No. of Observations.**—8.

Land Unit 14 (1360 km^2)

Field Criteria.—Downs, cracking clay soils.
Median Rainfall.—Nov.–Apr.: 350–420 mm. May–Oct.: 150–240 mm.
Material.—Labile, fine-grained sediments.
Relief.—Undulating lowland; slopes 1–3%.





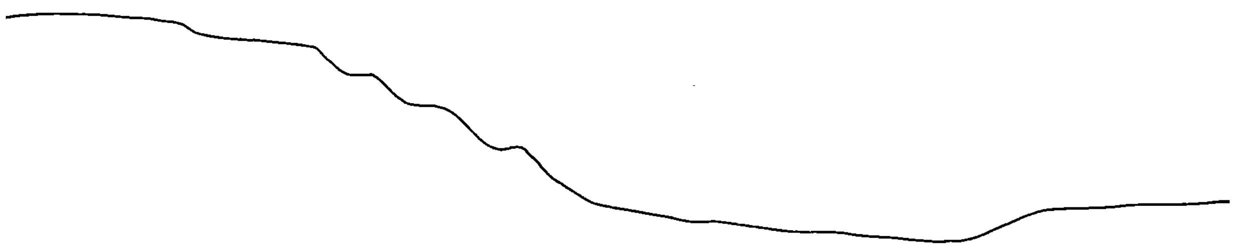
Position on Slope.—Predominantly middle and lower slopes.

Soil.—Cracking clay soils: brown and grey, moderately deep to deep (90–>150 cm), Cc (Ug5.32, 5.22, 5.14), self-mulching; generally neutral reaction at surface becoming strongly alkaline below 30 cm; occasionally strongly alkaline throughout, with small to moderate (3–15%) accumulations of carbonate and gypsum.

Vegetation.—Tussock grassland predominantly *Astrebla lappacea*, with less common *Aristida leptopoda*, *Panicum decompositum*, *P. queenslandicum*, *Eriochloa* spp., and *Thellungia advena* and occasional *Dichanthium* sp., *Cyperus bifax*, *Sporobolus mitchellii*, *Malvastrum spicatum*, and *Iseilema* spp.; scattered *Acacia farnesiana* and groves of *A. pendula* and *A. omalophylla* occur; composition of community changes considerably with grazing.

Land Capability.—III–IVc$_{3-4}$, k$_{2-3}$, e$_{2-3}$. **No. of Observations.**—16.

Geomorphic category	Fresh basalt (minor weathered basalt)						
Land system	BtS		BhMc part	BhMc part, BuI part		BuI part	
Terrain	Elevated tablelands and stripped margins		Hilly to mountainous	Gently undulating			



Soils	Humic red earths, Eh	Shallow brown to grey-brown soils, Bf; generally stony	Skeletal soils, Gb	Shallow cracking clay soils, Cf	Moderately deep self-mulching clay soils, Cf and Cd; generally stony	Shallow brown to grey-brown soils, Bf; carbonate enriched; stony	Alkaline–acid cracking clay soils, Cb
Vegetation	Tall thin-leaved stringybark forest	Mixed eucalypt woodland, grey gum, blue gum, yellow box	Mountain coolibah woodland	Silver-leaved ironbark or mountain coolibah woodland	Grassland with scattered mountain coolibah	Mountain coolibah woodland or softwood scrub	Brigalow forest
Land units	15	16	17	18	19	9	42

Fig. 7.—Distribution of land units on basalt.

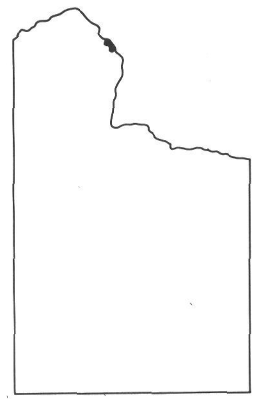
Land Unit 15 (40 km²)

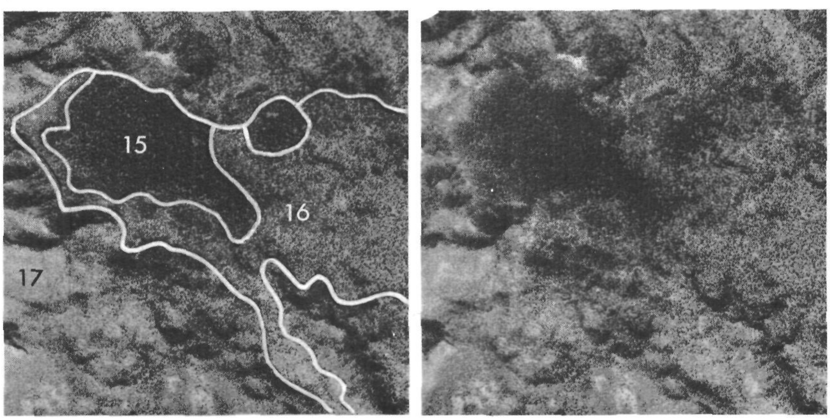
Field Criteria.—High basalt plateau, tall stringybark forest, massive earths.

Median Rainfall.—Nov.–Apr.: 500–550 mm. May–Oct.: 180–220 mm.

Material.—Leached basalt.

Relief.—High plateau about 1000 m above sea level; slopes 3–5%.





Position on Slope.—Plateau surface.

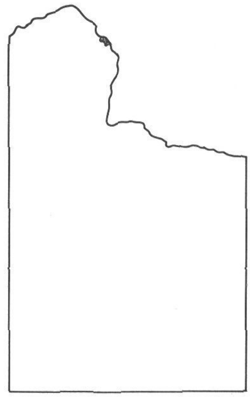
Soil.—Humic massive earths: moderately deep to deep (90–120 cm), Eh (Gn2.11); dark brown humic clay loam grading to reddish brown light to medium clay; weakly structured in surface horizons, massive beneath; slightly acid throughout; underlain by ferruginized basalt.

Vegetation.—Tall open-forest of *Eucalyptus eugenioides*; patchy lower tree layer of *Macrozamia moorei* and *Acacia implexa*; rather dense ground cover of *Themeda australis* and *Imperata cylindrica.*

Land Capability.—IIIc3. **No. of Observations.**—1.

N.B. Conservation of this landscape is recommended in view of poor access, high elevation, and scenic attributes.

Land Unit 16 (15 km²)

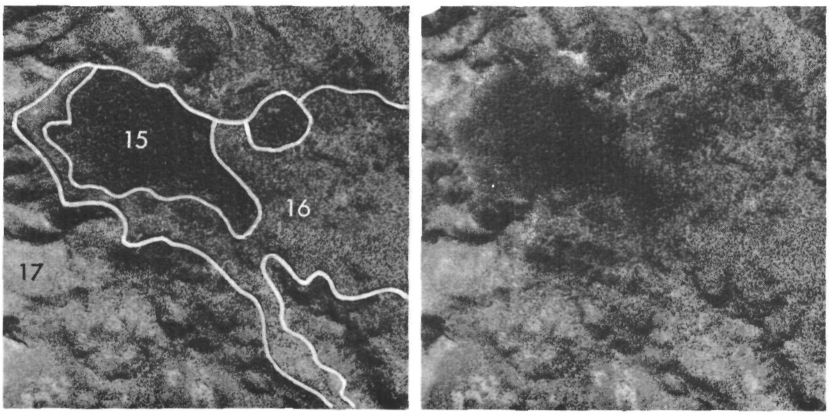


Field Criteria.—Steep basalt slopes, gum woodland, shallow brown soils.

Median Rainfall.—Nov.–Apr.: 500–550 mm. May–Oct.: 180–220 mm.

Material.—Basalt.

Relief.—Hills and mountains; steep rocky slopes 15–60%, locally more.



Position on Slope.—Upper and middle slopes.

Soil.— Shallow brown and grey-brown soils: <60 cm deep, Bf (Uf6.32); stones and boulders on surface in places; marginal to land unit 15.

Vegetation.—Woodland of *Eucalyptus saligna*, *E. punctata*, and occasional *E. melliodora*, occasionally *E. saligna* alone; lower tree layer of scattered *Macrozamia moorei*; ground cover rather dense, mainly *Themeda australis* and *Xanthorrhoea* sp.

Land Capability.—VI–VIIt$_{6-7}$, r$_{6-7}$. **No. of Observations.**—1.

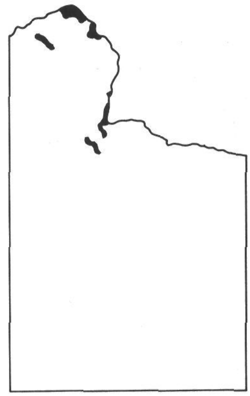
Land Unit 17 (470 km²)

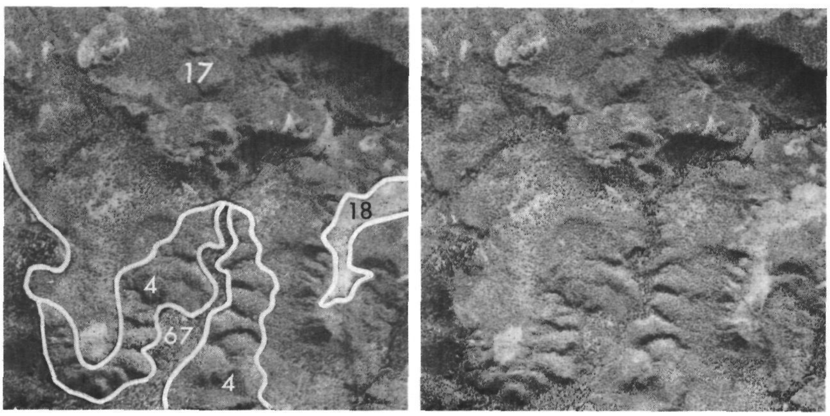
Field Criteria.—Steep basalt hills, mountain coolibah, skeletal soils.

Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 180–200 mm.

Material.—Basalt.

Relief.—Steep rocky hills and mountains; slopes probably about 15–60%.





Position on Slope.—Crest, upper and middle slopes.

Soil.—Skeletal soils: very shallow loams and clays, Gb (Um1, Uf1).

Vegetation.—Open-woodland of *Eucalyptus orgadophila*, occasional *E. punctata* and *E. dichromophloia*, probably some woodland of *E. drepanophylla*; scattered *Macrozamia moorei* in places; rather dense ground cover mainly *Themeda australis*.

Land Capability.—VI–VIIt$_{6-7}$, r$_{6-7}$. **No. of Observations.**—Nil.

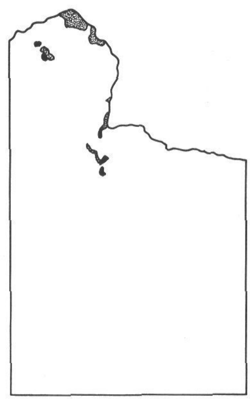
LAND UNIT 18 (190 KM^2)

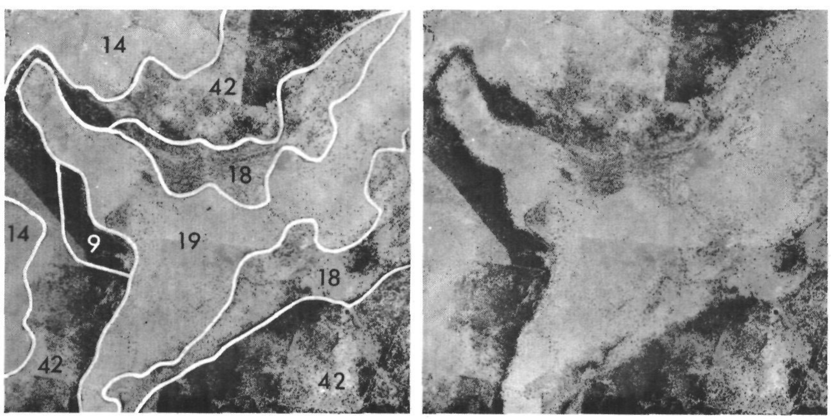
Field Criteria.—Basalt lowlands, silver-leaved ironbark or mountain coolibah open woodland, shallow cracking clays.

Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 180–200 mm.

Material.—Basalt and basaltic colluvium.

Relief.—Rolling and undulating; slopes 2–5%.





Position on Slope.—Middle slopes and colluvial lower slopes.

Soil.—Shallow cracking clay soils: 40–60 cm deep, Cf (Ug5.12); minor deep soils on colluvium, Bd (Uf6.32).

Vegetation.—Open-woodland of *Eucalyptus melanophloia*, sometimes *E. orgadophila*, usually no shrubs, *Acacia decora* sometimes on shallow soils; ground cover usually moderately dense, *Dichanthium* spp. (mainly *D. affine*), *Panicum decompositum*, *Thellungia advena*, *Aristida leptopoda*, and *Cyperus bifax*.

Land Capability.—IVd_{3-4}, c_{3-4}. **No. of Observations.**—5.

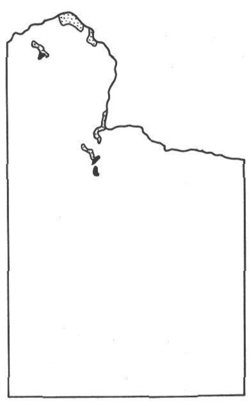
Land Unit 19 (115 km^2)

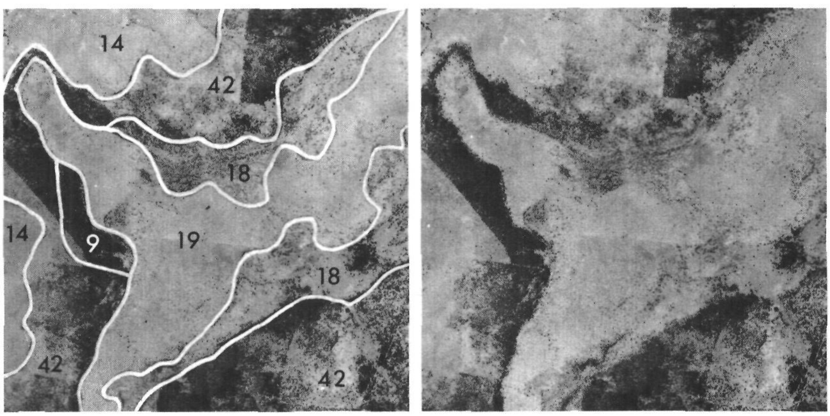
Field Criteria.—*Downs on basalt, cracking clay soils.*

Median Rainfall.—Nov.–Apr.: 400–550 mm. May–Oct.: 180–200 mm.

Material.—Basalt and basaltic colluvium, possibly deeply weathered in part.

Relief.—Undulating lowlands, frequently stony; slopes 1–3%.





Position on Slope.—Lower slopes.

Soil.—Cracking clay soils: shallow to moderately deep (50–90 cm), self-mulching, Cf and Cd (Ug5.12); stones (10–15 cm in diameter) on surface in places.

Vegetation.—Tussock grassland, sometimes with scattered *Eucalyptus orgadophila* and *Acacia victoriae*, of *Astrebla* spp., *Aristida leptopoda*, *Thellungia advena*, *Malvastrum spicatum*, and occasional *Dichanthium* spp.

Land Capability.—III–IVd_{3-4}, r_{3-4}, c_{3-4}. **No. of Observations.**—2.

Geomorphic category	Indurated weathered sediments (severely stripped)		Moderately resistant weathered sediments		Unresistant weathered sediments				
Land system	(S)rXM (S)rNi	(S)rBe	(S)uM, (S)uXM (S)uX part, (S)uIX part	(S)uBu	(S)hY part	(S)hY part	Parts of (S)uIX, (S)uX, (S)uXB, (S)uBl	(S)uXB part, (S)uBl part	(S)uBl part
Terrain	Rolling to hilly		Level to gently undulating		Scarps and hilly (sporadic)		Level to gently undulating		

Variously denuded lateritic profiles

Soils	Massive earths, Ea (Eg, Gb); duplex soils, Dc in 21	Skeletal soils, Gb, and shallow massive earths, Eg (Ea)	Massive earths, Ea (Ec, Ee, Eg)	Duplex soils, Dd, De (Dc)	Skeletal soils, Gb and shallow duplex soils, Dc in 28	Brown and grey-brown soils, Bb, Bc, Ba; mainly stony	Duplex soils, Da, Db, Dc (Dg, Dd)	Brown and grey-brown soils, Bc (Bb, Ba), and cracking clay soils, Cb	Gilgaied cracking clay soils, Ca
Vegetation									
(*a*) Mesic, > 560 mm rainfall per annum	Narrow-leaved ironbark, spotted gum woodland	Lancewood forest	Box and/or silver-leaved ironbark woodland	Box, narrow-leaved iron-bark, bulloak shrub woodland	Yapunyah and/or green-leaved box woodland	Yapunyah and/or ooline–belah	Belah, brigalow forest/ woodland	Belah, brigalow, box shrub woodland and belah–brigalow forest	Belah–brigalow forest
(*b*) Xeric, < 560 mm rainfall per annum	Box, mulga, Queensland peppermint woodland	Bendee forest	Mulga forest with emergent box and/or silver-leaved ironbark				Box or box–mulga woodland	Box–cypress pine woodland	Low brigalow forest
Land units									
(*a*)	20, 21	22 part	26 part	31	28, 35	36 part	30, 37, 38	39, 40, 41, 42, 43	44 part
(*b*)	23	22 part	24, 25, 26 part 27			36 part	29, 32, 33	34	44 part

Fig. 8.—Distribution of land units on weathered sediments.

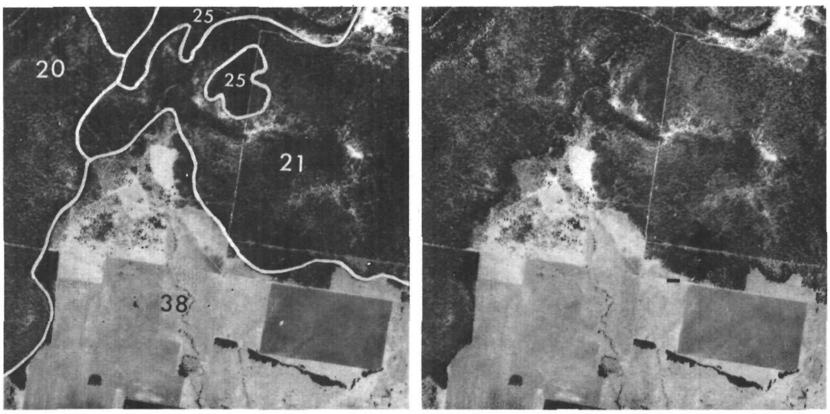
LAND UNIT 20 (1335 km^2)

Field Criteria.—Rises with narrow-leaved ironbark woodland; shallow earths.

Median Rainfall.—Nov.–Apr.: 350–450 mm. May–Oct.: 150–240 mm.

Material.—Indurated weathered sediments.

Relief.—Low rises with occasional outcrops of indurated mottled zone; slopes 1·5–4%.



Position on Slope.—Dominantly upper slopes and crests.

Soil.—Shallow massive earths: mainly less than 60 cm deep, underlain by weathered zone, Eg (Gn2.11, 2.41), gravel increasing with depth (5–30%); minor deeper soils, Ee (Gn2.81) and Ea (Gn2.42).

Vegetation.—Woodland of *Eucalyptus drepanophylla* with occasional *E. melanophloia* and *E. exserta*; sometimes dense lower tree layer of *Acacia burrowii* or occasionally *A. cunninghamii* or *A. sparsiflora*; shrub layer sometimes extremely dense of *Ricinocarpos bowmanii* and *Phebalium glandulosum* or moderate of *Eremophila mitchellii* and *Carissa ovata*; sparse ground cover of *Aristida caput-medusae, Neurachne mitchelliana, N. xerophila, Cymbopogon refractus*, and occasionally *Bothriochloa decipiens*.

Land Capability.—VId_{4-6}, r_{4-6}. **No. of Observations.**—9.

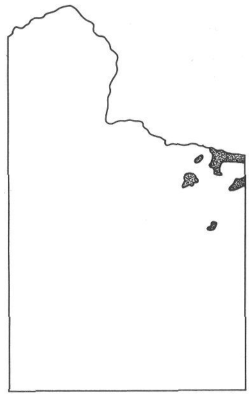
LAND UNIT 21 (100 KM²)

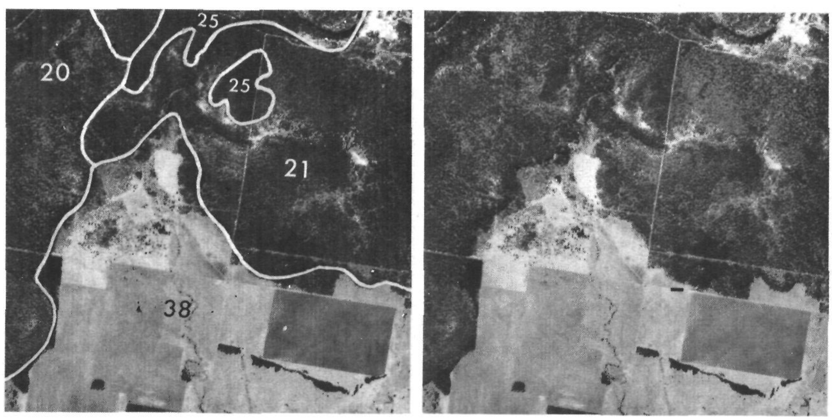
Field Criteria.—Lowlands with narrow-leaved ironbark woodland, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 400–450 mm. May–Oct.: 200–250 mm.

Material.—Indurated and moderately resistant weathered fine-grained sediments.

Relief.—Undulating and rolling; slopes 1·5–4%.





Position on Slope.—Dominantly lower slopes.

Soil.—Texture-contrast soils: 85–>120 cm deep, underlain by weathered zone; thin loamy, slightly acid surface horizons over strongly acid blocky subsoils, Dc (Dr2.21, Db1.21).

Vegetation.—Woodland of *Eucalyptus drepanophylla* or *E. maculata*, scattered low trees of *Acacia cunninghamii*; sparse ground cover, mainly *Aristida caput-medusae* and occasional *Lomandra leucocephala*.

Land Capability.—IVp$_{3-4}$, e$_{3-4}$. **No. of Observations.**—4.

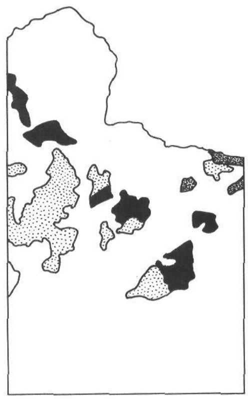
LAND UNIT 22 (3000 KM²)

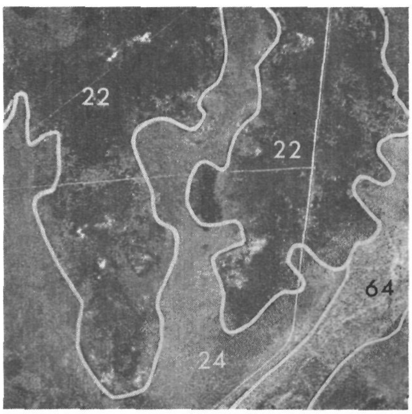
Field Criteria.—Rises, bendee open-forest, shallow soils.

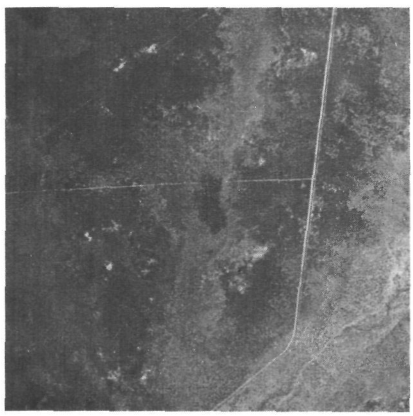
Median Rainfall.—Nov.–Apr.: 350–420 mm. May–Oct.: 160–250 mm.

Material.—Indurated weathered sediments.

Relief.—Rolling country and low scarps with frequent outcrops of indurated mottled zone; slopes 1·5–6%.







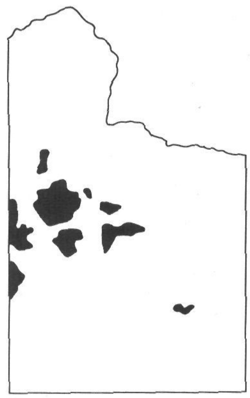
Position on Slope.—Crests and upper slopes.

Soil.—Skeletal soils and shallow massive earths: generally gravelly or stony, underlain by weathered zones, Gb (Um1.43, 1.41) and Eg (Gn 2.11); neutral to strongly acid reaction; minor Ea (gravelly Gn 2.11, 2.14).

Vegetation.—Open-forest of *Acacia catenulata* or *A. shirleyi*, or (near Yuleba and Glenmorgan) *A. aprepta*, with emergent *Eucalyptus populnea*, *E. melanophloia*, or, in the north-east, *E. drepanophylla*, rarely *E. thozetiana*, *E. microcarpa*, *E. trachyphloia*, *E. decorticans*, or *E. exserta*; shrub layer absent or patchy, *Eriostemon difformis*, *Phebalium glandulosum*, *Baeckea jucunda*, or *Geijera parviflora*; ground cover sparse, *Aristida caput-medusae*, *Neurachne mitchelliana*, *N. xerophila*, *Eragrostis lacunaria*, *Sida brachypoda*, *Digitaria diminuta*, and *Paspalidium* spp.; occasionally (particularly near "Bonus Downs") open-forest of *Acacia microsperma* with shrub layer of *Geijera parviflora* and very sparse ground cover; rarely woodland of *Eucalyptus melanophloia* with dense but patchy lower tree layer of *Acacia burrowii* and similar ground cover.

Land Capability.—VId$_{4-6}$, r$_{4-6}$, c$_{3-6}$. **No. of Observations.**—31.

Land Unit 23 (2015 km²)

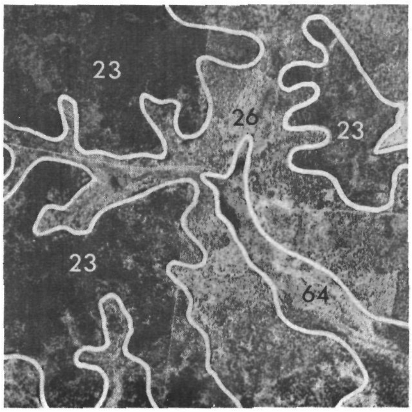


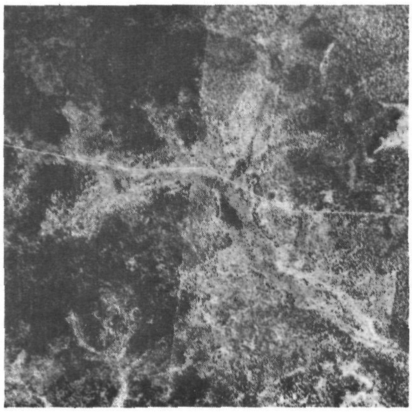
Field Criteria.—Rises, ironbark, box, or Queensland peppermint woodland with mulga understorey, shallow gravelly red earths.

Median Rainfall.—Nov.–Apr.: 300–350 mm. May–Oct.: 150–220 mm.

Material,—Indurated weathered sediments.

Relief.—Rolling with some undulating; slopes 1–5%.





Position on Slope.—Predominantly upper slopes and crests.

Soil.—Gravelly massive earths and skeletal soils: shallow to moderately deep, containing 10–50% fine to coarse gravel (5–50 mm diam.), generally medium acid, Ea (Gn2.11), Eg (Gn2.11, 2.12), and Gb (Um1.43); severely eroded in some occurrences.

Vegetation.—Woodland of *Eucalyptus melanophloia* or *E. populnea* with lower tree layer, often dense, of *Acacia aneura* or less commonly open-forest of *A. aneura* with emergent eucalypts, including on the western edge of the area *E. exserta* and *E. terminalis*; sometimes moderate shrub layer of *Eremophila mitchellii*, or dense *Cassia nemophila*, or *C. artemesioides*, or scattered *Eremophila latrobei*; ground cover usually very sparse, *Neurachne mitchelliana*, *N. xerophila*, *Aristida jerichoensis*, *Eragrostis lacunaria*, *E. eriopoda*, *Digitaria brownii*, and *Sida brachypoda*.

Land Capability.—VId_{4-6}, r_{4-6}, e_{4-6}, c_{3-6}. **No. of Observations.**—12.

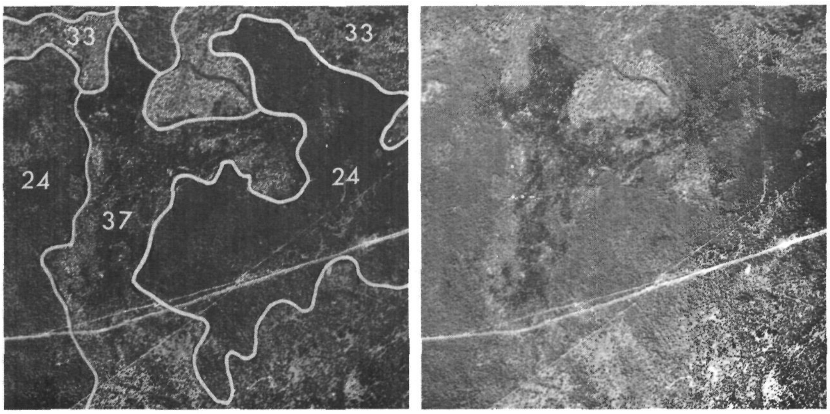
LAND UNIT 24 (5200 KM²)

Field Criteria.—Lowlands, mulga and emergent box or silver-leaved ironbark, loamy red earths with scattered ferruginous gravel.

Median Rainfall.—Nov.–Apr.: 300–350 mm. May–Oct.: 150–220 mm.

Material.—Moderately resistant weathered sediments; occasional ferruginous gravel on surface.

Relief.—Undulating lowlands; slopes 0·5–2·5%.



Position on Slope.—Occurs on all parts of slope.

Soil.—Massive earths: moderately deep to deep (65–> 120 cm), dominantly (75%) loamy red earths with varying content of fine gravel in subsoils (3–50%, average 10–20%), Ea (Gn2.12, 2.11); minor occurrences of other soils—alkaline red earths, Ec (Gn2.13), loamy yellow earths, Ee (Gn2.42, 2.82), shallow red earths, Eg (Gn2.11, 2.12), and skeletal soils, Gb (Um1.43). Extensive areas of these soils are severely sheet-eroded (estimated 5–8 cm of surface soil removed) and a lag of ferruginized fine gravel occurs on the surface.

Vegetation.—Open-forest of *Acacia aneura* with occasional eucalypts or woodland of *Eucalyptus populnea* or less commonly *E. melanophloia*, with lower tree layer of *A. aneura* or shrubs, scattered or occasionally dense patchy *Eremophila mitchellii*; ground cover usually sparse, *Neurachne mitchelliana*, *N. xerophila*, *Aristida jerichoensis*, *Eragrostis lacunaria*, *Digitaria brownii*, and *Paspalidium constrictum*, occasional *Eulalia fulva*, *Chloris acicularis*, *Themeda australis*, and *Tripogon loliiformis*.

Land Capability.—IV or VIr$_4$, m$_4$, e$_4$, c$_{3-6}$. **No. of Observations.**—60.

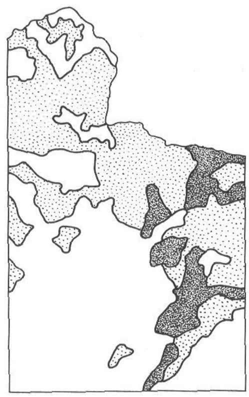
LAND UNIT 25 (2615 KM^2)

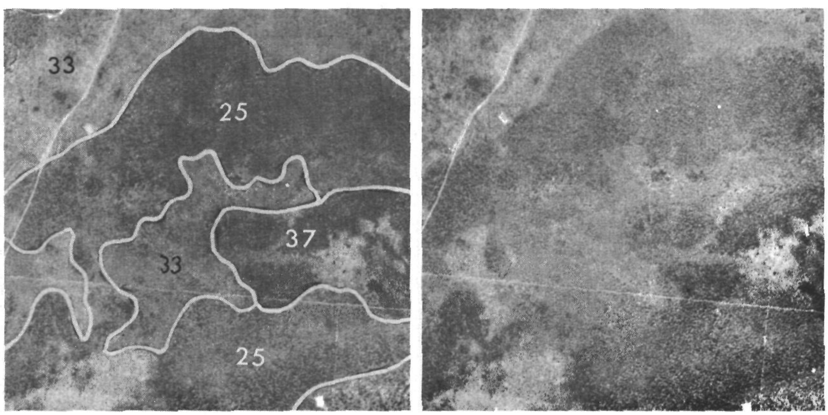
Field Criteria.—Lowlands, ironbark, box, or apple woodland with cypress pine understorey, deep red earths.

Median Rainfall.—Nov.–Apr.: 300–450 mm. May–Oct.: 150–250 mm.

Material.—Moderately resistant weathered fine-grained sediments; occasional ferruginous gravel.

Relief.—Undulating lowlands; slopes 0·5–2·5%.





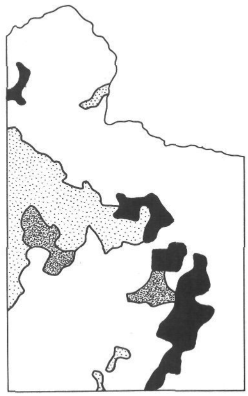
Position on Slope.—Mainly upper slopes.

Soil.—Deep massive earths: mainly loamy red earths with varying content of fine gravel, Ea (Gn2.11, 2.12, 2.41); minor loamy yellow, sandy, and shallow massive earths, Ee (Gn2.41, 2.81), Ed (Gn2.12), and Eg (Gn2.11, 2.12).

Vegetation.—Woodland of *Eucalyptus melanophloia* or *E. drepanophylla* (in north-east) or less commonly *E. populnea*, or open woodland of *Angophora costata*; usually with dense but patchy and fire-affected lower layer of *Callitris columellaris* and sometimes *Casuarina inophloia*, occasionally with *Heterodendrum oleifolum*, *Alphitonia excelsa*, or *Petalostigma pubescens*; shrub layer occasional, moderate *Eremophila mitchellii* and/or *Geijera parviflora*, *Canthium oleifolium*, and lower *Carissa ovata* and *Cassia nemophila*, or low and open (with *Angophora*) of *Eriostemon difformis* and *Monotoca scoparia*; ground cover sparse, usually *Aristida* spp. (*A. jerichoensis*, *A. echinata*, *A. caput-medusae*, and less commonly *A. ramosa* and *A. muricata*) and *Triodia mitchellii* with occasional *Bothriochloa decipiens*, *Chloris acicularis*, *Neurachne mitchelliana*, and *Tripogon loliiformis*.

Land Capability.—IVr_4, m_4, e_4, c_{3-4}. **No. of Observations.**—30.

LAND UNIT 26 (4265 KM²)

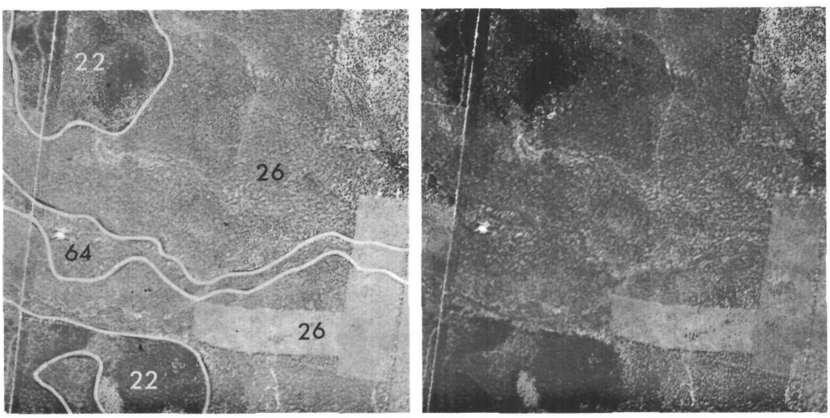


Field Criteria.—Gently undulating lowlands, box woodland and shrubs, deep red earths with sparse surficial ferruginous gravel.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–230 mm.

Material.—Moderately resistant weathered fine-grained sediments; colluvium.

Relief.—Gently undulating lowlands and plains; slopes 0·2–1·5%.



Position on Slope.—Lower and middle slopes.

Soil.—Deep massive earths: mainly loamy red earths with varying contents of fine gravel, Ea (Gn2.12); minor occurrences of other soils—alkaline red earths, Ec (Gn2.13), loamy yellow earths, Ee (Gn2.42, 2.24), loamy red earths, Eb (Gn2.42), and shallow red earths, Eg (Gn2.12).

Vegetation.—Woodland of *Eucalyptus populnea* rarely with *E. melanophloia*; shrub layer rarely absent but patchy and varying considerably in density, often *Eremophila mitchellii*, or with *Geijera parviflora*, *Acacia excelsa*, and *Heterodendrum oleifolium*, or with lower layer of *Cassia nemophila*, *Dodonaea attenuata*, or *Carissa ovata*; ground cover sparse to moderately dense, varying in composition, *Bothriochloa decipiens*, *Aristida jerichoensis*, *Chloris acicularis*, and *Bassia birchii* most common but *Neurachne mitchelliana*, *Paspalidium constrictum*, *Aristida ramosa*, *A. echinata*, *Triraphis mollis*, *Danthonia linkii*, and *Bassia convexula* locally prominent.

Land Capability.—IV–VIr_4, m_4, c_{3-6}. **No. of Observations.**—43.

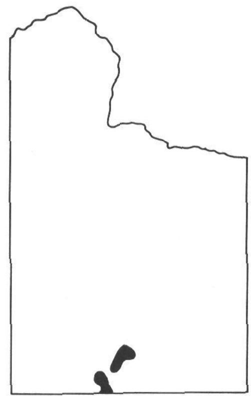
LAND UNIT 27 (170 KM²)

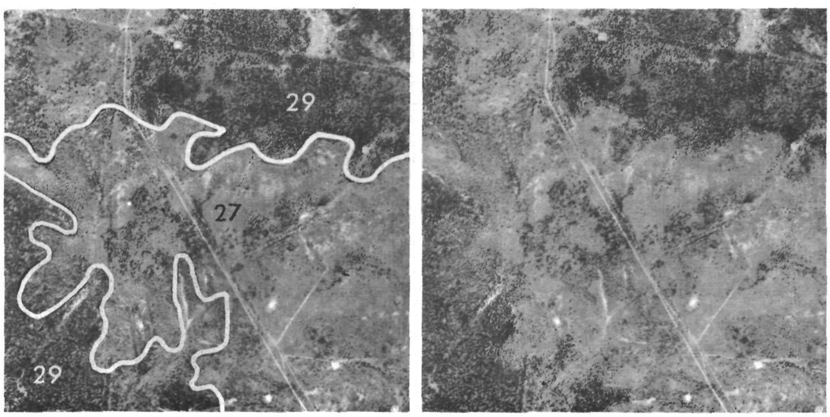
Field Criteria.—Lowlands, silver-leaved ironbark and cypress pine woodland without shrubs, shallow gravelly earths.

Median Rainfall.—Nov.–Apr.: 250–300 mm. May–Oct.: 160–180 mm.

Material.—Weathered Cainozoic gravels, usually silicified.

Relief.—Undulating.





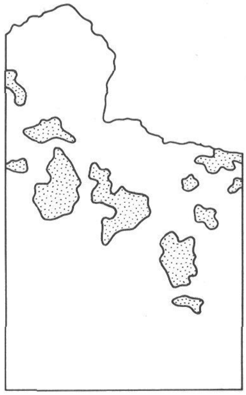
Position on Slope.—Probably upper slopes and crests; slopes probably 1–3 %.

Soil.—Shallow gravelly massive earths: mainly Eg (Gn2.12, 2.41), 30–60 cm deep with 10–50 % gravel and stones, underlain by "billy" boulders or ferruginized gravel; some deeper soils, Ea (Gn 2.12), interspersed.

Vegetation.—Woodland of *Eucalyptus melanophloia* often with patchy lower storey of *Callitris columellaris*; shrubs absent; ground cover sparse, *Eriachne mucronata* common and constant, *Neurachne mitchelliana* and *Aristida browniana* occasional.

Land Capability.—VIr_{4-6}, c_6, m_4. **No. of Observations.**—3.

LAND UNIT 28 (610 KM^2)

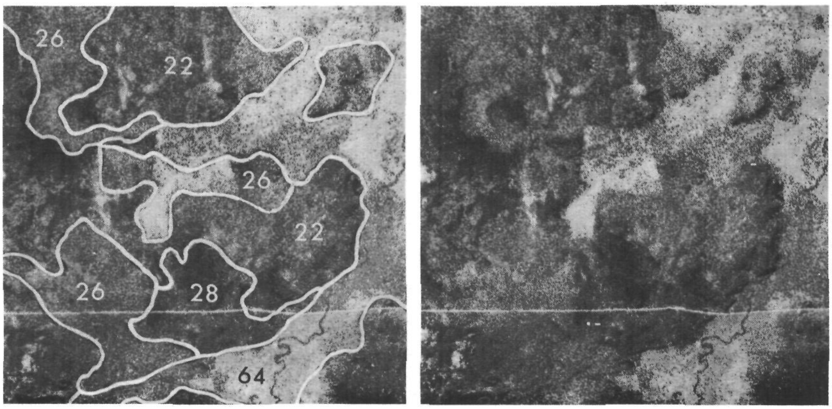


Field Criteria.—Lower scarp slopes, green-leaved box or yapunyah woodland with brigalow, belah, and shrubs, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 350–450 mm. May–Oct.: 150–240 mm.

Material.—Moderately resistant and unresistant weathered labile sediments.

Relief.—Rolling and undulating lower portions of low scarps; slopes 1·5–3%.



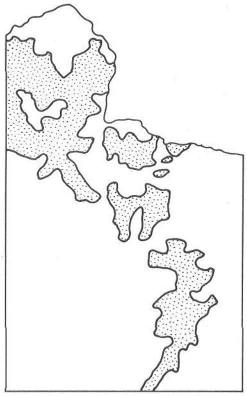
Position on Slope.—Lower slopes.

Soil.—Texture-contrast soils: shallow to moderately deep (40–100 cm) underlain by weathered zone; thin sandy or loamy surface horizons over very strongly acid to neutral subsoils, Dc (Db1.21, Dr2.21, Db2.22).

Vegetation.—Woodland of *Eucalyptus microcarpa*, occasionally *E. thozetiana*; sparse to moderately dense lower tree layer of *Acacia harpophylla*, occasionally *Casuarina cristata*, shrub layer, dense in places, of *Eremophila mitchellii* and *Geijera parviflora*; ground cover sparse to moderately dense, *Paspalidium* spp., *Aristida caput-medusae*, *Chloris ventricosa*, and *C. unispicea*, rarely *Bothriochloa decipiens*, and *Aristida jerichoensis* as well; in (S)uBu land system *Casuarina luehmannii* sometimes replaces *Acacia harpophylla*.

Land Capability.—IV or VIp_{3-4}, e_{3-4}, c_{3-6}. **No. of Observations.**—5.

LAND UNIT 29 (600 KM²)

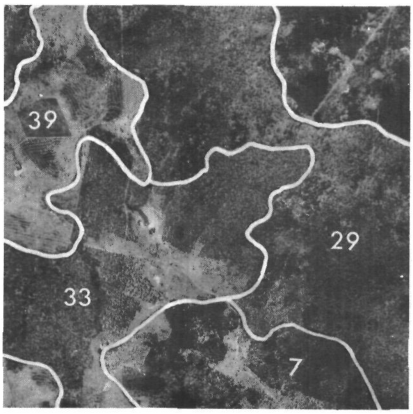


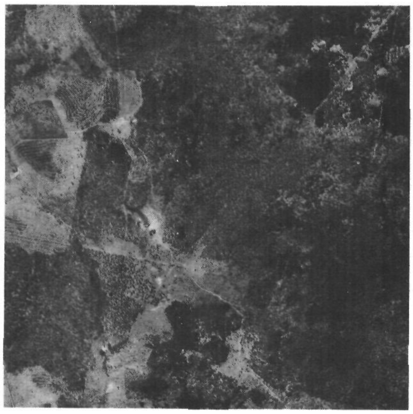
Field Criteria.—Undulating country, box woodland with shrubs, texture-contrast soils with thick sandy surface horizons.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–230 mm.

Material.—Quartzose sandstone, sublabile sandstone and siltstone.

Relief.—Undulating and rolling; slopes 1·5–4%.





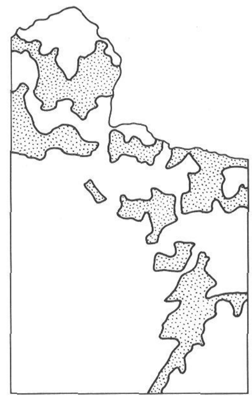
Position on Slope.—Crests and upper slopes.

Soil.—Deep texture-contrast soils: thick (35–70 cm) sandy surface horizons over yellowish brown to yellowish red, generally mottled subsoils, mainly Dg (Dy3.42, Db1.22, Dr3.21), minor Df (Dy3.43).

Vegetation.—Woodland of *Eucalyptus populnea*, sometimes with lower tree layer of *Callitris columellaris* though usually only shrub layer of *Eremophila mitchellii* and *Geijera parviflora* developed; ground cover sparse to moderate, mainly *Aristida ramosa*, *A. jerichoensis*, and less frequently *Bothriochloa decipiens*, *Chloris ventricosa*, *Eragrostis lacunaria*, and *Tripogon loliiformis*.

Land Capability.—IVp_{3-4}, e_{3-4}, c_{3-4}. **No. of Observations.**—6.

LAND UNIT 30 (940 KM^2)

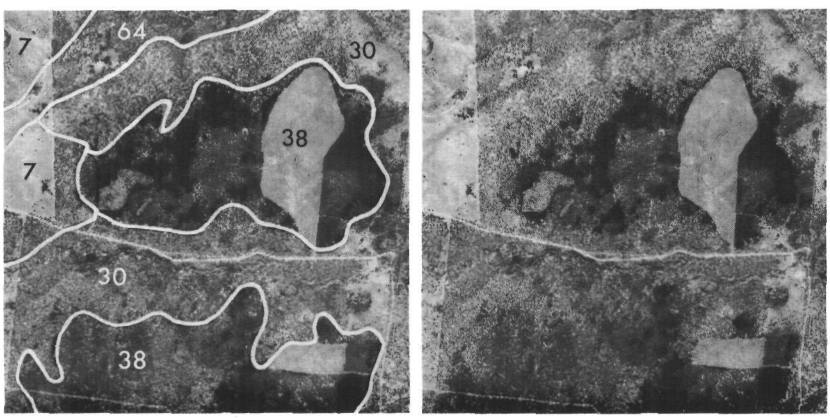


Field Criteria.—Undulating and rolling country, box or ironbark woodland with shrubs, texture-contrast soils with thin sandy surface horizons.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–230 mm.

Material.—Moderately resistant weathered fine-grained sediments.

Relief.—Undulating with some rolling; slopes 1·5–5%.



Position on Slope.—On all parts of slopes.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over strongly alkaline to acid subsoils; mainly Da (Dr2.23, 2.13) and Dc (Dy3.22, Db1.31); minor Db (Dy 2.23); intergrading with columnar-structured soils, De (Dr2.42), in some occurrences.

Vegetation.—Predominantly woodland of *Eucalyptus populnea*, occasionally of *E. melanophloia* or *E. drepanophylla*, with lower tree layer, moderately dense and sometimes affected by fire, of *Callitris columellaris*, rarely with *Casuarina luehmannii* or *Acacia burrowii*; shrub layer of *Eremophila mitchellii* and *Geijera parviflora* or rarely *Eriostemon difformis*, but usually absent; ground cover very sparse, mainly *Aristida* spp. with *Bothriochloa decipiens*, *Chloris acicularis*, *Neurachne mitchelliana*, and *Tripogon loliiformis*.

Land Capability.—IVp_{3-4}, e_{3-4}, c_{3-4}. **No. of Observations.**—16.

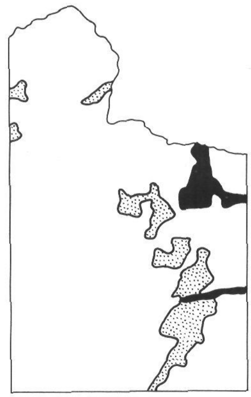
LAND UNIT 31 (1530 KM²)

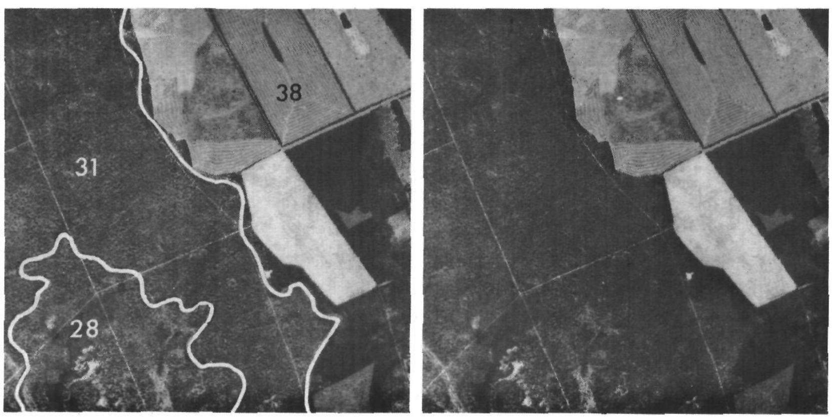
Field Criteria.—Undulating country, eucalypt woodland with bull oak, texture-contrast soils with hard columnar subsoils.

Median Rainfall.—Nov.–Apr.: 350–420 mm. May–Oct.: 160–250 mm.

Material.—Moderately resistant weathered quartzose and sublabile sediments.

Relief.—Undulating; slopes $1\cdot0$–$2\cdot5$%.





Position on Slope.—Dominantly upper slopes.

Soil.—Deep texture-contrast soils with columnar structure: thin sandy or loamy surface horizons over mainly brown or yellow subsoils with coarse columnar structure and very hard consistence, Dd (Dy3.23, 3.43, Db2.43) and De (Db1.21, 1.42, Dy3.42); strongly alkaline to acid reaction; commonly with bleached A_2 horizons above columns; minor Dc (Db 1.31, Dr2.22).

Vegetation.—Woodland of *Eucalyptus populnea* or *E. drepanophylla* or occasionally *E. melanophloia* or, in vicinity of Westmar, of *E. intertexta* with sparse to dense lower tree layer of *Casuarina luehmannii* and *Callitris columellaris*, the latter sometimes predominant; moderate shrub layer of *Eremophila mitchellii* or occasionally *Acacia ixiophylla* or *A. conferta* or *Dodonaea attenuata*; ground cover varied but sparse, *Aristida echinata*, *A. caput-medusae*, *A. leichhardtii*, *A. ramosa*, and *Cleistochloa subjuncea* locally common, and occasional *Chloris acicularis*, *Bothriochloa decipiens*, *Panicum effusum*, and *Lomandra leucocephala*.

Land Capability.—IVp_4, e_4. **No. of Observations.**—21.

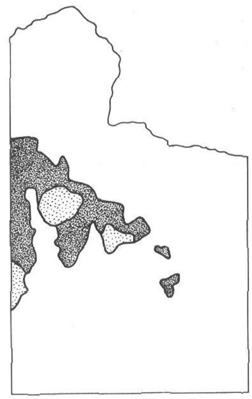
Land Unit 32 (480 km^2)

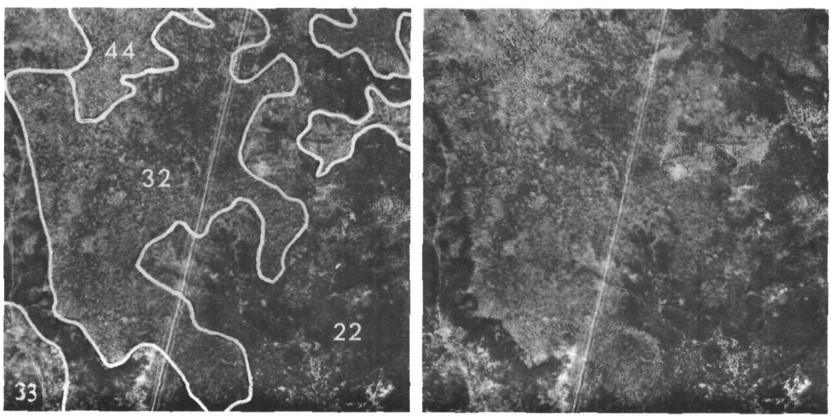
Field Criteria.—Undulating country, box–mulga woodland often with shrubs, deep texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 300–350 mm. May–Oct.: 150–220 mm.

Material.—Moderately resistant fine-grained weathered sediments.

Relief.—Undulating; slopes 1–3%.





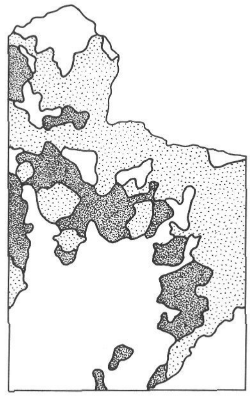
Position on Slope.—Mainly upper slopes and crests.

Soil.—Deep texture-contrast soils: loamy or sandy surface horizons (45–75 cm thick) over strongly alkaline blocky red or yellow subsoils, Da (Dr2.23) and Db (Dy3.23).

Vegetation.—Woodland of *Eucalyptus populnea*, often with occasional *E. melanophloia*, with lower tree layer, often dense, of *Acacia aneura* occasionally with some *Callitris columellaris*; sometimes open-forest of *A. aneura* with scattered eucalypts; moderate shrub layer often present, mainly *Eremophila mitchellii*, lesser *Cassia nemophila*, *Dodonaea attenuata*, and *Geijera parviflora*; sparse ground cover of *Aristida jerichoensis*, *Eragrostis lacunaria*, *Neurachne mitchelliana*, *Digitaria brownii*, and *Tripogon loliiformis*, occasional *Danthonia bipartita*, *Eriachne mucronata*, and *Chloris acicularis*.

Land Capability.—IV or $\mathrm{VI}p_{3-4}$, c_{3-6}, e_{3-4}. **No. of Observations.**—6.

LAND UNIT 33 (4485 KM²)

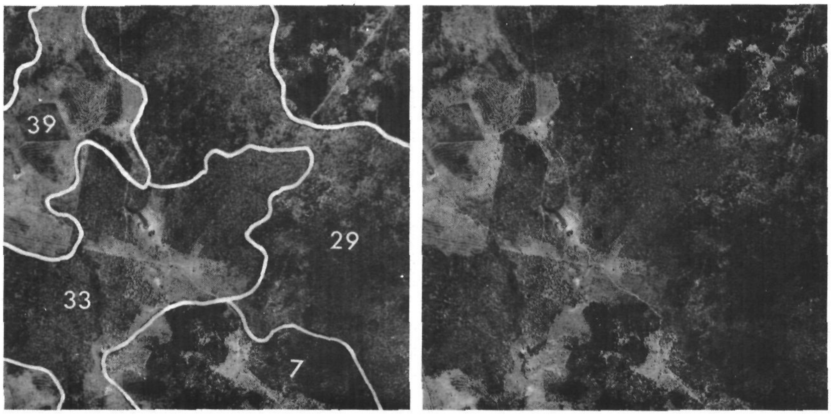


Field Criteria.—Undulating lowlands, box woodland with shrubs and minor belah or brigalow, texture-contrast soils with thin loamy surface horizons.

Median Rainfall.—Nov.–Apr.: 300–450 mm. May–Oct.: 150–250 mm.

Material.—Moderately resistant fine-grained weathered sediments.

Relief.—Undulating; slopes 0·5–2·5%.



Position on Slope.—Predominantly lower slopes.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over strongly alkaline to neutral clay subsoils, mainly Da (Dr2.23, 2.13, Db1.23) but Db (Dy2.23, Db1.13) and Dc (Dr2.12, Dy3.42) occur extensively; minor occurrences of soil with columnar structure, Dd (Db1.23) and dark brown and grey-brown soils, Bc (Uf6.31, 6.32) and Ba (Gn3.25, 3.11).

Vegetation.—Woodland of *Eucalyptus populnea*, rarely with occasional *E. melanophloia* or *E. intertexta* or with scattered lower *Casuarina cristata* or *Acacia harpophylla*; patchy, usually moderately dense shrub layer, rarely absent, predominantly *Eremophila mitchellii*, occasional *Geijera parviflora*, less common *Canthium oleifolium*, and *Heterodendrum oleifolium*, sometimes lower layer of *Carissa ovata*, *Cassia nemophila*, or *Dodonaea attenuata*; ground cover usually sparse, varied in composition, *Chloris acicularis*, *Bothriochloa decipiens*, and *Aristida ramosa* widespread and common, *Aristida armata*, *A. jerichoensis*, *Eragrostis lacunaria*, *Chloris ventricosa*, *Paspalidium constrictum*, *P. gracile*, *Ancistrachne uncinulatum*, *Enneapogon pallidus*, and *Bassia birchii* quite common in some localities.

Land Capability.—IV or VIp_{3-4}, s_{3-4}, e_{3-4}, c_{3-6}. **No. of Observations.**—56.

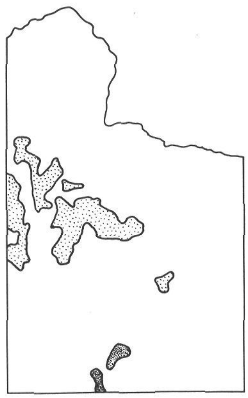
Land Unit 34 (120 km^2)

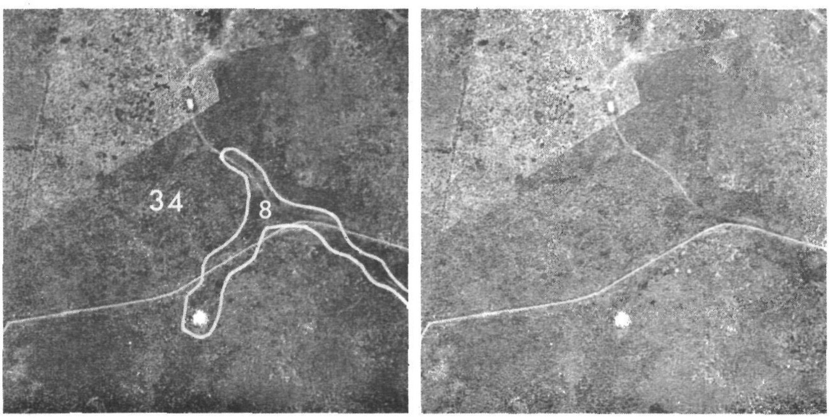
Field Criteria.—Rolling country, box and cypress pine woodland, brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 300–350 mm. May–Oct.: 150–220 mm.

Material.—Moderately resistant fine-grained weathered sediments.

Relief.—Rolling; slopes 2–6%.





Position on Slope.—On all parts of slope.

Soil.—Brown and grey-brown soils: 65–>105 cm deep; subsoil reaction neutral to strongly alkaline, Ba (Gn3.12, Uf6.31), Bb (Gn3.13, 3.56), and Bc (Gn3.23).

Vegetation.—Woodland of *Eucalyptus populnea* or occasionally of *E. melanophloia* with lower layer of *Callitris columellaris* (often considerably affected by fire) with some *Casuarina luehmannii*; shrub layer sparse; ground cover of *Aristida* spp. (commonly *A. jerichoensis* and *A. ramosa*) and occasional *Bothriochloa decipiens*, *Chloris acicularis*, *Digitaria ammophila*, and *Tripogon loliiformis*.

Land Capability.—IV or VIe$_{3-4}$, s$_{3-4}$, c$_{3-6}$. **No. of Observations.**—5.

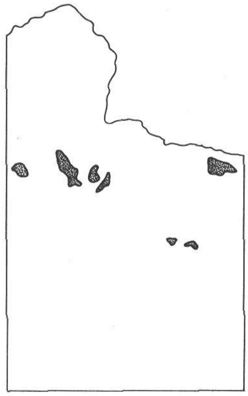
LAND UNIT 35 (400 KM²)

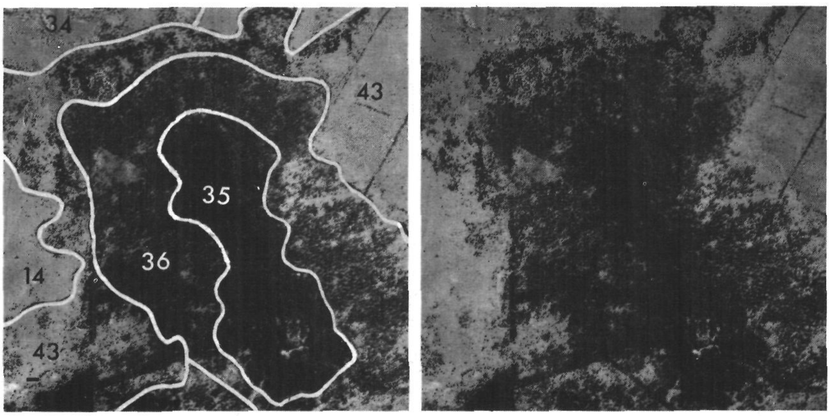
Field Criteria.—Upper scarp slopes, yapunyah woodland and shrubs, skeletal soils.

Median Rainfall.—Nov.–Apr.: 350–420 mm. May–Oct.: 150–240 mm.

Material.—Moderately resistant and unresistant weathered sediments, locally indurated; surficial silcrete gravel.

Relief.—Scarps 5–25 m high; slopes 5–25%.





Position on Slope.—Upper slopes.

Soil.—Skeletal soils: very shallow gravelly or stony slightly to strongly acid loams and clays underlain by weathered zone, Gb (Uf1.43, Um1.41, 1.43); minor Bf (Uf6.33); extensive outcrop in places.

Vegetation.—Woodland of *Eucalyptus thozetiana*, occasionally *E. microcarpa*, sometimes with occasional *Casuarina cristata*; shrub layer often dense, *Carissa ovata*, *Eremophila mitchellii*, *Geijera parviflora*, and *Heterodendrum oleifolium*; ground cover very sparse, *Eragrostis megalosperma*, *Chloris unispicea*, *Paspalidium radiatum*, *Bassia tetracuspis*, and *Enchylaena tomentosa*; in the area slightly south and east of Morven *Cadellia pentastylis* replaces *Eucalyptus thozetiana.*

Land Capability.—VId$_6$, r$_{4-6}$, t$_{4-6}$. **No. of Observations.**—7.

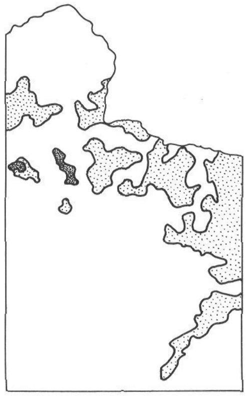
LAND UNIT 36 (935 KM^2)

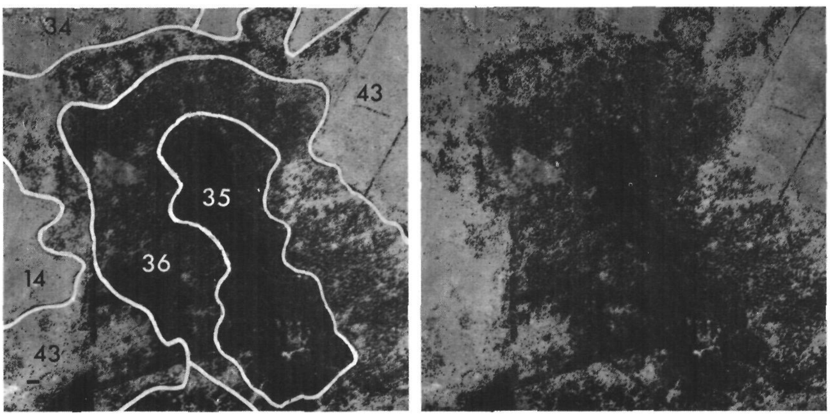
Field Criteria.—Rolling country, yapunyah woodland, brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 350–420 mm. May–Oct.: 160–250 mm.

Material.—Unresistant weathered labile sediments; surficial silcrete gravel.

Relief.—Escarpments 5–25 m high and rolling terrain; slopes 1·5–4·5%.





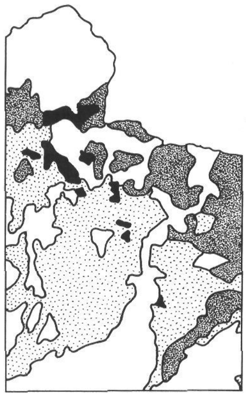
Position on Slope.—Predominantly lower slopes.

Soil.—Brown and grey-brown soils: 70–105 cm deep; mainly uniform clay, occasionally light clay grading to heavy clay, Bb (Uf6.5, 6.33), Bc (Uf6.31, Gn3.26), and Ba (Uf6.31, Gn3.11); generally strongly alkaline reaction in subsoils; surface strew of gravel and stones common.

Vegetation.—Woodland of *Eucalyptus thozetiana*, rarely *E. microcarpa*, with occasional *Casuarina cristata* or with lower tree layer of *Casuarina cristata* and *Acacia harpophylla*; occasional shrub layer of *Carissa ovata*, *Heterodendrum diversifolium*, *Eremophila mitchellii*, and *Geijera parviflora*; ground cover sparse, *Rhagodia parabolica*, *R. nutans*, *Chloris acicularis*, *Ancistrachne uncinulatum*, *Paspalidium* spp., and *Bassia tetracuspis*; slightly to the south and east of Morven *Cadellia pentastylis* occurs in the community either associated with *Eucalyptus thozetiana* and *E. microcarpa* or alone.

Land Capability.—IV or VIr_{4-6}, s_{3-4}, c_{3-4}. **No. of Observations.**—12.

LAND UNIT 37 (4755 KM^2)

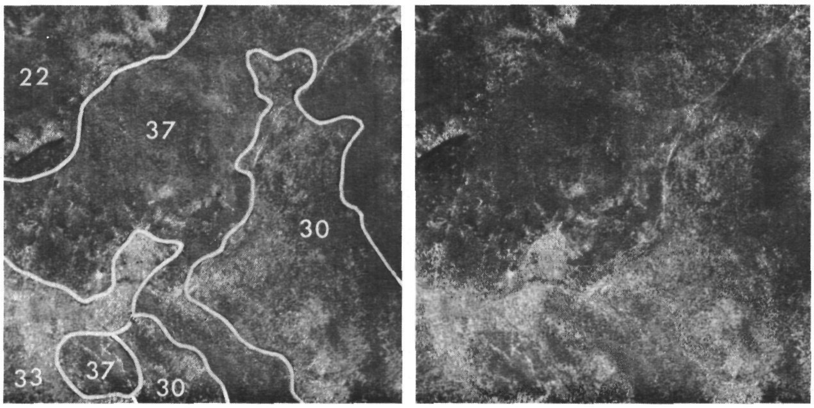


Field Criteria.—Undulating lowlands, box–brigalow woodlands and shrubs, deep texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 200–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered fine-grained sediments.

Relief.—Undulating; slopes 0·5–4%.



Position on Slope.—Lower slopes.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over blocky subsoils, mainly strongly alkaline, less commonly with neutral to acid reaction, Da (Dr2.13, Db1.13), Db (Dd1.23, Dy2.33), and Dc (Dr2.22, Db1.11); these soils intergrade with columnar-structured soils in places, mainly Dd (Db1.23, 2.43), minor De (Dd1.22).

Vegetation.—Woodland of *Eucalyptus populnea* with lower tree layer, usually dense, commonly *Acacia harpophylla* and sometimes *Casuarina cristata*, rarely *Acacia omalophylla*, sometimes *C. cristata* in canopy layer, moderately dense shrub layer, *Eremophila mitchellii* common and constant, *Geijera parviflora*, *Capparis lasiantha*, and *Cassia nemophila* occasional; ground cover sparse to moderately dense depending on the density of woody plants, *Paspalidium gracile*, *P. radiatum*, *Aristida ramosa*, *Rhagodia nutans*, and *Chloris acicularis* most common.

Land Capability.—III, IV, or VIp_{3-4}, e_{3-4}, s_{3-4}, c_{3-6}. **No. of Observations.**—34.

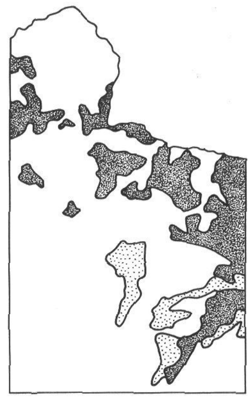
LAND UNIT 38 (5700 KM²)

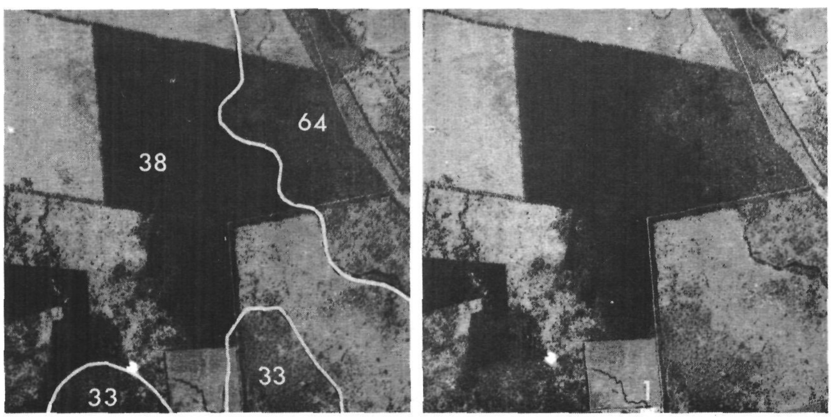
Field Criteria.—Gently undulating plains, belah forest and some brigalow and shrubs, deep texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Gently undulating; slopes 0·6–1 %.





Position on Slope.—Predominantly lower slopes.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over strongly alkaline, blocky, mainly red or brown subsoils, Da (Dr2.23, Db1.33), less commonly yellow or dark subsoils, Db (Dy2.23, Dd1.13); minor occurrences of soils with neutral reaction, Dc (Db1.22, Dd1.42) or columnar structure, Dd (Db1.43, 1.23).

Vegetation.—Open-forest of *Casuarina cristata* with occasional *A. harpophylla*, occasionally with *Eucalyptus populnea*; shrub layer sparse to moderately dense, rarely absent, of *Eremophila mitchellii* and/or *Geijera parviflora*, occasionally lower *Carissa ovata* or *Myoporum deserti*; ground cover sparse, *Paspalidium radiatum*, *P. gracile*, *P. criniforme*, *Chloris acicularis*, *Enchylaena tomentosa*, *Rhagodia nutans*, *Bassia tetracuspis*, and, less commonly, *Aristida ramosa*, *Ancistrachne uncinulatum*, *Cyperus gracile*, *Chloris ventricosa*, and *Atriplex semibaccatum*.

Land Capability.—III–IVp_{3-4}, s_{3-4}, c_{3-4}. **No. of Observations.**—42.

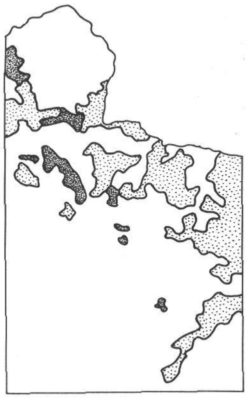
LAND UNIT 39 (950 km^2)

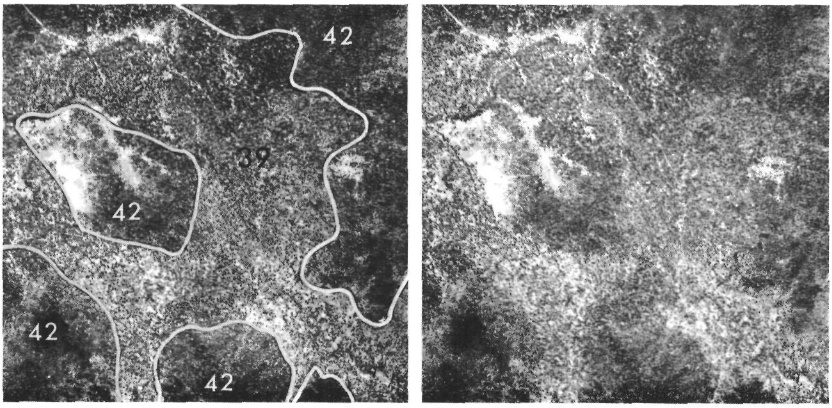
Field Criteria.—Lowlands, box–brigalow woodland and shrubs, brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Undulating; slopes 1–3%.





Position on Slope.—Lower slopes.

Soil.—Brown and grey-brown soils: 90 cm or more in depth, uniform fine-textured or gradational (loams to clays), mainly Bc (Uf6.31, Gn3.23) with neutral reaction in surface horizons, becoming strongly alkaline and moderately calcareous in subsoils; occurrences of Ba (Gn3.12) and Bb (Uf6.31, Gn3.13) soils in some locations.

Vegetation.—Woodland of *Eucalyptus populnea* with moderately dense understorey of *Acacia harpophylla*, sometimes with *Casuarina cristata*; moderately dense understorey of *Eremophila mitchellii*, occasionally with *Geijera parviflora*, or *Eremocitrus glauca*; sparse ground cover of *Paspalidium gracile*, *P. radiatum*, *Chloris acicularis*, *Aristida ramosa*, and *Ancistrachne uncinulatum*.

Land Capability.—III–IVk$_{3-4}$, s$_{3-4}$, c$_{3-4}$. **No. of Observations.**—16.

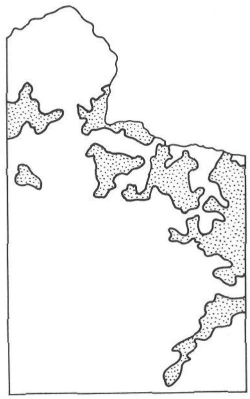
LAND UNIT 40 (1245 KM[2])

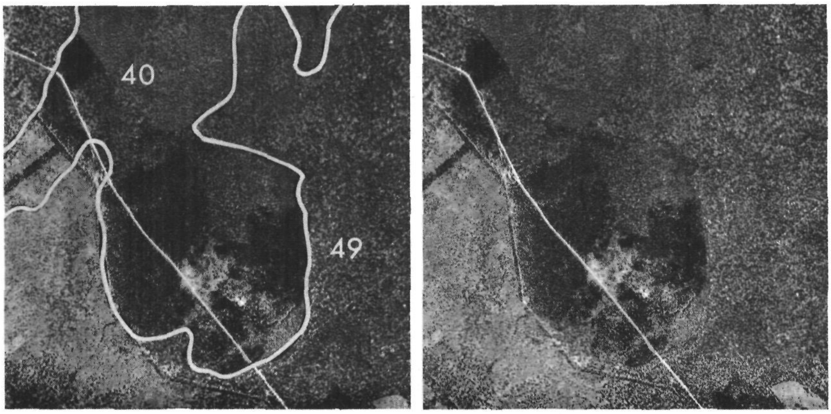
Field Criteria.—Lowlands, open-forest of belah or brigalow and shrubs, brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Undulating; slopes 1–3·5%.





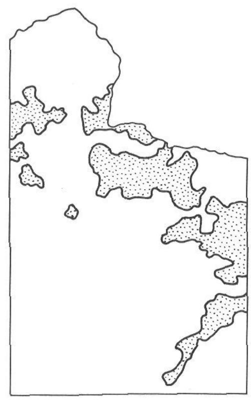
Position on Slope.—On all parts of slopes.

Soil.—Brown and grey-brown soils: generally >90 cm deep; clay loams grading to clay or uniform medium to heavy clay, Bc (Gn3.23, Uf6.33, 6.31) and Bb (Gn3.16, 3.13); mainly neutral reaction in surface horizons grading to strongly alkaline in subsoils, occasionally strongly alkaline throughout; small to moderate (3–15%) accumulations of soft carbonate; minor reddish brown acid to neutral subsoils, Ba (Gn3.12, Uf6.31); surface gravel common; moderate to severe sheet erosion at some locations.

Vegetation.—Open-forest of *Casuarina cristata* with occasional *Acacia harpophylla* or, mainly in the west of the area, of *A. harpophylla* with occasional *C. cristata*, both sometimes with occasional *Eucalyptus populnea*, *E. microcarpa*, or rarely *E. orgadophila*; shrub layer usually present, sparse to moderately dense of *Eremophila mitchellii* and *Geijera parviflora*, sometimes with dense *Carissa ovata*; ground cover sparse, *Paspalidium radiatum*, *P. gracile*, *Chloris acicularis*, *Rhagodia nutans*, *Enchylaena tomentosa*, *Bassia tetracuspis*, and less commonly *Ancistrachne uncinulatum*, *Atriplex* spp., and *Aristida ramosa*.

Land Capability.—III–IVk$_{3-4}$, s$_{3-4}$, c$_{3-4}$. **No. of Observations.**—21.

LAND UNIT 41 (540 KM^2)

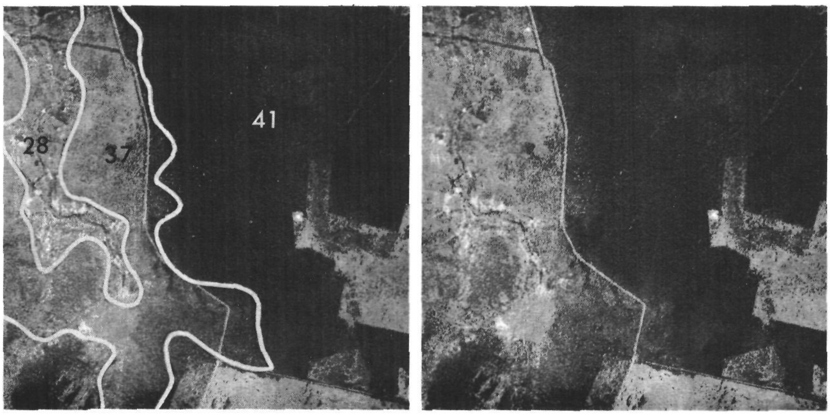


Field Criteria.—Undulating margins of downs, woodland of belah, brigalow, whitewood, or bauhinia, calcareous cracking clays.

Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–250 mm.

Material.—Fresh and slightly weathered shale and labile siltstone.

Relief.—Undulating; slopes 0·5–3 %.



Position on Slope.—Predominantly lower slopes.

Soil.—Cracking clay soils: 65–135 cm deep; Cb (Ug5.23); minor Cf (Ug5.22), and non-cracking clays Bc and Bd (Uf6.31); commonly with carbonate (3–10 %) and gypsum (5–20 %) accumulations; strongly alkaline at or near the surface and acid beneath or neutral at surface grading to strongly alkaline.

Vegetation.—Woodland of *Casuarina cristata* with occasional *Acacia harpophylla, Atalaya hemiglauca, Bauhinia carronii*, and *Heterodendrum oleifolium*, with sparse shrub layer of *Eremophila mitchellii* and *Geijera parviflora*; occasionally low open-woodland of *Atalaya hemiglauca* and/or *Bauhinia carronii* without shrubs; ground cover sparse to moderately dense, in open communities, of *Rhagodia parabolica, Paspalidium gracile, Chloris acicularis, Bassia tetracuspis, Aristida leptopoda*, and *Astrebla* spp., when heavily grazed often scattered plants of *Bassia* spp., *Atriplex* spp., and *Trianthema crystallina.*

Land Capability.—III–IV k_{3-4}, s_{3-4}, c_{3-4}. **No. of Observations.**—9.

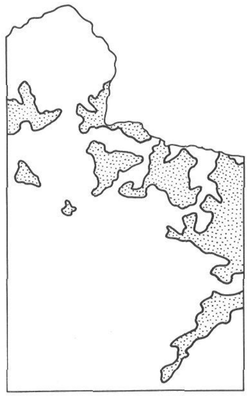
Land Unit 42 (890 km^2)

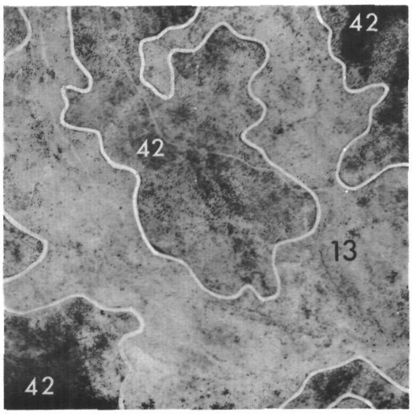
Field Criteria.—Lowlands, brigalow and shrubs, cracking clay soils, no gilgai.

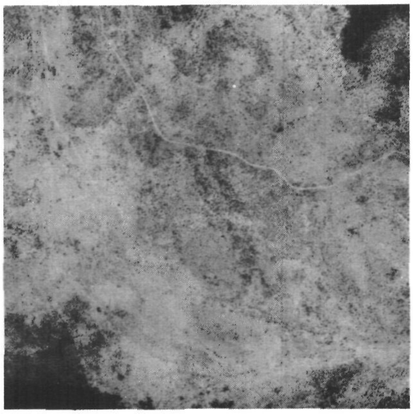
Median Rainfall.—Nov.–Apr.: 320–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Undulating; slopes 1–3%.







Position on Slope.—On all parts of slope.

Soil.—Cracking clay and brown and grey-brown soils: 80–>150 cm deep; mainly Cb (Ug5.12, 5.13, 5.14), less extensive Bc (Gn3.93, 3.43); minor shallow soils <60 cm, Cf (Ug5.12) and Bf (Uf6.31).

Vegetation.—Open-forest (rarely woodland) of *Acacia harpophylla* sometimes with occasional *Casuarina cristata*, *Cadellia pentastylis*, or emergent *Eucalyptus thozetiana*; shrub layer open to dense of *Eremophila mitchellii* and/or *Geijera parviflora*; ground cover sparse, *Chloris acicularis*, *Paspalidium gracile*, *P. radiatum*, *Rhagodia nutans*, and *Bassia tetracuspis* or, in open communities adjacent to grassland, *Astrebla* spp., *Thellungia advena*, and *Panicum decompositum*; shrub layer sometimes (east of "Womblebank") contains elements of semi-evergreen vine thicket.

Land Capability.—III–IV k_{3-4}, s_{3-4}, c_{3-4}. **No. of Observations.**—9.

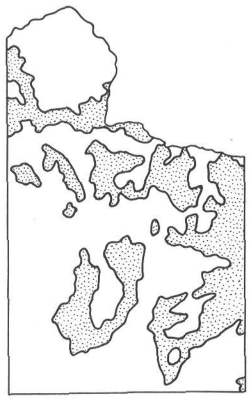
LAND UNIT 43 (2145 KM²)

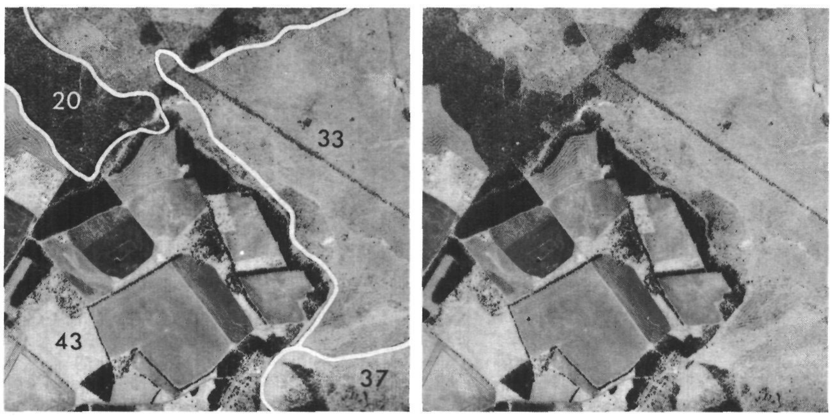
Field Criteria.—Lowlands and plains, belah and minor brigalow and shrubs, cracking clay soils rarely gilgaied.

Median Rainfall.—Nov.–Apr.: 250–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Gently undulating to level; slopes 0·5–2·5%.





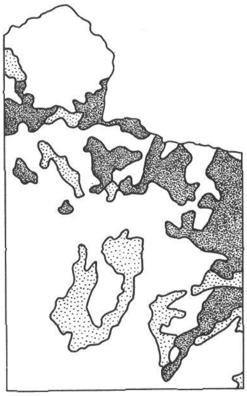
Position on Slope.—Lower slopes.

Soil.—Cracking clay soils: 110–>150 cm deep; dark grey-brown to reddish brown medium to heavy clays, Cb (Ug5.24, 5.34, 5.37); generally strongly alkaline near the surface, where soft carbonate accumulations (3–15%) are common, and medium to strongly acid in gypseous horizons; slight microrelief in places (< 30 cm); weakly to strongly self-mulching when dry.

Vegetation.—Open-forest of *Casuarina cristata*, always with some *Acacia harpophylla*, sometimes as a lower layer; moderately dense shrub layer of *Geijera parviflora*, occasionally with *Eremophila mitchellii*; ground cover sparse, *Paspalidium radiatum*, *P. gracile* (rarely other *P.* spp.), *Chloris acicularis*, *Ancistrachne uncinulatum*, *Rhagodia nutans*, and *Enchylaena tomentosa*.

Land Capability.—III–IV k_{3-4}, s_{3-4}, c_{3-4}. **No. of Observations.**—14.

LAND UNIT 44 (2835 KM^2)

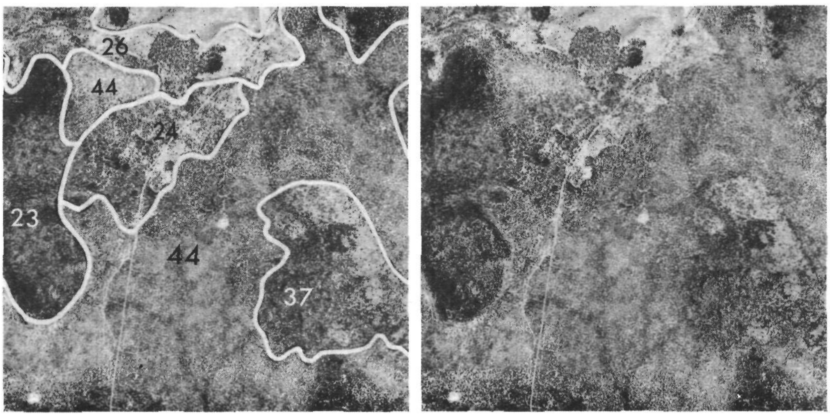


Field Criteria.—Lowlands and plains, brigalow, gilgaied clay soil.

Median Rainfall.—Nov.–Apr.: 250–450 mm. May–Oct.: 150–250 mm.

Material.—Unresistant weathered labile sediments.

Relief.—Gently undulating to level; slopes probably 0·5–2·5%.



Position on Slope.—Probably lower slopes.

Soil.—Gilgaied deep cracking clay soils: >150 cm deep, Ca (Ug5.24, 5.34); microrelief 60–180 cm; generally mildly to strongly alkaline in upper 60–90 cm where small accumulations of soft carbonate may occur and slightly to strongly acid in mottled horizons beneath; less commonly acid throughout or strongly alkaline in lower profiles; weakly self-mulching.

Vegetation.—Open-forest of *Acacia harpophylla*, often with *Casuarina cristata*, sometimes with emergent *Eucalyptus populnea* or less commonly *E. thozetiana* or *E. microcarpa*; or open-forest of *Casuarina cristata* with occasional *Acacia harpophylla* and occasionally emergent *E. populnea*; shrub layer variable, often dense *Geijera parviflora* and/or *Eremophila mitchellii*; sometimes a low shrub layer of *Carissa ovata*; ground cover sparse, *Paspalidium radiatum*, *P. gracile*, *Ancistrachne uncinulatum*, *Chloris acicularis*, *Enchylaena tomentosa*, *Rhagodia nutans*, and *Bassia tetracuspis*.

Land Capability.—IVg_4, s_4, c_{3-4}. **No. of Observations.**—20.

Geomorphic category	Cainozoic deposits (coarse- to medium-textured)		Cainozoic deposits (medium- to fine-textured)			
Land system	CpCp	CpXM part, CpM part	CpXM part, CpM part, CpBXM	CpBl part, CpG part	CpG part	CpBl part, CpG part
Terrain	Very gently undulating	Almost level to very gently undulating—uneven microlief (30–90 cm) in some areas				

Soils	Uniform sandy soils, Fa, Fb	Massive earths, Eb (Ec, Ed)	(*a*) Sandy duplex soils, Df, and massive earths, Ec (*b*) Sandy and loamy duplex soils, Df, Da (*c*) Duplex soils, Db	Mosaics of massive earths, Eb, Ec; duplex soils, Da; brown and grey-brown soils, Bc, Bb, Ba; and gilgaied clays, Ca	Cracking clay soils, Cb	Gilgaied cracking clay soils, Ca
Vegetation	(*a*) *Angophora melanoxylon* woodland (*b*) Box, ironbark, cypress pine woodland (*c*) Silver-leaved ironbark, mulga woodland	Box, silver-leaved ironbark, and/or forest gum woodland with mulga or cypress pine understorey	(*a*) Brigalow, box, mulga woodland (*b*) Box, forest gum, mulga, cypress pine woodland (*c*) Box, brigalow, gidgee woodland	Box–brigalow and/or belah woodland with brigalow, belah, and/or gidgee on gilgaied clays	Brigalow low open woodland	Belah, brigalow, or gidgee forest
Land units	(*a*) 45, (*b*) 46, (*c*) 47	48, 49	(*a*) 50, (*b*) 51, (*c*) 52	53, 54, 55, 56	57	58, 59

Fig. 9.—Distribution of land units on depositional plains.

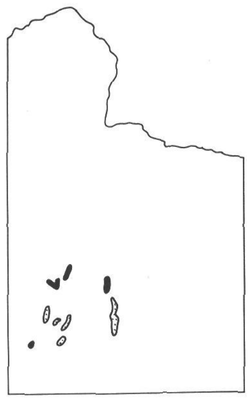
LAND UNIT 45 (315 KM²)

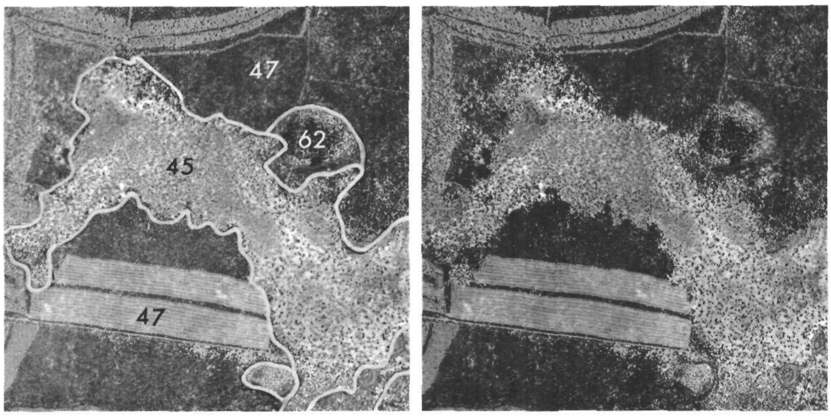
Field Criteria.—Plains and low rises of sand, apple and dense shrubs, uniform sandy soils.

Median Rainfall.—Nov.–Apr.: 200–300 mm. May–Oct.: 140–190 mm.

Material.—Cainozoic sand locally reworked by wind.

Relief.—Plains; old levees and dunes, slopes 0·3–1·5%.





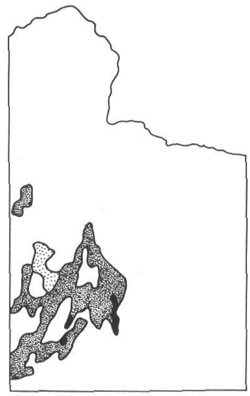
Position on Slope.—Upper slopes and crests.

Soil.—Uniform sandy soils: medium sand to loamy sand, 130–>150 cm deep, reddish brown to yellowish brown, Fa (Uc1.23) and Fb (Uc5.11, 1.22).

Vegetation.—Open-woodland of *Angophora melanoxylon* with occasional *Eucalyptus melanophloia*, *E. dealbata*, and *Callitris columellaris*; dense varied shrub layer mainly *Acacia* sp. aff. *lineata*, *A. maitlandii*, *Grevillea parallela*, *Calytrix tetragona*, *Leucopogon mitchellii*, *Baeckea jucunda*, and *Ricinocarpos bowmanii*; ground cover sparse, mainly *Triodia mitchellii*, *Aristida echinata*, *A. muricata*, *Eriachne mucronata*, *Amphipogon caricinus*, and *Digitaria divaricatissima*; shrub layer often predominates possibly because of suppression of trees by fire.

Land Capability.—VIc_6, m_4. **No. of Observations.**—8.

Land Unit 46 (1450 km²)

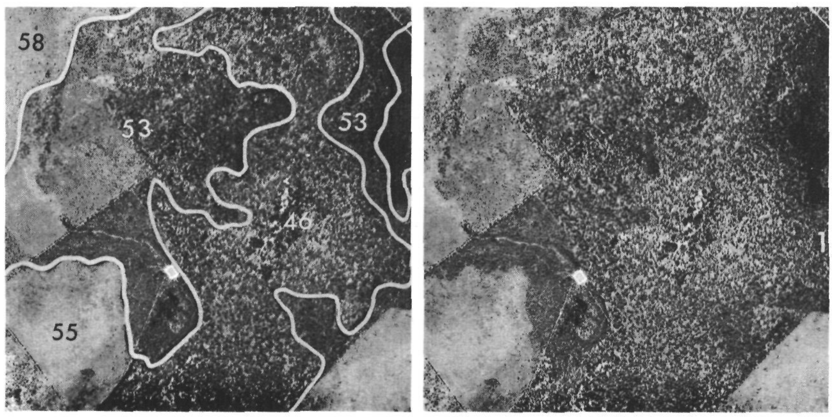


Field Criteria.—Plains, silver-leaved ironbark, forest gum, or box woodland with cypress pine or mulga understorey; sandy soils with no gravel.

Median Rainfall.—Nov.–Apr.: 200–300 mm. May–Oct.: 140–190 mm.

Material.—Cainozoic sands.

Relief.—Plains; slopes 0·1–0·5%.



Position on Slope.—Predominantly upper slopes.

Soil.—Uniform sandy soils: 110–>150 cm deep; underlain by clayey D horizons in places; reddish brown to red, less commonly brown, sands to loamy sands, Fa (Uc1.23) and Fb (Uc1.21, 1.23); well drained, soft, structureless; medium acid to neutral reaction.

Vegetation.—Woodland of *Eucalyptus melanophloia*, rarely *E. intertexta* or *E. populnea*, or, in south-west, open-woodland of *E. tessellaris*, with lower tree layer of *Callitris columellaris*, often with considerable *Acacia aneura*, *Angophora melanoxylon*, or occasional *A. excelsa*; shrubs usually absent; ground cover very sparse, *Aristida jerichoensis*, *A. echinata*, *Neurachne mitchelliana*, *Chloris acicularis*, and *Paspalidium constrictum* most common.

Land Capability.—IV or VIc_{4-6}, m_4. **No. of Observations.**—12.

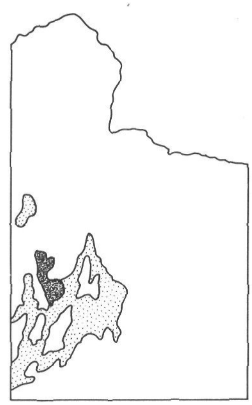
Land Unit 47 (480 km²)

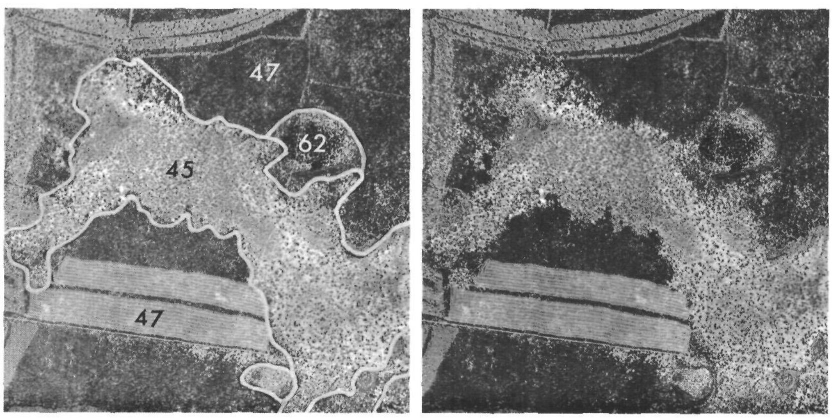
Field Criteria.—Plains, open-forest of mulga and emergent eucalypts, deep sandy soils.

Median Rainfall.—Nov.–Apr.: 200–300 mm. May–Oct.: 140–190 mm.

Material.—Cainozoic sands.

Relief.—Plains; slopes 0·3–1%.





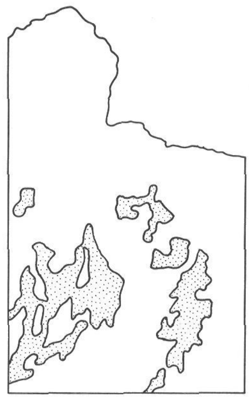
Position on Slope.—Predominantly upper slopes.

Soil.—Uniform sandy soils: very deep (> 150 cm); reddish brown to red neutral to acid loamy sands, Fa (Uc1.23); evidence of slight erosion by wind and water in places.

Vegetation.—Open-forest of *Acacia aneura* with occasional *Angophora melanoxylon* or *Eucalyptus dealbata*, or woodland of *E. melanophloia* with occasional *E. intertexta* and dense lower tree layer of *Acacia aneura*; shrubs usually absent; ground cover extremely sparse, *Aristida jerichoensis*, *Neurachne mitchelliana*, *Sida brachypoda*, *Tripogon loliiformis*, and *Cheilanthes sieberi*.

Land Capability.—IV or VIc_{4-6}, m_4. **No. of Observations.**—3.

Land Unit 48 (940 km^2)

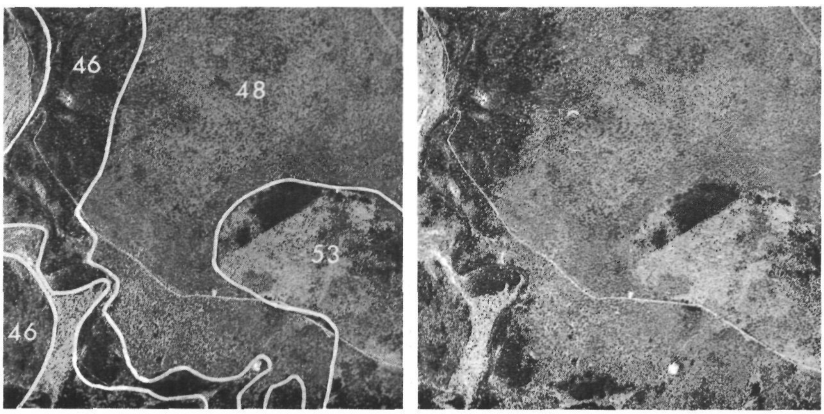


Field Criteria.—Plains and lowlands, silver-leaved ironbark woodland with cypress pine lower storey, loamy red earths.

Median Rainfall.—Nov.–Apr.: 200–400 mm. May–Oct.: 150–220 mm.

Material.—Cainozoic silts and mixed fine sediments; minor areas of moderately resistant weathered sediments.

Relief.—Plains with slopes 0·2–1% and undulating sandy colluvial spreads with slopes 1–2·5%.



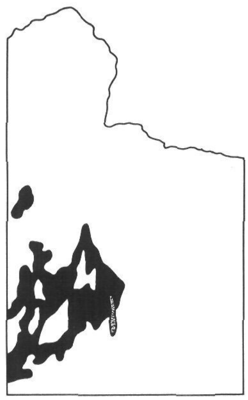
Position on Slope.—Predominantly upper slopes.

Soil.—Deep massive earths: mainly loamy red earths, more than 100 cm deep, gravel-free, Eb (Gn-2.12); minor sandy, alkaline, and loamy red and yellow earths, Ed (Gn2.21, 2.11), Ec (Gn2.13), and Ee (Gn2.45).

Vegetation.—Woodland of *Eucalyptus melanophloia*, rarely *E. populnea* or *E. intertexta* with dense but patchy lower layer of *Callitris columellaris* and occasionally a patchy shrub layer, mainly *Hovea longipes* or *Dodonaea attenuata*; ground cover sparse, *Aristida jerichoensis*, *A. ramosa*, *Bothriochloa decipiens*, *Neurachne mitchelliana*, *Paspalidium constrictum*, and *Enneapogon pallidus* being conspicuous.

Land Capability.—IV or VIm_4, c_{3-6}. **No. of Observations.**—16.

LAND UNIT 49 (6440 KM²)

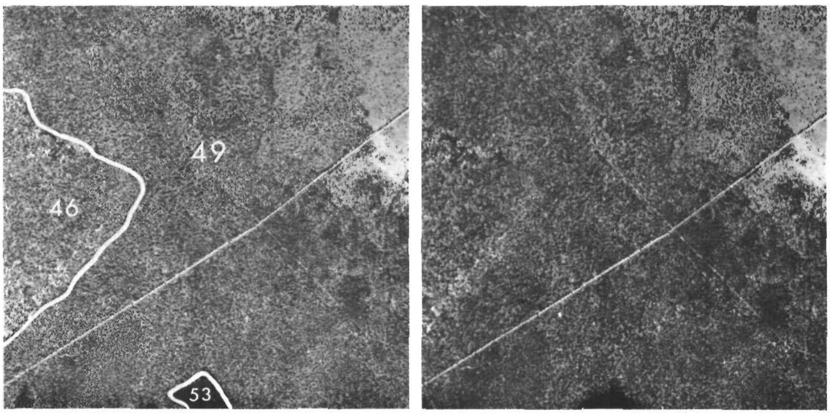


Field Criteria.—Plains, box, forest gum, or ironbark woodland, deep red earths with no gravel.

Median Rainfall.—Nov.–Apr.: 200–400 mm. May–Oct.: 150–220 mm.

Material.—Cainozoic silts and mixed fine sediments.

Relief.—Plains; slopes 0·1–0·7%.



Position on Slope.—On all parts of slopes.

Soil.—Deep massive earths: mainly loamy red earths on transported materials, Eb (Gn2.12, 2.11); minor occurrences of loamy red earths with gravel, Ea (Gn2.12), alkaline red earths, Ec (Gn2.13), and sandy red earths, Ed (Gn2.12).

Vegetation.—Woodland of *Eucalyptus populnea*, sometimes of *E. melanophloia* or *E. intertexta*, with considerable intermixing of the three; lower tree layer of *Acacia aneura*, occasionally with considerable *Callitris columellaris* and sporadic *A. excelsa* and *Brachychiton populneum*; sometimes moderately dense rather tall shrub layer of *Eremophila mitchellii* with lesser *Geijera parviflora*, and *Notelaea microcarpa*, sometimes a lower shrub layer of *Cassia nemophila or Dodonaea attenuata*; ground cover usually sparse, *Neurachne mitchelliana* and *Aristida jerichoensis*, *Paspalidium constrictum*, *Sida brachypoda*, and *Eragrostis lacunaria* and occasionally *Digitaria brownii*, *Chloris acicularis*, *Hibiscus sturtii*, and *Bassia* spp.

Land Capability.—IV or VIc$_{4-6}$, m$_4$. **No. of Observations.**—42.

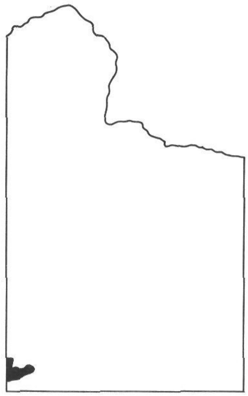
Land Unit 50 (115 km^2)

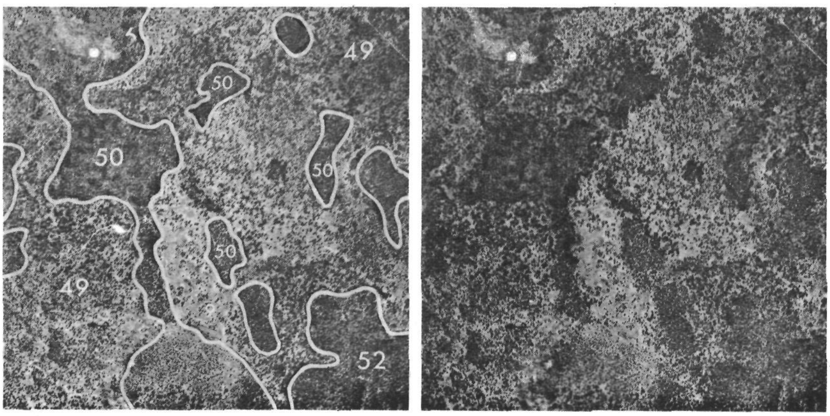
Field Criteria.—Plains, brigalow and mulga woodland with emergent eucalypts, texture-contrast soils and red earths.

Median Rainfall.—Nov.–Apr.: 200–220 mm. May–Oct.: 140–160 mm.

Material.—Cainozoic mixed fine sediments.

Relief.—Plains.





Position on Slope.—No information.

Soil.—Texture-contrast soils and massive earths: thick sandy surface horizons over strongly alkaline subsoils with soft carbonate accumulations, Df (Dr2.63), and alkaline loamy red earths, Ec (Gn2.13); 10–15% gravel in lower subsoils.

Vegetation.—Woodland of *Acacia harpophylla* with emergent *Eucalyptus populnea* and patchy *A. aneura*; irregular shrub layer of *Eremophila mitchellii* and *Geijera parviflora*; ground cover sparse, *Paspalidium gracile*, *Rhagodia nutans*, *Neurachne mitchelliana*, *Bassia diacantha*, and *Eragrostis lacunaria*.

Land Capability.—VIc_6, m_4, p_{3-4}. **No. of Observations.**—2.

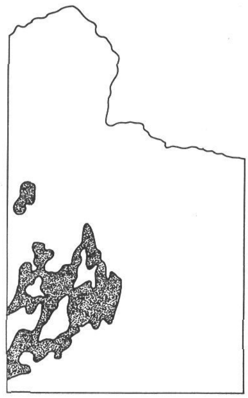
LAND UNIT 51 (1880 KM^2)

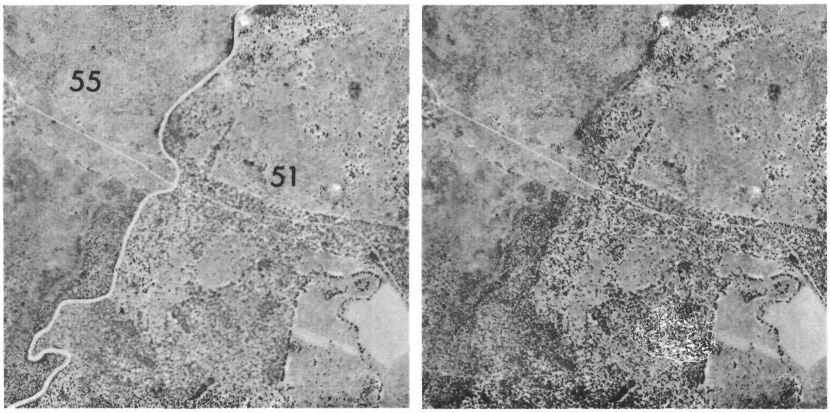
Field Criteria.—Plains, box and forest gum woodland with cypress pine or mulga understorey, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 220–450 mm. May–Oct.: 140–200 mm.

Material.—Cainozoic mixed fine sediments; minor sandy colluvium.

Relief.—Plains.





Position on Slope.—On all parts of slope.

Soil.—Deep texture-contrast soils: mainly thick (> 38 cm) sandy or loamy surface horizons over strongly alkaline subsoils, Df and Da (Dr2.23, 2.13); minor Dg and Dc (Dy3.42, 3.22).

Vegetation.—Woodland of *Eucalyptus populnea* (or *E. intertexta*) with lower tree layer of *Callitris columellaris* or *Acacia aneura* or both intermixed, sometimes considerably modified; shrub layer of *Eremophila mitchellii* and *Cassia nemophila*; ground cover open, mainly *Aristida jerichoensis*, *Neurachne mitchelliana*, *Digitaria ammophila*, *Eragrostis lacunaria*, and *Tripogon loliiformis*.

Land Capability.—IV or VIc_{4-6}, m_4, p_{3-4}. **No. of Observations.**—10.

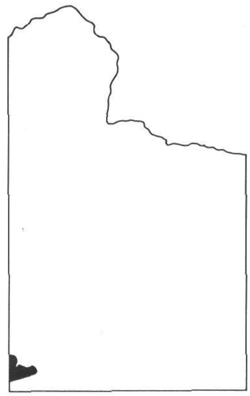
LAND UNIT 52 (115 KM^2)

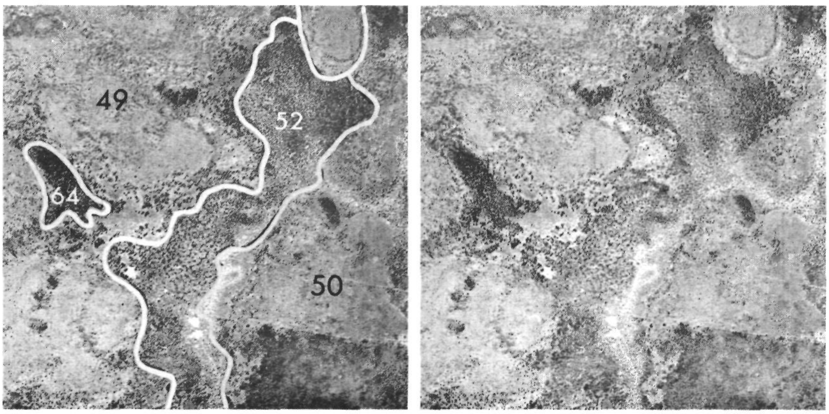
Field Criteria.—Clay plains, black box woodland with interspersed gidgee and brigalow, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 200–220 mm. May–Oct.: 140–160 mm.

Material.—Cainozoic clay.

Relief.—Plains; slopes presumably about 0·2–1%.





Position on Slope.—No information.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over blocky strongly alkaline subsoils, Db (Dy2.43, 2.23).

Vegetation.—Woodland of *Eucalyptus largiflorens* with occasional *Acacia cambagei* and *A. harpophylla*; occasionally a shrub layer of *Eremophila mitchellii* and *Rhagodia parabolica*; ground cover sparse, *Eragrostis setifolia*, *Tripogon loliiformis*, *Sporobolus caroli*, *Paspalidium gracile*, and *Bassia* spp.

Land Capability.—VIc_6, p_{3-4}, s_{3-4}. **No. of Observations.**—3.

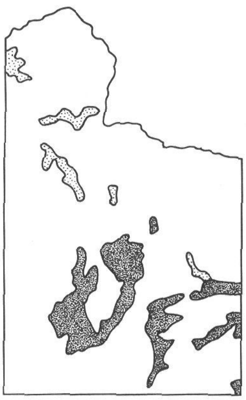
LAND UNIT 53 (1610 KM^2)

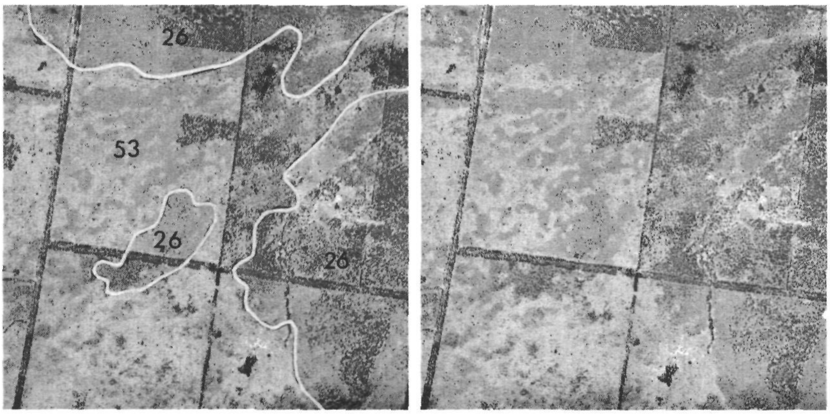
Field Criteria.—Clay plains, mosaic of belah and box woodland, mosaic of gilgaied clays and red earths.

Median Rainfall.—Nov.–Apr.: 220–450 mm. May–Oct.: 140–200 mm.

Material.—Cainozoic clay.

Relief.—Plains with gilgai.





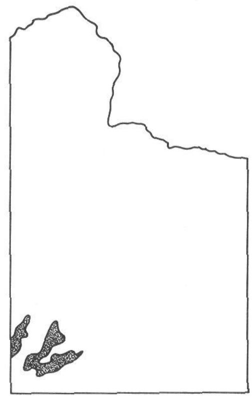
Position on Slope.—Presumably lower slopes.

Soil.—Mosaic of gilgaied cracking clays and massive earths: Ca (Ug5.24, 5.34) and loamy massive earths, Ec (Gn2.13, occasionally Gc2.12) and Eb (Gn2.12), in varying proportions. The massive earths are commonly shallow and underlain by a thin gravelly mottled layer above strongly alkaline calcareous pale grey clay. This unit commonly adjoins uniform areas of loamy red earths (land units 48 and 49).

Vegetation.—Open-forest of *Casuarina cristata* with *Eucalyptus populnea* or woodland of *E. populnea* with rather dense lower tree layer of *C. cristata*; moderately dense shrub layer of *Eremophila mitchellii* and *Geijera parviflora*; sparse ground cover of *Chloris acicularis, Paspalidium radiatum, P. gracile,* and occasionally *Aristida ramosa* and *Bothriochloa decipiens.*

Land Capability.—IV or VIg_4, s_{3-4}, c_{3-6}. **No. of Observations.**—8.

Land Unit 54 (365 km²)

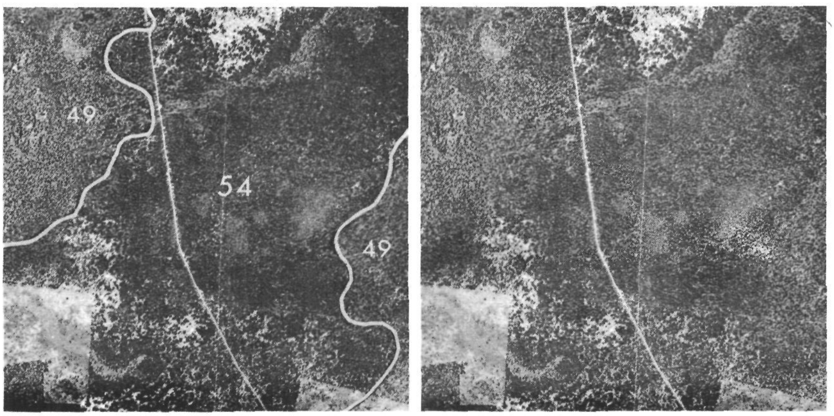


Field Criteria.—Clay plains, mosaic of gidgee and box or belah, mosaic of gilgaied clays and red earths.

Median Rainfall.—Nov.–Apr.: 200–250 mm. May–Oct.: 140–160 mm.

Material.—Cainozoic clay.

Relief.—Plains with gilgai.



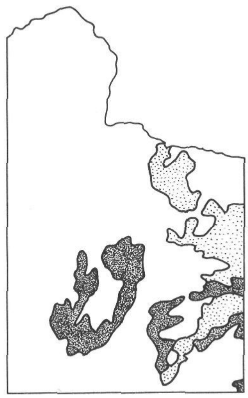
Position on Slope.—Presumably lower slopes.

Soil.—Mosaic of gilgaied cracking clay soils and massive earths: Ca (Ug5.24) and massive earths, mainly Ec (Gn2.13, 2.23, 2.83), minor Ea (Gn2.12) in varying proportions; the massive earths are commonly underlain by gravelly layers and calcareous carbonate-enriched clays.

Vegetation.—Open-forest, sometimes rather low, of *Acacia cambagei*, sometimes with occasional *Eucalyptus populnea* or *Casuarina cristata*; shrub layer, moderately dense and patchy, of *Eremophila mitchellii* and *Geijera parviflora*; ground cover sparse, *Chloris acicularis*, *Bassia diacantha*, *Enchylaena tomentosa*, *Paspalidium gracile*, and *Sporobolus caroli*.

Land Capability.—VIc$_6$, g$_4$, s$_{3-4}$. **No. of Observations.**—5.

LAND UNIT 55 (2065 KM²)

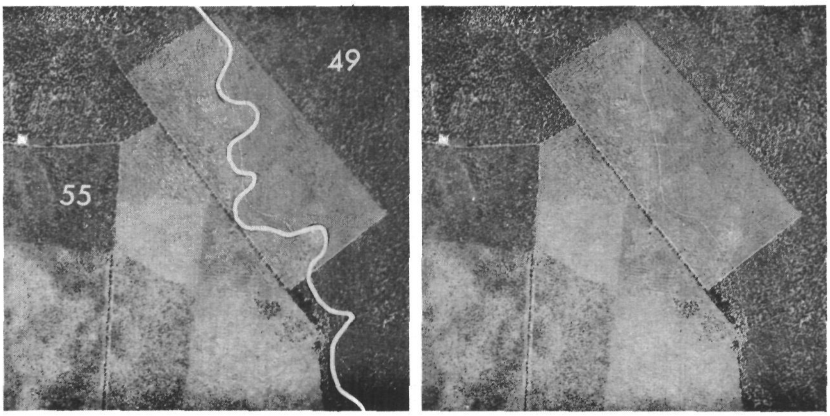


Field Criteria.—Plains, box woodland with brigalow–belah understorey, mosaic of gilgaied clays, texture-contrast soils, and dark brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 300–400 mm. May–Oct: 200–250 mm.

Material.—Cainozoic clay; minor unresistant weathered sediments.

Relief.—Plains and undulating lowlands; slopes 0·4–1%.



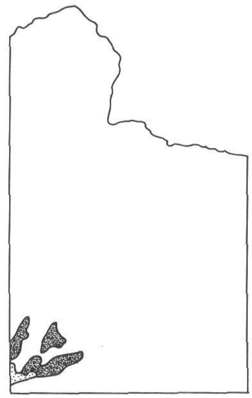
Position on Slope.—Predominantly lower slopes but also on broad interfluves.

Soil.—Mosaic of gilgaied cracking clay and other soils: Ca (Ug5.24, 5.34) and texture-contrast soils, Da (Dr2.23, 2.23, Db1.23), and/or dark brown and grey-brown soils, Bb, Bc, and Ba (Gn3.13, 3.96, Uf6.31) in varying proportions. The gilgaied soils are commonly strongly alkaline throughout and less commonly are alkaline at or near the surface and acid beneath. The non-gilgaied soils generally have subsoil accumulations of soft carbonate.

Vegetation.—Woodland of *Eucalyptus populnea* with lower tree layer of *Acacia harpophylla* and *Casuarina cristata* in varying proportions, rarely open-forest of *A. harpophylla* and/or *C. cristata* with emergent *E. populnea*, moderately dense shrub layer of *Eremophila mitchellii* and *Geijera parviflora*; ground cover sparse, *Paspalidium gracile* and *P. radiatum*, *Ancistrachne uncinulatum*, *Chloris acicularis*, and less commonly *Aristida ramosa* and *Bothriochloa decipiens*.

Land Capability.—IV or VIg_4, s_{3-4}, c_{3-6}. **No. of Observations.**—17.

Land Unit 56 (380 km^2)

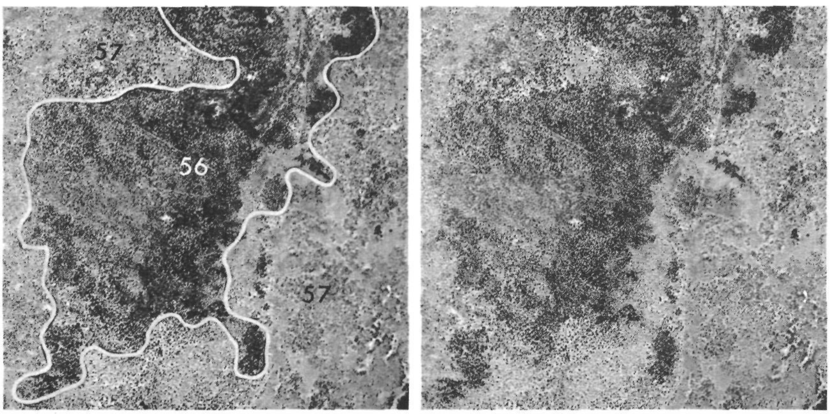


Field Criteria.—Clay plains, gidgee forest on mosaic of gilgaied clays, texture-contrast soils, and brown soils.

Median Rainfall.—Nov.–Apr.: 200–250 mm. May–Oct.: 140–160 mm.

Material.—Cainozoic clay.

Relief.—Plains with gilgai.



Position on Slope.—Presumably lower slopes.

Soil.—Mosaic of gilgaied cracking clay and other soils: Ca (Ug5.24, 5.34), texture-contrast soils, Da (Db1.23), and/or dark brown and grey-brown soils, Bc (Uf6.33, 6.51), in varying proportions.

Vegetation.—Open-forest of *Acacia cambagei* occasionally with some *A. harpophylla*; shrub layer usually open, *Eremophila mitchellii*, *Geijera parviflora*, *Myoporum deserti*, and *Pimelea pauciflora*; ground cover sparse, *Tripogon loliiformis*, *Bassia* spp. (*B. calcarata*, *B. diacantha*, amd *B. lanicuspis*).

Land Capability.—VIc$_6$, g$_4$, s$_{3-4}$. **No. of Observations.**—4.

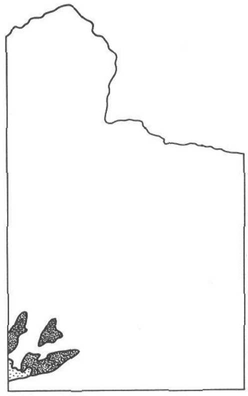
LAND UNIT 57 (235 km^2)

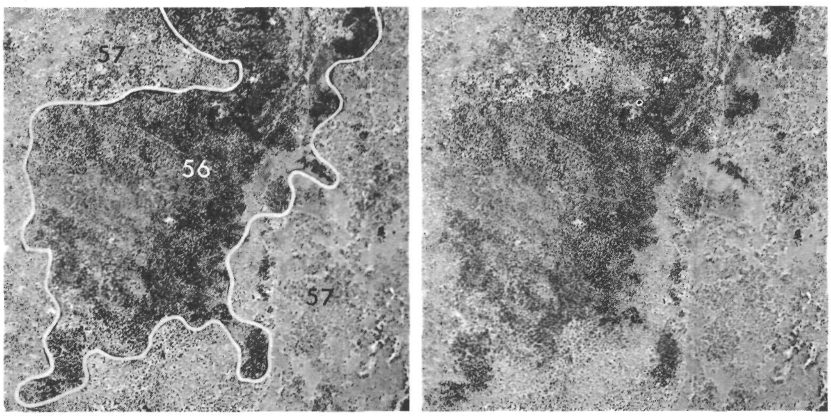
Field Criteria.—Clay plains, low open woodland of brigalow, cracking clay soils without gilgai.

Median Rainfall.—Nov.–Apr.: 200–250 mm. May–Oct.: 140–160 mm.

Material.—Cainozoic clays and possibly unresistant weathered shales.

Relief.—Plains; slopes 0·4–1%.





Position on Slope.—Presumably on all parts of slope.

Soil.—Cracking clay soils; very deep (>150 cm), self-mulching, strongly alkaline throughout, Cb (Ug5.34); mottled, with gypsum accumulations (10–20%) below 90 cm.

Vegetation.—Low open-woodland of *Acacia harpophylla* with occasional *Eucalyptus populnea*; ground cover sparse, *Solanum esuriale*, *Atriplex muelleri*, *Enchylaena tomentosa*, *Sida trichopoda*, *Bassia diacantha*, and occasional *Astrebla* spp.

Land Capability.—VIc$_6$, s$_{3-4}$. **No. of Observations.**—1.

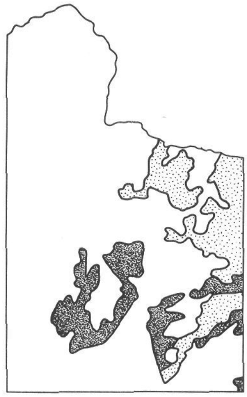
LAND UNIT 58 (3060 KM^2)

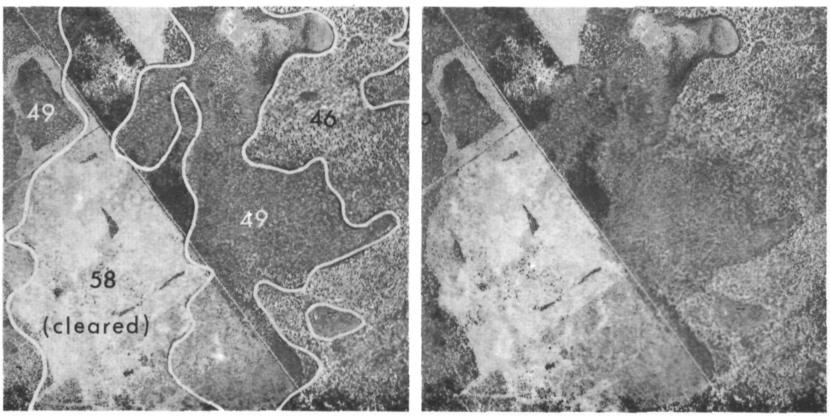
Field Criteria.—Clay plains, belah forest, gilgai.

Median Rainfall.—Nov.–Apr.: 300–400 mm. May–Oct: 200–250 mm.

Material.—Cainozoic clay.

Relief.—Plains with gilgai.





Position on Slope.—Predominantly lower and middle slopes.

Soil.—Gilgaied deep cracking clay soils: >150 cm deep, commonly much deeper, Ca (Ug5.24); generally strongly alkaline at or near the surface and slightly acid to neutral beneath, less commonly strongly alkaline throughout; small to moderate (3–30%) accumulations of soft carbonate and gypsum in upper and lower horizons respectively; prominent red mottling common at depth.

Vegetation.—Open-forest of *Casuarina cristata*, occasionally with sparse lower layer of *Acacia harpophylla* or with *A. cambagei* or *Eucalyptus populnea*; sparse to dense shrub layer of *Eremophila mitchellii, Geijera parviflora*, and occasionally *Atalaya hemiglauca, Myoporum deserti*, and *Carissa ovata*; ground cover sparse, *Paspalidium radiatum, P. gracile, Chloris acicularis, Abutilon oxycarpum, Rhagodia nutans*, and *Sporobolus caroli*.

Land Capability.—IV or VIg$_4$, s$_{3-4}$, c$_{3-6}$. **No. of Observations.**—9.

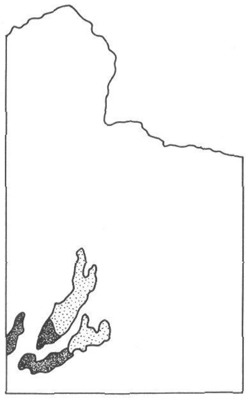
LAND UNIT 59 (800 KM^2)

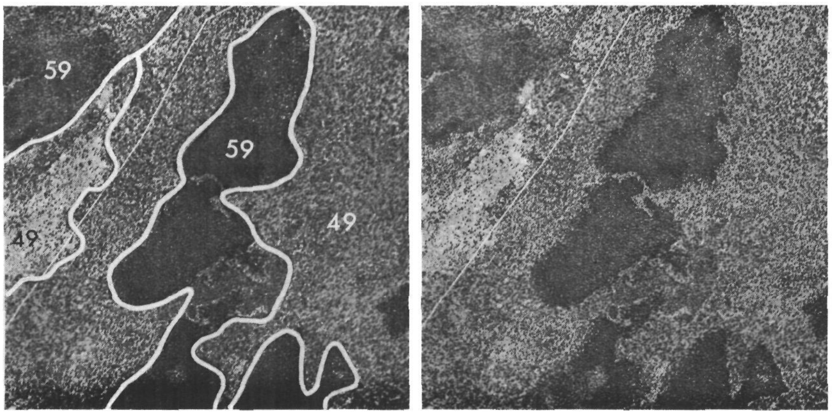
Field Criteria.—Clay plains, gidgee forest, gilgai.

Median Rainfall.—Nov.–Apr.: 200–300 mm. May–Oct.: 140–190 mm.

Material.—Cainozoic clay; possibly some alluvial clay.

Relief.—Plains with gilgai.





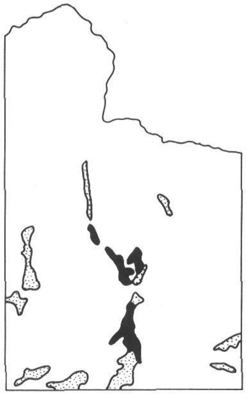
Position on Slope.—No information.

Soil.—Gilgaied cracking clay soils: very deep (>150 cm), self-mulching, neutral reaction in upper 90 cm, slightly acid, mottled, with gypsum accumulations beneath, Ca (Ug5.24).

Vegetation.—Open-forest of *Acacia cambagei* with occasional *Casuarina cristata* with sparse shrub layer of *Eremophila mitchellii* and lower *Myoporum deserti*, ground cover sparse, *Chloris acicularis*, *Enchylaena tomentosa*, *Paspalidium* spp., and *Bassia* spp.

Land Capability.—VIc$_6$, g$_4$, s$_{3-4}$. **No. of Observations.**—1.

LAND UNIT 60 (2325 KM²)

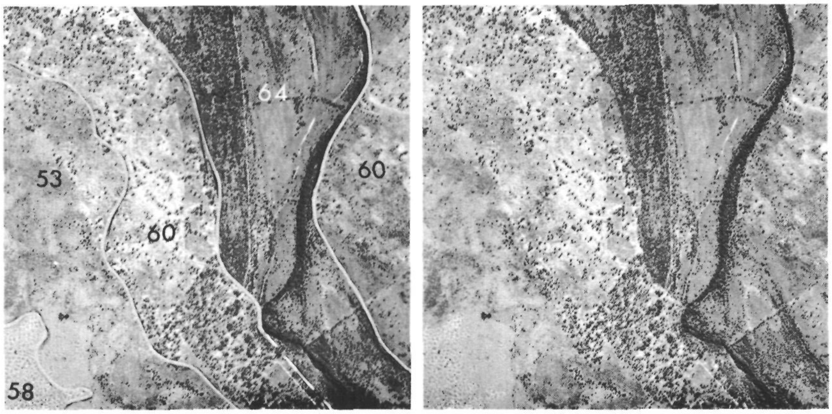


Field Criteria.—Levees and higher alluvial plains, ironbark or box woodland and some carbeen, cypress pine understorey, deep sandy soils.

Median Rainfall.—Nov.–Apr.: 250–350 mm. May–Oct.: 150–220 mm.

Material.—Alluvial sand and silt.

Relief.—Levees, higher alluvial plains, terraces; generally not flooded; slopes 0·2–1%.



Position on Slope.—Upper slopes.

Soil.—Deep uniform sandy soils; mainly red, less commonly yellow or brown, Fa (Uc1.23, 5.11) and Fb (Uc1.21, 1.22); minor red massive earths, Ef (Gn2.12) and alluvial soils, Aa (Um5.5 on sand) and Ab (shallow Um1 on sand and clay strata).

Vegetation.—Usually woodland of *Eucalyptus melanophloia* or of *E. populnea* with occasional *E. populnea* and *Angophora melanoxylon* with moderately dense lower tree layer of *Callitris columellaris* with scattered lower trees of *Acacia excelsa* or *A. murrayana*; occasionally open-forest of *Callitris columellaris* with occasional *E. populnea*, *E. melanophloia*, and *E. tessellaris* or open-woodland of *E. tessellaris* with occasional *E. polycarpa* with lower tree layer of *Callitris columellaris*; in all cases with ground cover (sparse in open-forest, open in woodland) of *Aristida echinata*, *A. jerichoensis*, *A. browniana*, *Paspalidium constrictum*, *Digitaria ammophila*, *Cymbopogon refractus*, and *Heteropogon contortus*. *Callitris columellaris* is often reduced by clearing and burning.

Land Capability.—IV or VIm$_4$, c$_{3-6}$. **No. of Observations.**—18.

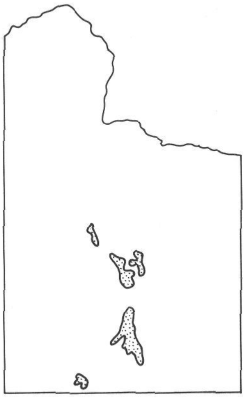
LAND UNIT 61 (250 KM²)

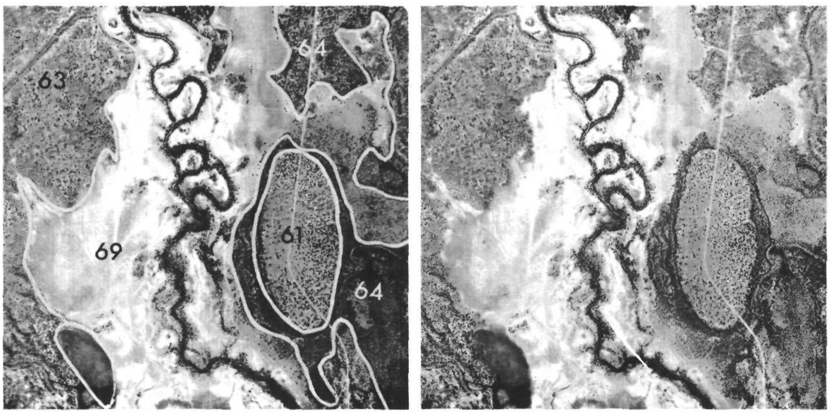
Field Criteria.—Dunes, ironbark and cypress pine woodland, deep *uniform sands.*

Median Rainfall.—Nov.–Apr.: 250–350 mm. May–Oct.: 150–220 mm.

Material.—Aeolian sand.

Relief.—Dunes up to 10 m high; slopes 1–5%.





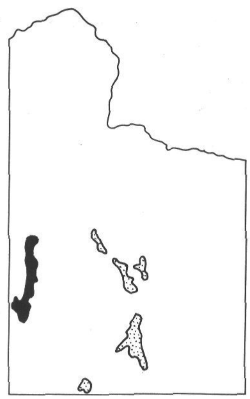
Position on Slope.—On all parts of the slope.

Soil.—Deep uniform sandy soils: mainly reddish brown medium to fine sands, Fa and Fb (Uc1.23. 5.11); minor texture-contrast soils, Dj (Dy5.82).

Vegetation.—Woodland of *Eucalyptus melanophloia* with lower tree layer, usually dense, of *Callitris columellaris* with occasional *E. tessellaris* and *E. populnea*, or open-woodland of *E. tessellaris* with lower tree layer of *Callitris columellaris*, or (on lower part of Maranoa) open-woodland of *Angophora melanoxylon* with lower tree layer of *Callitris columellaris*; in all cases with sparse ground cover of *Aristida echinata* and occasional *Aristida jerichoensis*, *Paspalidium constrictum*, rare *Chloris acicularis*, and *Bothriochloa decipiens*.

Land Capability.—IV or VIm_4, c_{4-6}. **No. of Observations.**—6.

LAND UNIT 62 (420 KM²)

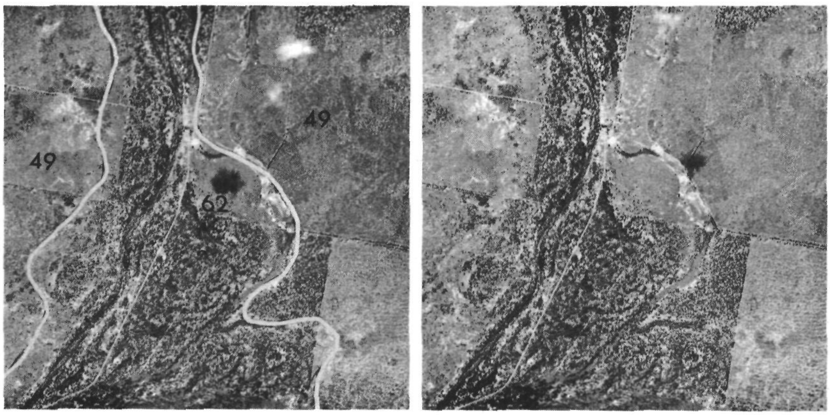


Field Criteria.—Alluvial plains, shrubby box–mulga woodland, massive earths.

Median Rainfall.—Nov.–Apr.: 250–350 mm. May–Oct.: 150–220 mm.

Material.—Mixed alluvial sand, silt, and clay.

Relief.—Back plains.



Position on Slope.—No information.

Soil.—Massive earths: >90 cm deep; strongly alkaline reaction in subsoils, Ec (Gn2.13).

Vegetation.—Layered woodland of *Eucalyptus populnea* with lower tree layer of *Acacia aneura*; moderately dense shrub layer of *Eremophila mitchellii*; ground cover sparse *Chloris acicularis* and *Aristida ramosa* often replaced by *Bassia birchii.*

Land Capability.—IV or VIc_{4-6}, m_4. **No. of Observations.**—2.

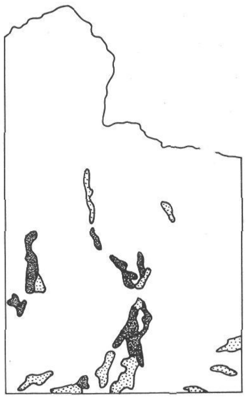
LAND UNIT 63 (1120 KM²)

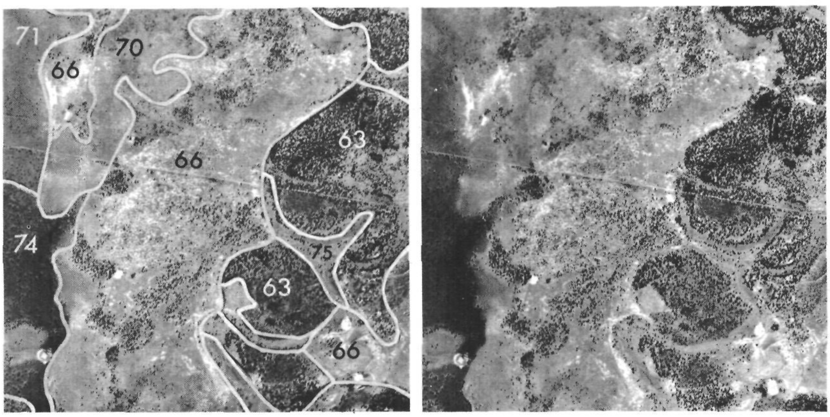
Field Criteria.—Levees and higher alluvial plains, box or ironbark woodland with cypress pine and shrubs, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 250–350 mm. May–Oct.: 150–220 mm.

Material.—Mixed alluvial sand, silt, and clay.

Relief.—Levees, back plains, and terraces generally not flooded; slopes 0·2–0·5%.





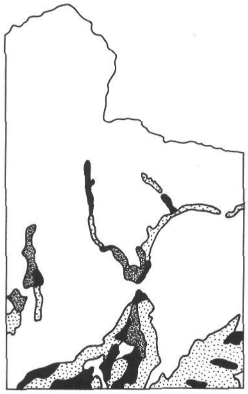
Position on Slope.—Upper and middle slopes.

Soil.—Deep texture-contrast soils: mainly thick sandy surface horizons over neutral blocky to massive subsoils, Dj (Dy3.22, 5.82); minor Di (Dy2.13, 3.63) and De (Dy3.41).

Vegetation.—Woodland of *Eucalyptus populnea*, rarely of *E. melanophloia*, with moderately dense lower tree layer of *Callitris columellaris* and occasional *E. dealbata*, often with shrub layer of *Geijera parviflora*, *Eremophila mitchellii*, sometimes *Alstonia constricta*; moderate ground cover of *Bothriochloa decipiens*, *Chloris acicularis*, *Triraphis mollis*, *Eragrostis lacunaria*, and occasional *Aristida echinata* and *A. jerichoensis*. Occasionally open-woodland of *Eucalyptus tessellaris* often with *E. polycarpa*; lower tree layer of *Callitris columellaris*, sparse ground cover, mainly *Aristida echinata*, *A. jerichoensis*, and *Paspalidium constrictum*; the *Callitris* stratum often considerably modified by fire and clearing.

Land Capability.—IV or VIp_{3-4}, c_{3-6}. **No. of Observations.**—11.

LAND UNIT 64 (6120 KM^2)

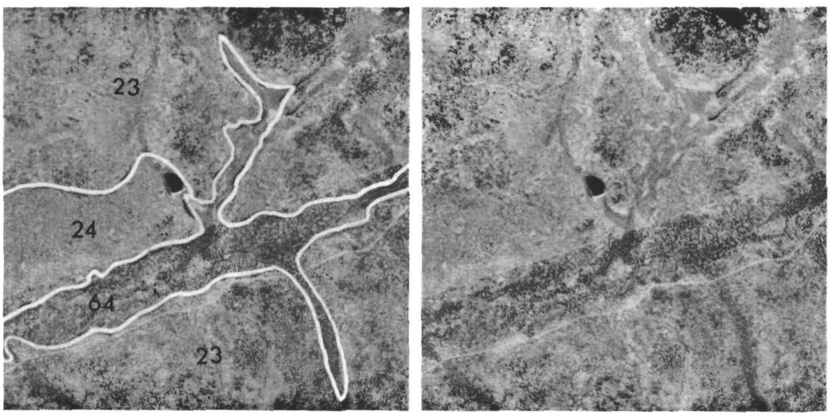


Field Criteria.—Alluvial plains, box woodland without cypress pine, texture-contrast soils.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Mixed alluvial sand, silt, and clay.

Relief.—Back plains, levees, and terraces generally not flooded; slopes 0·2–0·5%.



Position on Slope.—Upper slopes.

Soil.—Deep texture-contrast soils: mainly thin sandy or loamy surface horizons over strongly alkaline subsoils, Dh (Db1.23, Dr2.23) and Di (Dy3.23, Dd1.13); less extensive Dj (Dy3.42); minor dark brown and grey-brown soils, Be (Gn3.23, Uf6.33), and massive earths, Ef (Gn2.12, 2.42, 2.82).

Vegetation.—Woodland of *Eucalyptus populnea*, rarely of *E. melanophloia*, lower trees sporadic, *Casuarina cristata*, *Heterodendrum oleifolium*, or *Bauhinia carronii*; shrub layer patchy, sometimes dense, of *Eremophila mitchellii*, less commonly with *Geijera parviflora*; ground cover usually moderately dense of *Bothriochloa decipiens*, *Aristida ramosa*, and *Chloris acicularis* with occasional *Chloris ventricosa*, *Eragrostis lacunaria*, *Aristida jerichoensis*, *Paspalidium constrictum*, and *Tripogon loliiformis* on scalded areas; sometimes woodland of *Eucalyptus populnea* without shrubs and similar ground cover or with *Thellungia advena*, *Astrebla* spp., and *Dichanthium* spp., sometimes in southwest of region, open-woodland of *Eucalyptus populnea*, with lower tree layer of *Flindersia maculosa* and *Heterodendrum oleifolium* or scattered *Acacia pendula* and sparse ground cover of *Tripogon loliiformis*, *Sporobolus caroli*, and *Bassia* spp.

Land Capability.—IV or VIp$_{3-4}$, s$_{3-4}$, c$_{3-6}$. **No. of Observations.**—48.

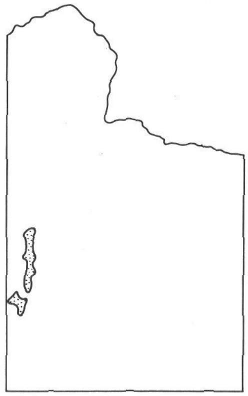
LAND UNIT 65 (40 KM²)

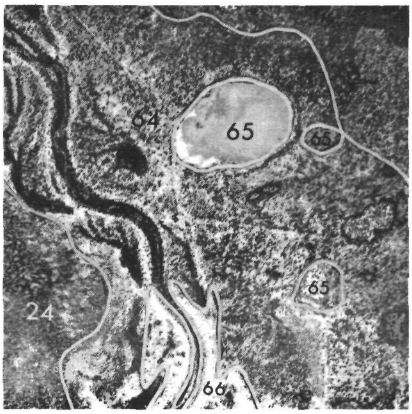
Field Criteria.—Clay pans.

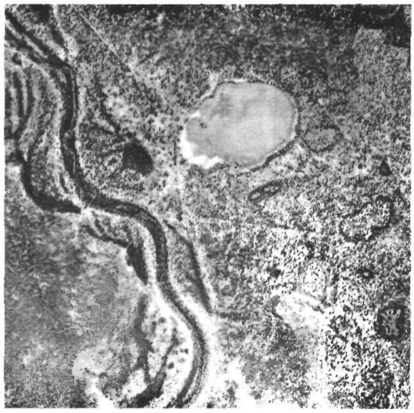
Median Rainfall.—Nov.–Apr.: 200–250 mm. May–Oct.: 140–160 mm.

Material.—Alluvial clay.

Relief.—Shallow pans up to 3 m deep and 1000 m wide.







Soil.—Texture-contrast soils on margins: >90 cm deep, Dh (Db2.23); probably cracking or non-cracking clay soils (Ug5/Uf6) towards centre.

Vegetation.—Grassy woodland of *Eucalyptus populnea* with moderate mid-height grass, mainly *Bothriochloa decipiens*; open-woodland of *E. microtheca* with sparse *Astrebla* spp. and *Thellungia advena*; rarely open-forest of *E. camaldulensis* with almost bare ground.

Land Capability.—VIc$_6$, w$_5$. **No. of Observations.**—1.

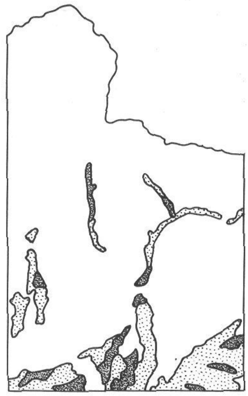
LAND UNIT 66 (1195 KM²)

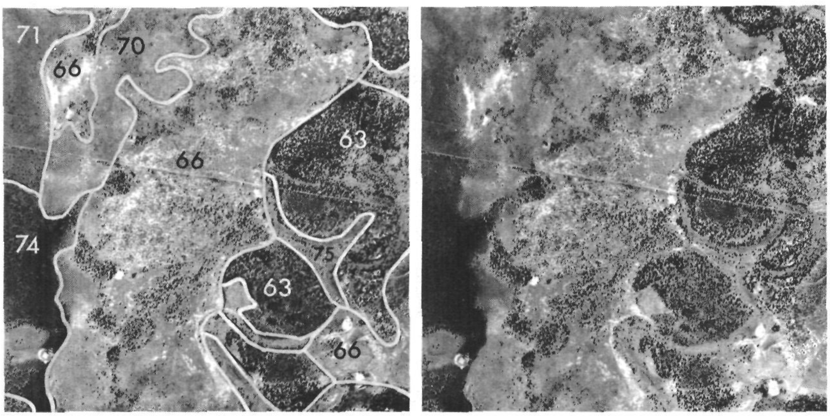
Field Criteria.—Alluvial plains, minute grass, scattered shrubs, leopard-wood and whitewood, deep texture-contrast soils often extensively eroded.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Mixed alluvial sand, silt, and clay.

Relief.—Levees and back plains above flood level; slopes 0·1–0·8%.





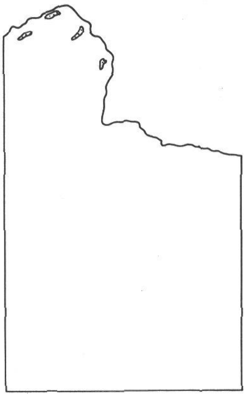
Position on Slope.—Upper slopes.

Soil.—Deep texture-contrast soils: thin sandy or loamy surface horizons over strongly alkaline clay subsoils, Dh (Dr2.43, 2.23) and Di (Dy2.33, 3.23); minor alluvial soils, Ac (sand over clay layers); extensive severe erosion by water and wind action in parts of this unit (5–15 cm of surface soil completely removed).

Vegetation.—Open-grassland of *Tripogon loliiformis*, occasional *Aristida latifolia*, *A. platychaeta*, *Chloris divaricata*, and *Sporobolus actinocladus* (often with many forbs), *Bassia calcarata*, *B. diacantha*, *B. lanicuspis*, *B. tetracuspis*, and *Kochia coronata*; sometimes low open-woodland of *Flindersia maculosa*, *Atalaya hemiglauca*, and occasional *Heterodendrum oleifolium*, with the same ground cover.

Land Capability.—IV or VIp_{3-4}, e_{3-4}, c_{3-6}. **No. of Observations.**—11.

LAND UNIT 67 (285 KM^2)

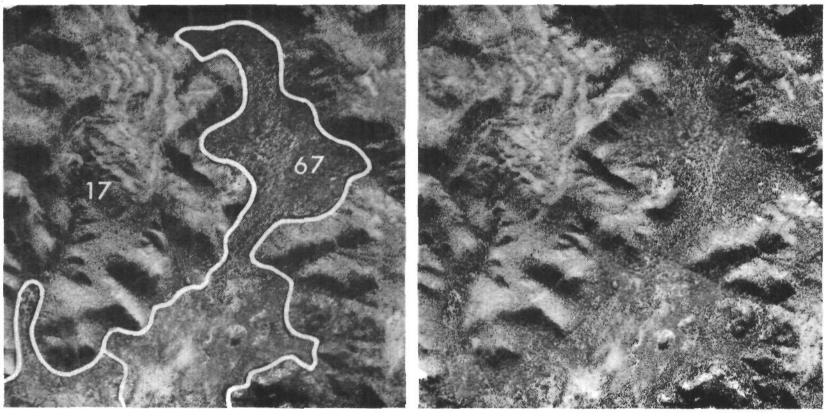


Field Criteria.—Narrow strips of basaltic alluvium, box or silver-leaved ironbark woodland, brown and grey-brown soils.

Median Rainfall.—Nov.–Apr.: 380–450 mm. May–Oct.: 160–190 mm.

Material.—Alluvial basaltic clay with some silt.

Relief.—Back plains occasionally flooded.



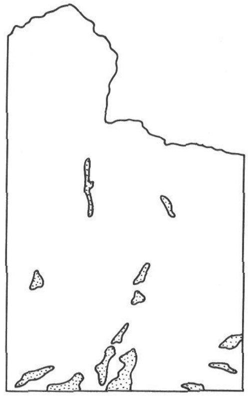
Position on Slope.—No information.

Soil.—Brown and grey-brown soils: deep (>90 cm) uniform clays or loams grading to clay, Be (Uf6.32, Gn3.92); minor recent alluvial soils, Ab (shallow Uf on sand and clay strata).

Vegetation.—Woodland of *Eucalyptus populnea* or *E. melanophloia*; no shrubs; rather dense ground cover, chiefly *Bothriochloa decipiens* with less frequent *Aristida ramosa, Thellungia advena*, and *Dichanthium* sp.; occasionally ground cover of *Eremochloa bimaculata* and *Sorghum leiocladum.*

Land Capability.—III–IVw_{3-4}. **No. of Observations.**—4.

LAND UNIT 68 (180 KM^2)



Field Criteria.—Alluvial plains, box woodland, cracking clay soils without gilgai.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Alluvial clay.

Relief.—Back plains; slopes probably 0·1–0·8%.

Position on Slope.—No information.

Soil.—Cracking clay soils: >150 cm deep, Ce (Ug5.5); fine layer of silt and very fine sand on surface; neutral reaction at surface becoming strongly alkaline below 60 cm where small accumulations of carbonate and gypsum occur.

Vegetation.—Woodland of *Eucalyptus populnea*, sparse shrub layer, ground cover sparse, usually scattered *Tripogon loliiformis*, *Bassia calcarata*, *B. birchii*, and *Atriplex* spp.

Land Capability.—IV or VIp_{3-4}, w_{3-4}, c_{3-6}. **No. of Observations.**—1.

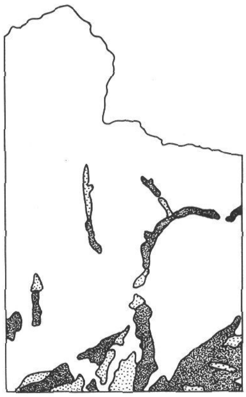
LAND UNIT 69 (1530 KM²)

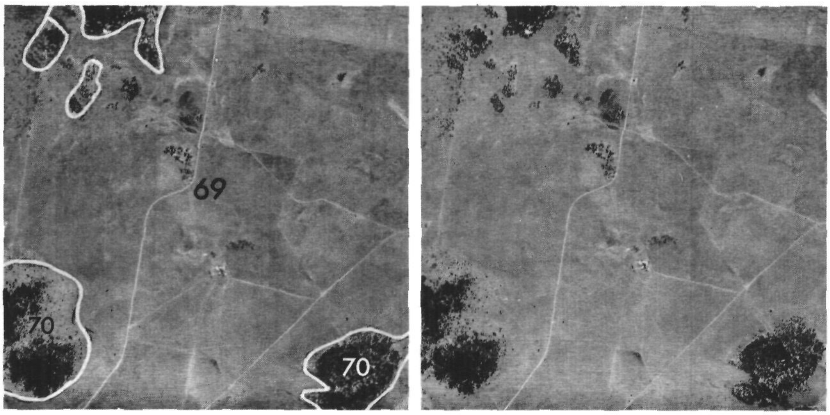
Field Criteria.—Alluvial plains, grassland, cracking clay soils without gilgai.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Alluvial clay.

Relief.—Back plains, occasionally flooded; slopes 0·1–0·6%.





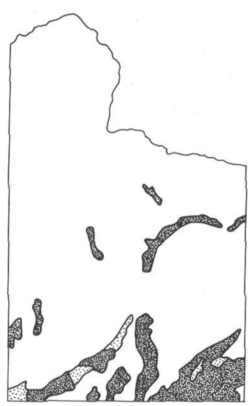
Position on Slope.—No information.

Soil.—Deep cracking clay soils: >150 cm; dark grey-brown to grey, Ce (Ug5.24, 5.16) mainly neutral to mildly alkaline at or near the surface and strongly alkaline beneath where small accumulations of carbonate and gypsum commonly occur; minor Be (Uf6.31, 6.5).

Vegetation.—Tussock grassland, predominantly *Astrebla* spp. (usually *A. lappacea*), common *Panicum decompositum*, *Eriochloa* spp., *Thellungia advena*, *Bassia quinquecuspis*, *Malvastrum spicatum*, and (in the south-west) *Sporobolus mitchellii*; *Aristida leptopoda* common when heavily grazed and forbs such as *Sida* spp. and *Bassia* sp. when eroded; scattered *Acacia victoriae* or *A. farnesiana* sometimes occur.

Land Capability.—III–VIc_{3-6}, w_{3-4}, k_{3-4}, s_{3-4}. **No. of Observations.**—15.

LAND UNIT 70 (1275 KM²)



Field Criteria.—Alluvial cracking clay plains, belah woodland.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Alluvial clay, possibly unresistant weathered labile sediments in places.

Relief.—Back plains occasionally flooded; slopes 0·05–0·3%.

Position on Slope.—No information.

Soil.—Cracking clay soils: >150 cm deep, Ce (Ug5.24, 5.16); gilgaied microrelief in places, possibly on weathered clay, Ca (Ug5.24); generally neutral reaction at surface becoming strongly alkaline below 60 cm where small to moderate (3–15%) accumulations of carbonate and/or gypsum are present; occasionally strongly alkaline throughout; minor dark brown and grey-brown soils, Be (Uf6.32).

Vegetation.—Woodland of *Casuarina cristata*, often with occasional *Eucalyptus microtheca*; shrubs usually sparse, often *Eremophila mitchellii* and *Geijera parviflora*, sometimes *Rhagodia spinescens;* ground cover sparse to moderately dense, rather variable *Panicum decompositum*, *Paspalidium jubiflorum*, *Eragrostis parviflora*, *Leptochloa* spp., *Thellungia advena*, and *Astrebla* spp. or *Paspalidium radiatum*, *P. gracile*, *Chloris acicularis*, and *Bassia tetracuspis*.

Land Capability.—III–IVc$_{3-6}$, w$_{3-4}$, s$_{3-4}$, k$_{3-4}$. **No. of Observations.**—8.

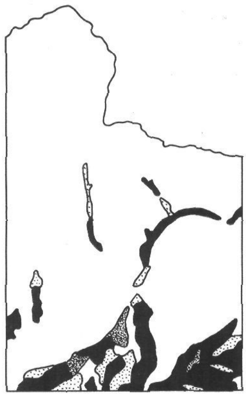
Land Unit 71 (7545 km²)

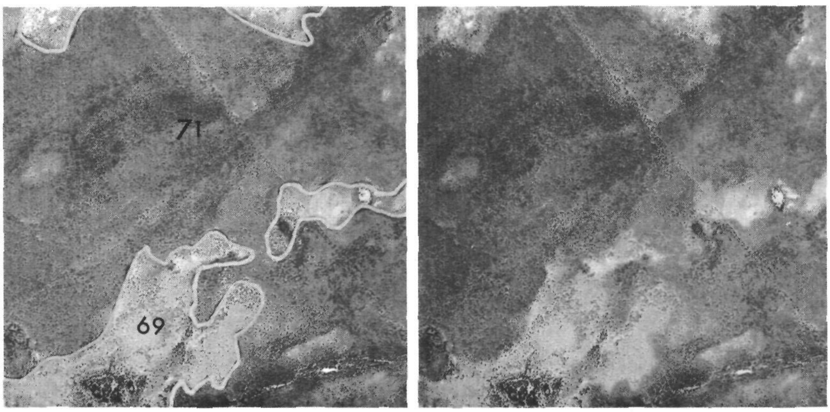
Field Criteria.—Alluvial cracking clay plains, coolibah.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–240 mm.

Material.—Alluvial clay.

Relief.—Back plains and back swamps subject to flooding; slopes 0·05–0·3%.





Position on Slope.—Presumably lower slopes.

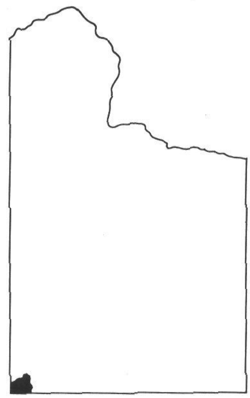
Soil.—Cracking clay soils: >150 cm deep, Ce (Ug5.24, 5.16); generally neutral to mildly alkaline at or near the surface becoming strongly alkaline below about 60 cm where small accumulations of carbonate and gypsum commonly occur; minor areas of brown and grey-brown soils, Be (Uf6.31), in mosaics with Ce soils in some occurrences.

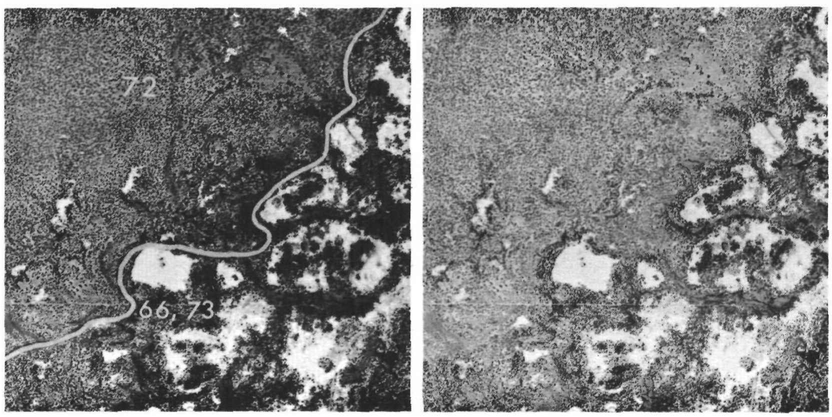
Vegetation.—Open woodland of *Eucalyptus microtheca*, occasional *Casuarina cristata*, usually scattered lower trees, *Acacia stenophylla*, occasional *A. pendula*, *A. omalophylla*, *Heterodendrum oleifolium*, and *Eremophila bignoniiflora*, rare *E. mitchellii*; scattered low *Muehlenbeckia cunninghamii*; ground cover usually open, usually *Astrebla* spp. (mainly *A. lappacea*), *Panicum decompositum*, *Thellungia advena*, *Cyperus bifax*, *Eriochloa* spp., and *Bassia quinquecuspis* or, in the south-west (especially ABb land system), *Eragrostis setifolia* and *Sporobolus mitchellii*, sometimes replaced by *Bassia* spp.; rarely very sparse *Tripogon loliiformis* and *Sporobolus actinocladus*; rarely (on transitions to woodland of *Eucalyptus populnea*), *Bothriochloa decipiens* and *Aristida ramosa*.

Land Capability.—Vw_5, c_{3-6}. **No. of Observations.**—41.

Land Unit 72 (300 km²)

Field Criteria.—Alluvial clay plains, black box, cracking clay soils.
Median Rainfall.—Nov.–Apr.: 200–220 mm. May–Oct.: 140–160 mm.
Material.—Alluvial clay.
Relief.—Back plains and back swamps subject to flooding; slopes probably 0·1–0·4%.





Position on Slope.—Presumably lower slopes.
Soil.—Cracking clay and brown and grey-brown soils: > 120 cm deep, Ce (Ug5.24) and Be (Uf6.51); minor texture-contrast soils, Di (Dy2.13); small accumulations of carbonate and/or gypsum commonly present in lower profiles.
Vegetation.—Woodland of *Eucalyptus largiflorens*, shrubs sparse except occasionally for *Eremophila mitchellii*; ground cover usually *Eragrostis setifolia*, *Sporobolus mitchellii*, and *Bassia tricuspis*, occasionally *Panicum decompositum* and *Astrebla* spp., rarely *Aristida ramosa* and *Chloris acicularis*.
Land Capability.—Vw_5, c_6. **No. of Observations.**—5.

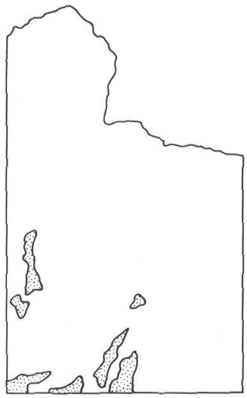
LAND UNIT 73 (280 KM^2)

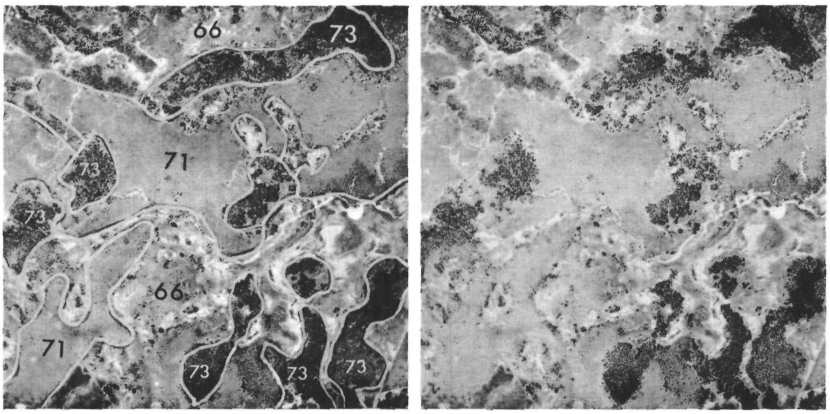
Field Criteria.—Alluvial clay plains, gidgee, cracking clay soils.

Median Rainfall.—Nov.–Apr.: 200–300 mm. May–Oct.: 140–190 mm.

Material.—Alluvial clay.

Relief.—Back plains occasionally flooded; slopes probably 0·05–0·3 %.





Position on Slope.—No information.

Soil.—Cracking clay soils: >120 cm deep, Ce (Ug5.24); a mosaic of cracking and non-cracking clays (Ce/Be) in some occurrences; neutral to mildly alkaline at and near the surface grading to moderately or strongly alkaline beneath where small accumulations of carbonate and gypsum occur.

Vegetation.—Open-forest, occasionally woodland of *Acacia cambagei*, sometimes with occasional *Eucalyptus microtheca*, *E. largiflorens*, and *Acacia harpophylla*; sparse shrubs, mainly *Eremophila mitchellii*; ground cover low, *Astrebla* spp., *Eragrostis setifolia*, and *Paspalidium gracile*, occasionally replaced by *Bassia* spp. (*B. diacantha*, *B. convexula*, *B. tricuspis*) and *Atriplex lindleyi*.

Land Capability.—IV–VIc_{4-6}, w_{3-4}, k_{3-4}. **No. of Observations.**—4.

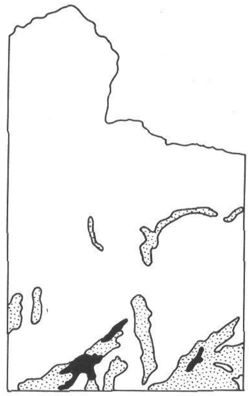
LAND UNIT 74 (1395 km^2)

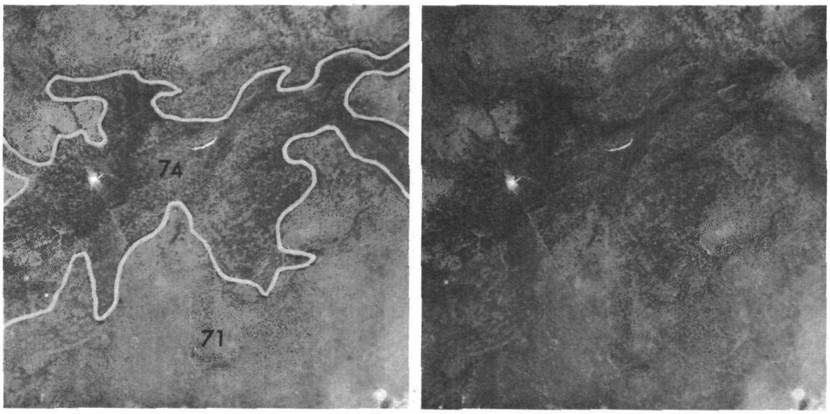
Field Criteria.—Flooded depressions in alluvial clay plains, coolibah, river myall, and river wilga, cracking clay soils.

Median Rainfall.—Nov.–Apr.: 220–380 mm. May–Oct.: 150–140 mm.

Material.—Alluvial clay.

Relief.—Back swamps and shallow channels, frequently flooded; slopes probably 0·1–1 %.





Position on Slope.—Presumably lower slopes.

Soil.—Cracking clay soils: > 150 cm deep, Ce (Ug5.24, 5.16); neutral reaction at and near the surface becoming moderately to strongly alkaline below about 60 cm where small accumulations of carbonate and gypsum are commonly present.

Vegetation.—Open-woodland of *Eucalyptus microtheca*, shrub layer of *Acacia stenophylla* and *Eremophila longifolia* usually open; sparse ground cover of *Panicum decompositum*, *Cyperus bifax*, *Sporobolus mitchellii*, *Paspalidium jubiflorum*, *Thellungia advena*, and *Bassia quinquecuspis*.

Land Capability.—Vw_5. **No. of Observations.**—4.

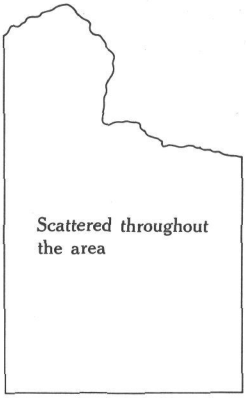
LAND UNIT 75 (170 KM²)

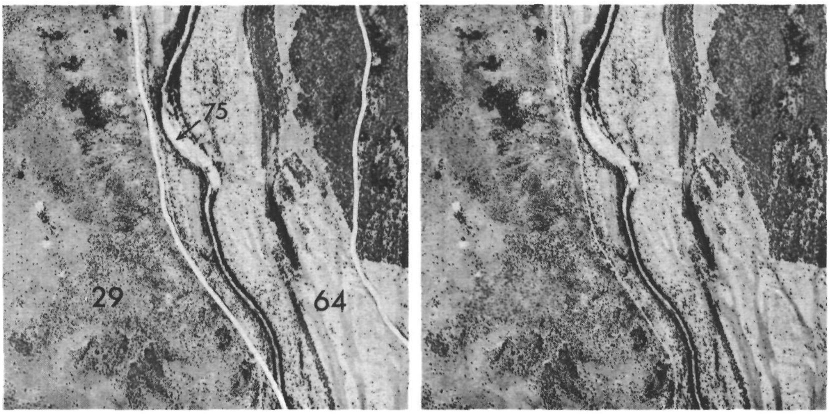
Field Criteria.—Channels and fringing forest of red gum.

Median Rainfall.—Nov.–Apr.: 200–500 mm. May–Oct.: 150–200 mm.

Material.—Alluvial sand and silts with minor clay.

Relief.—Channels.





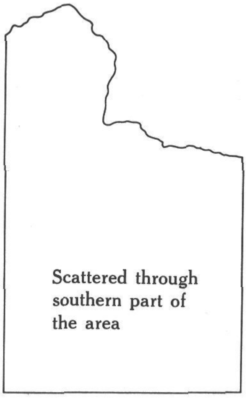
Soil.—Various soils and layered materials: mainly alluvial soils Aa and Ab consisting of layered sands, silts, and clays, minor cracking and non-cracking clay soils in some older channels, Ce (Ug5.16) and Be (Uf6.32).

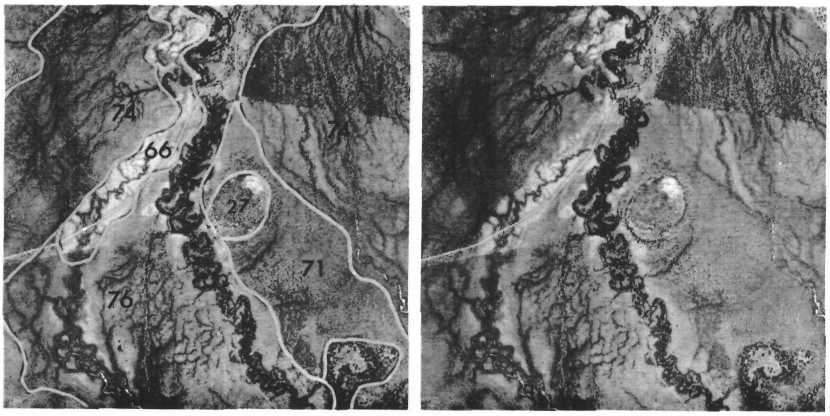
Vegetation.—Fringing open-forest or woodland of *Eucalyptus camaldulensis* with lower trees of *Melaleuca linariifolia* and sometimes (on upper Balonne) *Casuarina cunninghamiana*; *Chionachne cyathopoda* sometimes dense.

Land Capability.—VII–VIIIt$_{7-8}$, w$_5$. **No. of Observations.**—1.

LAND UNIT 76 (470 KM^2)

Field Criteria.—Channels, fringing forest of coolibah and shrubs.
Median Rainfall.—Nov.–Apr.: 220–400 mm. May–Oct.: 150–240 mm.
Material.—Alluvial clay.
Relief.—Channels.





Soil.—Cracking clay soils: deep grey-brown heavy clay soils, neutral to mildly alkaline, Ce (Ug5.16, 5.24).

Vegetation.—Fringing woodland of *E. microtheca*, often with dense shrub layer of *Muehlenbeckia cunninghamii* and/or *Acacia stenophylla.*

Land Capability.—V–VIt_{4-6}, w_5. **No. of Observations.**—5.

PART IV. CLIMATE OF THE BALONNE–MARANOA AREA

By J. D. KALMA*

I. INTRODUCTION

(a) *Principal Climatic Features*

The climate of the Balonne–Maranoa area can be characterized as a transition between warm temperate rainy and semi-arid steppe climates (Köppen 1931), as mesothermal semi-arid (Thornthwaite 1931), or as a transition between mesothermal subhumid and mesothermal semi-arid (Thornthwaite 1948).

Mean annual rainfall ranges from 600 mm in the north-eastern part of the area down to 400 mm in the south-west. Approximately two-thirds of the annual rainfall occurs in the six summer months. Relative variability of annual rainfall is about 30–35%.

Mean day-time temperature ranges from the high twenties (°C) in January down to the low tens in July, the prevailing daily temperature range being between 14 and 16 degC. However, heat-waves (Skerman 1958) and night frosts (Foley 1945) are appreciable risks. Regional differences in temperature within the area are relatively small.

(b) *Principal Climatic Controls*

The climate of the area is strongly influenced by south-easterly trade winds and the latitudinal position of subtropical anticyclonic centres moving in an easterly direction across Australia. The area falls in a broad transitional zone which separates the predominantly summer-active rainfall mechanisms of northern Australia from the winter-active rainfall mechanisms of southern Australia (Fitzpatrick 1964). Owing to its latitudinal position significant incursions of the north-westerly monsoon are absent but the influence of the winter westerlies becomes stronger in comparison with areas to the north-east.

During late autumn and winter, a general pattern of fine sunny days and cool nights exists while prevailing winds are predominantly south-westerly. The area is under the influence of the subtropical high-pressure belt and the inter-tropical convergence zone is well north of the continent. Occasionally well-developed troughs extending north-eastward from the easterly-moving low-pressure systems at higher latitudes or cols between successive anticyclonic cells may affect local weather and bring clouds and light to moderate rain. These brief spells of unsettled weather are often followed by periods in which cooler air from higher latitudes flows into the region. Clear and calm conditions in these periods are often accompanied by night frosts.

Spring is characterized by an increasing tendency towards winds from northerly directions. Increased radiation and longer days cause a sharp increase in day-time temperatures. The weather is usually fine. Hot dry weather comes in from central

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TABLE 3

MEAN MONTHLY AND ANNUAL RAINFALL (MM) (1901–65) WITH HIGHEST AND LOWEST ANNUAL RAINFALL RECORDED AND COEFFICIENT OF VARIATION (C.V.) FOR ANNUAL RAINFALL

Station	Elevation (m)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	Annual Max.	Annual Min.	C.V. (%)
Bollon	185	54	54	41	30	30	32	27	22	24	35	36	52	439	1054	180	38
Charleville*	305	70	62	62	32	24	29	29	19	22	35	42	60	488	1050	207	40
Coomritheh*	290	72	69	63	27	35	33	39	23	28	42	55	63	549	1030	236	34
Dalby*	350	87	73	71	36	32	43	38	28	34	57	74	92	661	948	332	24
Dirranbandi	170	54	54	48	29	33	35	29	21	23	31	41	54	451	993	120	34
Dulacca	320	80	75	58	31	35	39	39	24	28	54	61	75	598	1091	220	33
Fernlee	170	43	46	43	25	25	29	25	17	22	25	35	50	384	834	164	41
Forest Vale	365	77	77	68	35	27	33	29	20	28	45	56	74	570	1313	234	40
Goondiwindi*	215	77	66	58	31	37	42	40	32	33	48	62	71	597	971	266	28
Hebel	150	46	50	41	26	26	31	27	19	20	31	35	44	397	1035	157	39
Mitchell	335	78	80	63	34	27	35	37	22	27	45	59	69	576	1304	236	35
Morven	425	79	70	60	23	25	32	33	23	27	42	48	69	543	1092	256	37
Muckadilla	350	75	77	59	27	26	31	30	21	23	43	53	66	531	1065	217	35
Mungindi	170	61	62	53	29	33	36	33	24	26	37	27	54	492	1073	168	33
Redford	335	81	75	68	37	27	35	31	20	27	44	88	80	584	1300	253	38
Roma	305	77	76	63	32	29	35	36	24	29	49	54	66	570	1057	164	34
St. George	200	65	62	55	29	32	35	33	23	27	37	46	56	497	958	125	35
Surat	245	72	76	59	31	29	39	41	26	28	30	82	72	573	1124	165	36
Wallumbilla	305	73	86	62	30	33	35	37	23	29	48	58	75	588	1070	220	34
Westgrove*	490	89	89	72	37	32	35	31	20	28	48	67	87	636	1383	267	34
Yuleba	305	74	78	65	30	35	37	38	23	29	50	64	72	595	1012	246	32

* Station outside survey boundaries.

TABLE 4

MEAN MONTHLY AND ANNUAL RAINFALL (MM) FOR NON-STANDARD PERIODS, WITH HIGHEST AND LOWEST ANNUAL RAINFALL RECORDED AND COEFFICIENT OF VARIATION (C.V.) FOR ANNUAL RAINFALL FOR 13 STATIONS

Station	Elevation (m)	Length of record (yr)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean	Annual Max.	Annual Min.	C.V. (%)
Angellala Downs	450	59	75	65	50	31	21	31	29	19	23	36	47	62	491	1071	147	39
Boomi	180	58	74	72	55	28	32	41	37	27	28	37	53	61	548	960	237	32
Cytherea	330	48	67	67	88	30	22	27	26	23	25	37	42	57	482	1127	214	38
Ekari Park	390	60	75	69	58	30	24	33	30	23	21	40	44	63	511	1176	230	41
Glengarry	420	39	80	77	67	37	32	28	33	24	23	49	61	73	584	1227	233	34
Injune*	390	44	89	90	68	42	32	29	31	24	25	46	75	89	642	1307	120	33
Kenilworth	105	43	73	58	52	31	25	27	28	21	19	37	37	56	464	983	212	36
Lolworth	300	36	66	67	52	27	23	22	26	18	22	36	35	54	453	927	203	39
Mourilyan–St. George	195	31	76	63	64	36	34	28	29	29	26	42	43	48	519	1100	243	38
Totara	210	53	72	62	60	27	31	37	36	27	28	42	51	61	538	936	184	34
Welltown	180	80	74	68	57	31	34	41	38	25	29	41	48	55	543	1041	142	32
Wodonga	340	38	87	66	64	29	25	24	34	20	18	40	51	55	511	1094	266	38
Woodlands	270	53	60	64	55	28	24	29	31	21	21	35	42	56	467	949	209	37

* Station outside survey boundaries.

and northern Australia. However, active localized convection can take place accompanied by an influx of warm maritime air leading to scattered thunderstorms which become more frequent as the season advances.

Moist tropical air of maritime origin reaches the area in summer when the weather becomes strongly influenced by low-pressure systems over northern Australia with troughs extending in a south-easterly direction across Queensland. The intertropical convergence zone has reached northern Australia. The prevailing wind is north-easterly to south-easterly and frequent heavy rainfall occurs, decreasing inland. Centres of anticyclonic cells have moved well to the south. Mid and late summer show a marked increase in the occurrence of tropical cyclones along the Queensland coast. Their centres move landwards and often persist for several days as extensive depressions characterized by high rainfall and frequently by flooding. Thunderstorms and cyclones make late summer favourable for rainfall but also greatly increase its variability because of their erratic nature.

Finally, in April, a return to fine mild winter weather is made possible through a return of anticyclonic cells from the south and a weakening of the intrusion of moist maritime air. Rain becomes less frequent and cloudiness decreases.

II. General Climatic Characteristics

(a) *Rainfall*

Mean monthly rainfall and mean, highest, and lowest annual rainfall with the coefficient of variation for the standard period 1901–65 have been given in Table 3 for 16 stations within and 5 stations outside the area. In Table 4 mean monthly and mean annual rainfall with the coefficient of variation have been listed for 13 other stations with non-standard periods of records of at least 30 years. The mean annual isohyetal map of Figure 10 has been constructed with data from both tables. In addition, information given by Farmer *et al.* (1947), Coaldrake and Bryan (1957), and the Bureau of Meteorology (1966, 1968) has been used. Deciles of monthly and annual rainfall have been calculated for all stations mentioned in Tables 3 and 4. Median annual rainfall has also been mapped in Figure 10, while median monthly rainfall for January and June has been presented in Figure 11. For a number of representative stations with standard periods of records graphs have been constructed that show first and ninth deciles and medians of monthly rainfall (Fig. 11).

Mean annual rainfall is highest in the north-eastern part of the area, along the Great Dividing Range, reaching 600 mm north of Drillham and north-west of Westgrove. Mean annual rainfall decreases towards the south-west to 450 mm west of Morven and 400 mm at Hebel. Over the northern and southern parts of the area isohyets run approximately NW.–SE., whereas in the central Roma–Mitchell region the trend becomes more E.–W. Distance from the coast and the effect of the Great Dividing Range both play a role in the increasing aridity to the west and south-west. Median annual rainfall (Fig. 10) generally shows the same pattern. The north–south decrease in the central region, however, is more pronounced. Median annual rainfall in the northern and north-eastern region is about 50 mm greater than mean annual rainfall, whereas in the south-west the position is reversed and the median annual rainfall is less than the mean annual rainfall.

Relative variability of annual rainfall (Tables 3 and 4) is between 30 and 35% east of 148°30′E. and between 35 and 40% west of that longitude. These values agree favourably with those presented by Dick (1958). The six summer months account on the average for 66% of the annual total. Relative variability in summer is 30–40% as compared to 40–50% in the six winter months. Summer dominance in rainfall decreases in a south-westerly direction from 71% for Westgrove to 62% for Hebel.

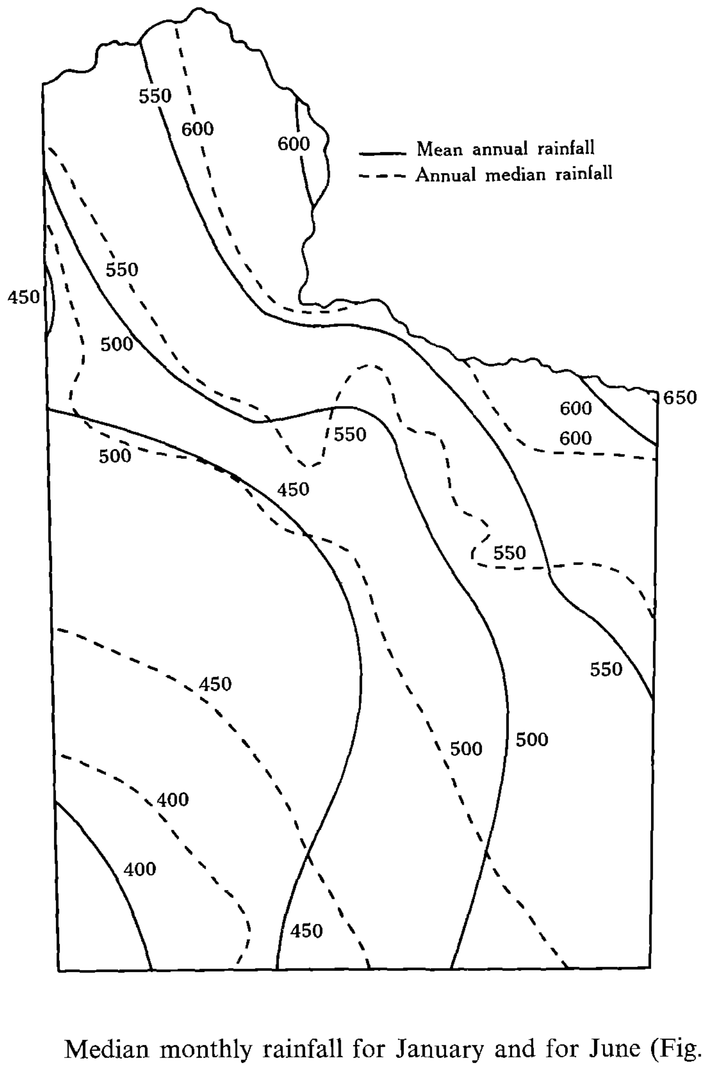

Fig. 10.—Isohyetal map showing mean annual and annual median rainfall (mm) over the area.

Median monthly rainfall for January and for June (Fig. 11) shows a decrease in a south-westerly direction for January, while June decreases in a predominantly westerly direction. Wind direction data for Roma (see Section II(c)) and Surat substantiate this by showing an increased tendency towards winds from easterly and south-easterly directions.

Monthly variability is shown for eight representative stations in Figure 11 by median, upper, and lower decile values of monthly rainfall. Monthly variability increases with decreasing annual rainfall.

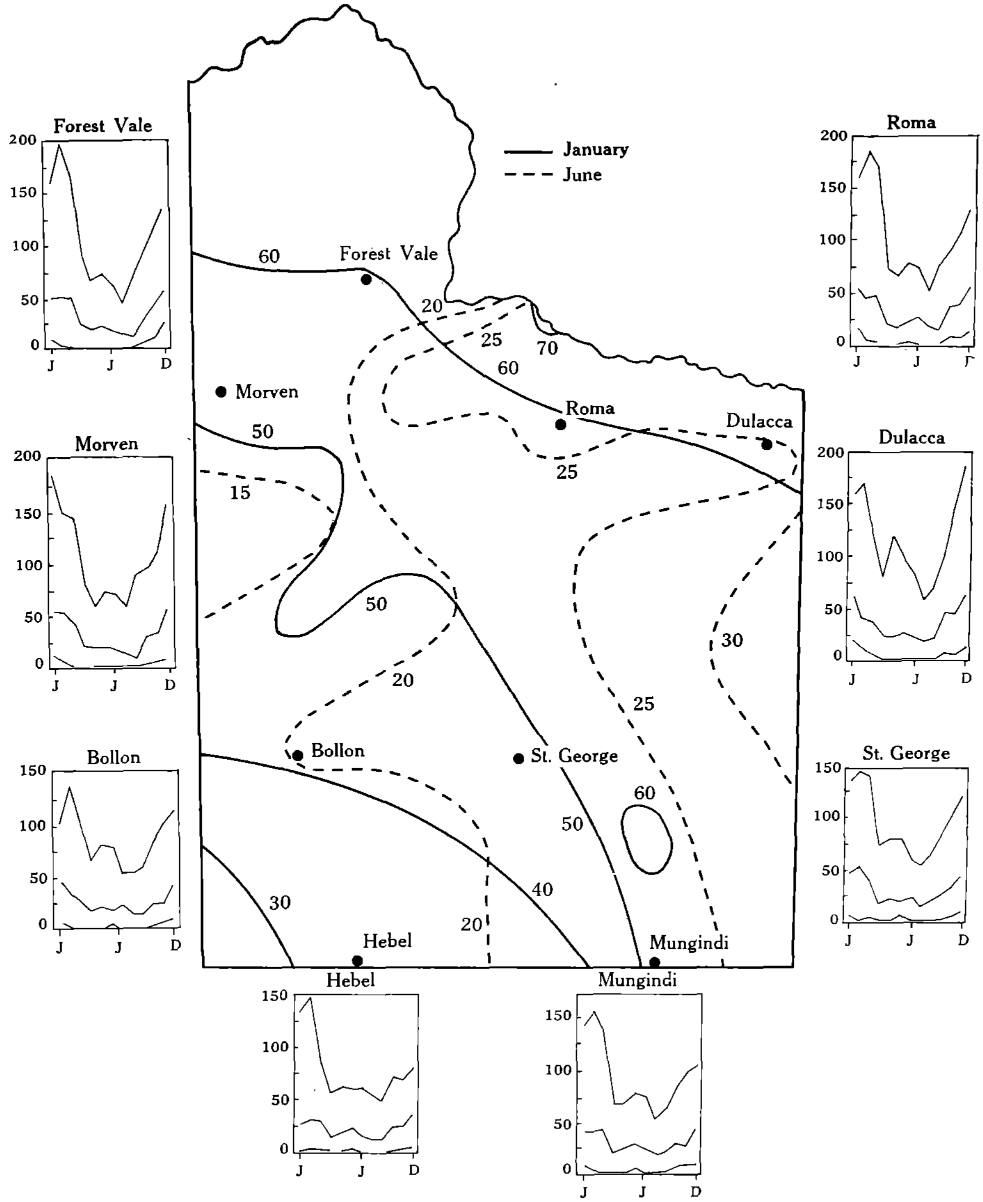

Fig. 11.—Isohyetal map showing median rainfall (mm) in January and June over the area. Insets show the seasonal variation (Jan.–Dec.) in monthly 10-percentile (top), median (middle), and 90-percentile (bottom) rainfall for eight selected stations. N.B.—Summation of these monthly median rainfalls does not give annual median rainfall.

In Table 5 frequency patterns of daily rainfall amounts have been shown for nine stations (including Charleville and Goondiwindi). The number of rain days with falls within specified classes has been given as relative frequencies for all four quarters of the year. No characteristic differences exist between the stations. At all stations the summer quarter shows a slight tendency toward higher intensities. However, daily falls greater than 100 mm are relatively rare throughout the area.

TABLE 5

PERCENTAGE FREQUENCY OF RAIN DAYS PER QUARTER WITH RAINFALL WITHIN SPECIFIED CLASSES

Station	Quarter	Class (mm/rain day) 0–5	6–25	26–50	51–100	101–150	>150
Bollon	MAM	58	31	8	2	0·4	0
	JJA	65	29	5	1	0	0
	SON	61	33	5	1	0	0
	DJF	55	31	10	4	0	0·1
Charleville	MAM	58	31	8	3	0·1	0·1
	JJA	65	28	6	1	0	0
	SON	61	32	5	1	0	0
	DJF	54	33	10	3	0·5	0
Goondiwindi	MAM	60	29	8	3	0	0
	JJA	64	29	6	1	0	0
	SON	58	34	7	1	0	0
	DJF	52	37	8	2	0·6	0·1
Mitchell	MAM	60	30	8	2	0·1	0
	JJA	65	29	5	1	0·3	0
	SON	50	33	6	1	0·1	0
	DJF	56	32	9	3	0·4	0·1
Mungindi	MAM	58	32	8	2	0·1	0
	JJA	65	29	5	0	0	0
	SON	61	34	4	0	0	0
	DJF	52	35	10	3	0·3	0
Roma	MAM	55	33	9	3	0·4	0
	JJA	58	34	7	1	0	0
	SON	53	39	7	1	0·2	0
	DJF	48	38	11	3	0·2	0
St. George	MAM	55	34	10	2	0·3	0
	JJA	63	30	6	1	0	0
	SON	57	34	7	1	0	0
	DJF	49	39	10	2	0·4	0
Surat	MAM	55	35	8	2	0·1	0
	JJA	59	33	7	1	0·1	0
	SON	54	36	8	1	0·2	0
	DJF	49	35	11	4	0·7	0
Yuleba	MAM	49	38	11	3	0	0
	JJA	56	37	6	2	0	0
	SON	49	39	11	2	0	0
	DJF	44	41	12	2	0·5	0·1

Table 6 presents for the same nine stations as in Table 5 average and maximum length of rainy and rainless periods and the relative frequency of rain days and rainless days. Rainy periods are defined as a series of consecutive rain days with more than 0·25 mm recorded on each day. Within the area, Bollon has on the average the greatest number of rainless days and Mitchell the lowest number, but spatial variation is relatively small. The mean length of rainy periods ranges from 1·5 to 1·9 days and of rainless periods from 6·5 to 14·3 days. Inter-seasonal differences in mean length of rainy periods are negligible but spring and summer are

TABLE 6

MEAN AND MAXIMUM RECORDED LENGTH (DAYS) OF RAINY AND RAINLESS PERIODS PER QUARTER, 1901–65

Station	Quarter	Length of rainy period		Percentage of rain days	Length of rainless period		Percentage of rainless days
		Mean	Max.		Mean	Max.	
Bollon	MAM	1·7	9	11·6	12·8	89	88·4
	JJA	1·7	6	11·7	13·2	185	88·3
	SON	1·6	7	13·7	9·6	63	86·3
	DJF	1·7	11	16·2	8·9	59	83·8
Charleville	MAM	1·8	9	12·4	12·8	120	87·6
	JJA	1·7	6	10·6	14·3	92	89·4
	SON	1·6	8	13·4	9·9	119	86·6
	DJF	1·9	15	18·5	8·0	89	81·5
Goondiwindi	MAM	1·7	10	14·2	10·7	65	85·8
	JJA	1·6	8	15·4	9·0	94	84·6
	SON	1·6	5	17·8	7·5	114	82·2
	DJF	1·8	9	20·7	6·7	40	79·3
Mitchell	MAM	1·8	8	13·8	11·1	82	86·2
	JJA	1·7	8	12·8	11·7	82	87·2
	SON	1·7	14	17·6	7·9	81	82·4
	DJF	1·8	10	22·2	6·5	50	77·8
Mungindi	MAM	1·6	7	12·8	11·2	86	87·2
	JJA	1·6	9	13·9	9·8	66	86·1
	SON	1·5	7	15·0	8·4	47	85·0
	DJF	1·7	9	17·2	7·9	55	82·8
Roma	MAM	1·7	11	12·3	12·2	75	87·7
	JJA	1·6	6	11·4	12·6	84	88·6
	SON	1·6	6	15·1	8·9	100	84·9
	DJF	1·8	10	19·6	7·6	91	80·4
St. George	MAM	1·7	8	12·0	12·4	90	88·0
	JJA	1·6	8	12·5	11·5	77	87·5
	SON	1·6	7	13·9	9·7	156	86·1
	DJF	1·7	14	17·2	8·3	51	82·8
Surat	MAM	1·7	8	12·5	11·8	88	87·5
	JJA	1·7	6	12·3	11·7	91	87·7
	SON	1·5	7	15·0	8·6	82	85·0
	DJF	1·8	13	19·0	7·6	89	81·0
Yuleba	MAM	1·6	8	11·6	12·1	89	88·4
	JJA	1·6	9	10·8	13·6	139	89·2
	SON	1·5	6	14·2	9·1	66	85·8
	DJF	1·8	11	19·3	7·5	52	80·7

consistently lower than autumn and winter in mean length of rainless periods. When a rainy or rainless period extends from one quarter to the next it has been included in that quarter in which the greater proportion occurs, so that, for example, in a

TABLE 7

MEAN MAXIMUM, MEAN MINIMUM, AND MEAN DAILY TEMPERATURES (°C) FOR SIX STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Bollon (51 yr)							
Maximum	35·4	34·0	31·9	27·5	22·9	19·2	18·8	21·2	25·4	29·5	32·9	35·0	27·8
Minimum	21·3	20·7	18·0	13·1	8·3	5·4	4·1	5·4	8·9	13·4	17·1	19·8	13·0
Mean	28·4	27·3	24·9	20·3	15·6	12·3	11·4	13·3	17·1	21·4	25·1	27·4	20·4
	(28·8)*	(27·8)	(25·2)	(20·2)	(15·4)	(12·6)	(11·4)	(13·4)	(17·4)	(21·7)	(25·5)	(27·6)	(20·6)*
						Mitchell (50 yr)							
Maximum	33·7	32·5	30·4	26·9	22·7	19·2	18·8	21·3	25·2	28·9	31·8	34·4	27·1
Minimum	19·8	19·3	16·7	11·2	6·5	4·2	2·9	3·8	7·2	12·2	16·0	18·4	11·5
Mean	26·8	25·9	23·6	19·0	14·6	11·7	10·9	12·6	16·2	20·6	23·9	26·0	19·3
	(27·1)	(26·1)	(23·7)	(19·2)	(14·8)	(11·8)	(10·9)	(12·5)	(16·4)	(20·8)	(24·2)	(26·1)	(19·4)
						Mungindi (42 yr)							
Maximum	35·4	33·9	31·6	27·0	22·8	18·9	18·6	20·8	24·9	28·7	32·3	34·6	27·4
Minimum	20·4	20·0	17·5	12·6	8·4	5·7	4·8	6·1	9·3	13·3	16·4	18·9	12·7
Mean	27·9	27·0	24·6	33·4	15·6	12·3	11·7	13·4	17·1	21·0	24·4	26·8	20·1
	(28·2)	(26·9)	(24·6)	(33·4)	(15·7)	(12·2)	(11·4)	(13·3)	(17·1)	(21·6)	(24·6)	(26·7)	(20·2)
						Roma (55 yr)							
Maximum	34·4	33·2	31·3	27·9	23·8	20·1	19·6	22·1	25·8	29·6	32·6	34·3	27·9
Minimum	20·2	19·6	17·3	12·6	8·1	5·0	3·9	5·2	8·7	13·5	16·9	19·2	12·6
Mean	27·3	26·4	24·3	20·2	16·0	12·4	11·8	13·6	17·3	21·6	24·8	26·8	20·2
	(27·4)	(26·7)	(24·5)	(20·1)	(15·7)	(12·4)	(11·8)	(13·7)	(17·4)	(21·6)	(24·9)	(26·6)	(20·3)
						St. George (19 yr)							
Maximum	34·7	32·7	31·3	26·8	22·4	18·4	18·7	20·5	24·8	28·4	32·1	35·2	27·2
Minimum	21·2	20·7	18·2	13·5	9·0	6·3	5·1	6·2	9·8	14·2	17·3	20·1	13·4
Mean	27·9	26·7	24·7	20·1	15·7	12·6	11·9	13·4	17·3	21·3	24·7	27·4	20·3
	(28·6)	(27·3)	(24·8)	(20·3)	(16·0)	(12·6)	(11·7)	(13·5)	(17·4)	(21·6)	(25·2)	(27·1)	(20·5)
						Surat (19 yr)							
Maximum	34·1	32·6	31·4	27·4	23·1	19·6	19·4	21·3	25·2	28·6	32·1	34·4	27·5
Minimum	20·2	20·0	17·7	12·6	8·7	5·3	4·3	5·3	9·0	13·6	16·7	19·4	12·8
Mean	27·1	26·3	24·6	20·0	16·2	12·4	11·8	13·3	17·1	21·1	24·4	26·9	20·1
	(27·6)	(26·9)	(24·4)	(20·3)	(15·9)	(12·6)	(11·8)	(13·6)	(17·4)	(21·5)	(24·6)	(26·7)	(20·3)

* Values in ( ) derived from Bureau of Meteorology (1956), referring to standard period 1911–40.

TABLE 8

PERCENTAGE FREQUENCY OF DAYS PER QUARTER WITH MAXIMUM AND MINIMUM TEMPERATURES WITHIN SPECIFIED CLASSES FOR ROMA (1957–69)

Quarter	Class (°C) ≤0·0	0·1–5·0	5·1–10·0	10·1–15·0	15·1–20·0	20·1–25·0	25·1–30·0	30·1–35·0	35·1–40·0	40·1–45·0	>45·0
Maximum temperature											
MAM				0·6	7·3	22·0	39·5	25·7	5·0	0·0	0·0
JJA				5·7	36·4	49·0	10·0	0·4	0·0	0·0	0·0
SON				0·1	2·1	13·0	34·0	36·3	13·1	1·4	0·0
DJF				0·0	0·2	2·1	12·2	43·4	38·2	4·0	0·0
Year				1·2	11·6	21·6	23·7	26·4	14·2	1·4	0·0
Minimum temperature											
MAM	0·4	10·8	16·7	28·8	34·4	8·9	0·1	0·0			
JJA	10·7	39·6	32·2	16·6	1·0	0·0	0·0	0·0			
SON	0·0	6·8	17·6	26·7	38·1	10·4	0·3	0·0			
DJF	0·0	0·0	0·2	3·8	45·4	47·7	2·8	0·1			
Year	2·8	14·3	16·7	18·8	29·7	16·8	0·8	0·0			

particular quarter the maximum length of the rainless period in days may be greater than the total number of days available.

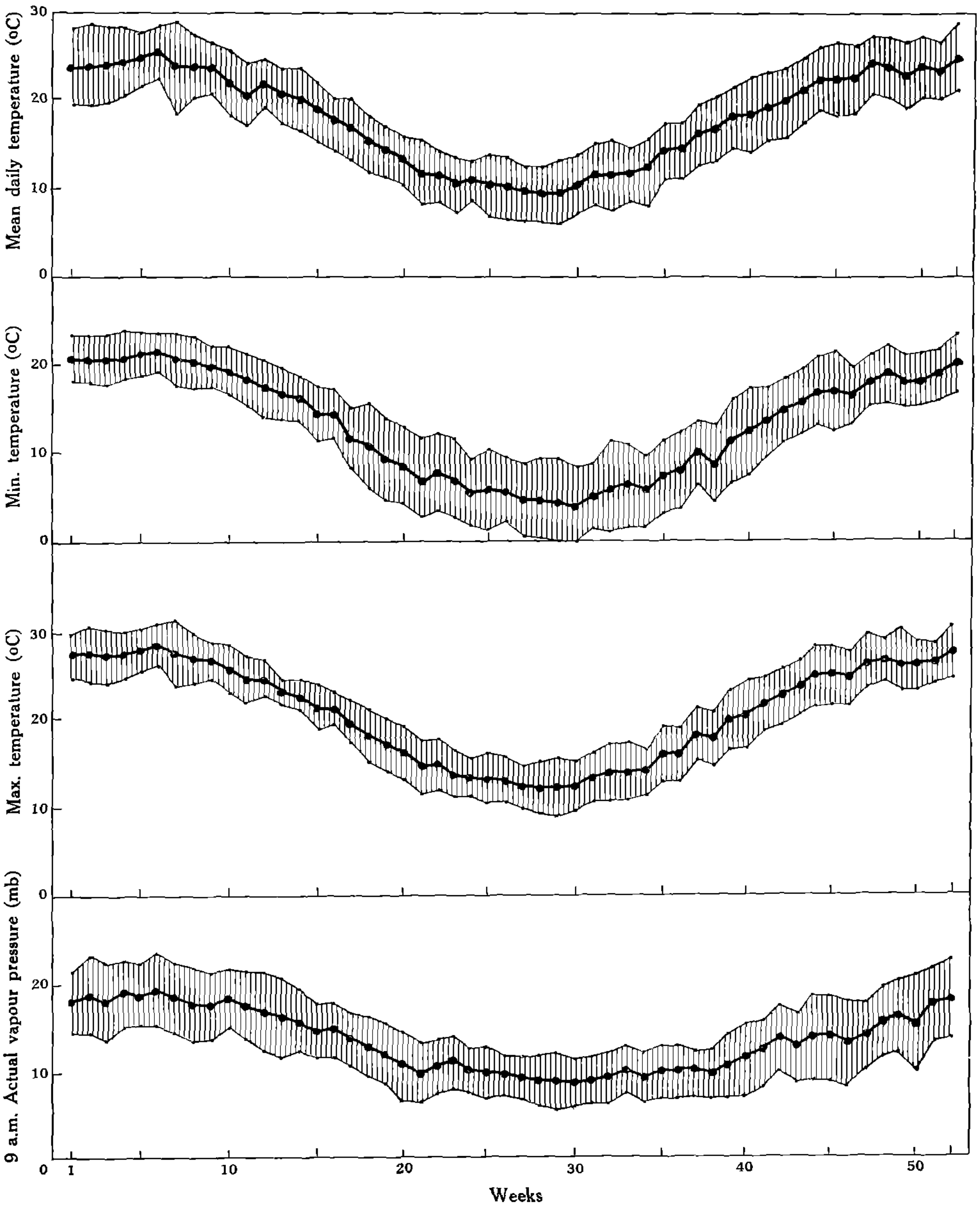

Fig. 12.—The long-term seasonal trends obtained from 13 years (1957–69 inclusive) of daily records for Roma. Mean standard deviations are indicated by lighter lines.

In conclusion, areal differences are small with respect to daily rainfall intensities and mean recorded length of rainy and rainless periods, although the scatter in maximum recorded length of rainless periods indicates that actual differences in drought risk may be greater than Table 6 indicates.

(*b*) *Temperature*

Temperature characteristics for six stations are shown in Table 7. Records do not cover a particular standard period but a comparison with mean daily temperatures calculated for the six stations for the standard period 1911–40 (Bureau of Meteorology 1956), as given in brackets, shows good agreement. At all stations July is the coolest month and January the hottest. Spatial differences over the area are not very marked although of the six stations given in Table 7 Mitchell seems slightly cooler and Bollon slightly warmer.

In Figure 12 averages of maximum, minimum, and mean daily temperature are shown for all 52 weeks of the year for Roma as calculated from 13 years of daily data. Standard deviations for these three parameters have been included. The maximum temperature is at its highest between February 5 and 11 (35·7 ± 3·1°C) and at its lowest between July 9 and 15 (19·5 ± 3·0°C). The minimum temperature reaches a maximum between February 5 and 11 (21·4 ± 2·2°C) and a minimum between July 23 and 30 (4·0 ± 4·1°C). The mean daily temperature is highest between February 5 and 11 (28·6 ± 2·4°C) and lowest between July 9 and 15 (12·0 ± 3·0°C).

Table 8 shows frequency distributions for daily values of maximum and minimum air temperatures between 1957 and 1969. Maximum temperature, in general terms, does not exceed 40°C in autumn, 30°C in winter, and 45°C in spring and summer and is not lower than 15°C in autumn and spring, 10°C in winter, and 20°C in summer. Minimum temperatures range between 0 and 25°C in autumn and spring, −5 and 20°C in winter, and 10 and 30°C in summer.

An appreciable high frost risk exists throughout the area for the five winter months May–September. Frost incidence, based on minimum temperature in the screen below 0°C, is greatest in the Mitchell–Roma–Yuleba region and smallest in the south. Table 9, derived from data presented by Foley (1945), shows the average number of frosts per month and per year for eight stations in the area, with the average dates of first and last occurrence.

(*c*) *Wind*

Between 1955 and 1962, the Department of Civil Aviation maintained a Dines anemograph at Roma airport. The instrument was mounted at 12 m above the ground. In Table 10 relative frequencies are shown for the whole period of hourly occurrences in four wind-speed classes* and for 16 wind directions, and of calm conditions during day-time hours (7 a.m.–6 p.m.) and night-time hours (7 p.m.–6 a.m.). The percentage frequency of calms during day-time was about 25% and during night-time about 61%. On a day-time basis dominant directions are NNW., N., and, to a lesser extent, NNE., NE., ESE., and SSW. For the 12 night-time hours wind comes predominantly from the north-east (NNE., NE., NW., N., and ENE. in order of frequency of occurrence). Winds of speeds over 25 km/hr are during day-time mainly from the north-west and during night-time from the north-east.

*1 mile/hr = 0·9 knot = 1·6 km/hr; 1 knot = 1·2 miles/hr = 1·9 km/hr; 1 km/hr = 0·6 mile/hr = 0·5 knot.

TABLE 9

INCIDENCE OF FROST*

(Based on minimum temperature in screen ⩽ 0°C)

Station	Elevation (m)	Commencing date		Average number of frosts							Finishing date	
		Average	Earliest	Apr.	May	June	July	Aug.	Sept.	Year	Average	Latest
Bollon	185	17 June	7 May	—	0·6	3·6	3·9	3·1	0·1	11·3	14 Aug.	13 Sept.
Miles	300	10 June	24 Apr.	—	0·3	6·0	6·6	6·1	1·3	20·3	29 Aug.	10 Oct.
Mitchell	335	3 June	11 Apr.	—	1·4	8·5	6·3	6·3	0·8	23·3	29 Aug.	10 Oct.
Mungindi	170	21 June	7 May	—	0·1	2·5	2·6	1·3	0·1	6·6	7 Aug.	15 Sept.
Roma	305	8 June	2 May	—	0·6	6·8	6·2	4·3	0·5	18·4	20 Aug.	22 Sept.
St. George	200	19 June	1 May	—	0·1	1·8	2·4	0·6	—	4·9	4 Aug.	2 Sept.
Surat	245	12 June	24 Apr.	—	0·6	5·0	4·1	3·3	—	13·0	12 Aug.	4 Sept.
Yuleba	305	20 May	24 Apr.	0·3	2·1	5·0	9·1	7·6	1·5	25·6	5 Sept.	27 Sept.

* Based on Foley (1945) and original records.

TABLE 10

PERCENTAGE FREQUENCY OF HOURLY OCCURRENCE OF WINDS IN SPECIFIED CLASSES OF SPEED AND DIRECTION, FOR DAY-TIME AND NIGHT-TIME, AT ROMA AIRPORT, 1956–61 INCLUSIVE

Speed (km/hr)	Calm	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Total
								Day-time (7 a.m.–6 p.m.)										
Calm	24·53																	24·53
≤16		4·77	4·31	4·90	3·39	3·05	4·77	3·30	3·68	3·08	4·27	3·28	2·57	1·77	1·76	1·78	5·66	56·29
17–32		2·53	1·47	1·35	1·00	0·88	0·98	0·45	0·69	1·00	1·44	1·36	1·23	0·73	0·55	0·50	1·75	17·91
33–48		0·11	0·07	0·03	0·03	0·05	0·03	0·04	0·05	0·08	0·06	0·11	0·16	0·10	0·13	0·03	0·14	1·22
≥49							0·01		0·01					0·02				0·05
Total	24·53	7·41	5·85	6·28	4·42	3·98	5·79	3·79	4·43	4·16	5·77	4·75	3·97	2·62	2·44	2·31	7·55	100·00
								Night-time (7 p.m.–6 a.m.)										
Calm	60·77																	60·77
≤16		2·94	5·94	4·09	2·68	1·80	1·96	1·12	1·52	1·21	1·50	1·28	1·12	0·78	0·60	0·60	3·66	32·80
17–32		0·94	1·42	0·75	0·42	0·25	0·22	0·16	0·25	0·18	0·27	0·21	0·16	0·09	0·07	0·10	0·52	6·01
33–48		0·03	0·03	0·02	0·02	0·01	0·06	0·03	0·02	0·02	0·02	0·01	0·01	0·01	0·01	0·02	0·05	0·34
≥49			0·01	0·01		0·01	0·01		0·01		0·01			0·01		0·01		0·08
Total	60·77	3·91	7·40	4·87	3·12	2·07	2·25	1·31	1·80	1·41	1·80	1·50	1·29	0·89	0·68	0·73	4·23	100·00

A frequency distribution of daily 9 a.m. wind-speed observations at Roma between 1957 and 1969 (Table 11) reveals great seasonal similarity between autumn and winter, a shift to the 15·1–22·5 km/hr range in spring and summer, and to >22·5 km/hr in spring.

The relative frequency of wind direction has been studied for all 12 months of the year for daily 3 p.m. observations at Roma. A strong south-westerly component is present in May–October, while dominant directions in December–April are between NE. and SE. November is a month of transition.

TABLE 11

PERCENTAGE FREQUENCY OF DAYS PER QUARTER WITH WIND SPEED AT 9 A.M. WITHIN SPECIFIED CLASSES AT G.P.O., ROMA, 1957–69 INCLUSIVE

Quarter	Speed (km/hr)				
	0·0	0·1–7·5	7·6–15·0	15·1–22·5	>22·5
MAM	0·6	25·7	48·2	19·2	6·3
JJA	0·6	31·2	43·8	17·0	7·4
SON	0·1	19·8	36·0	28·3	15·9
DJF	0·0	18·3	47·1	27·4	7·2
Year	0·3	23·7	43·7	23·0	9·3

The seasonal pattern of wind direction in the Balonne–Maranoa area shows great resemblance to that in the Dawson–Fitzroy region (Fitzpatrick 1968), but is distinctly different from that in the Isaac–Comet area (Fitzpatrick 1967*b*) where a large proportion of winds throughout the year is from compass points between east and south.

TABLE 12

PERCENTAGE FREQUENCY OF DAYS PER QUARTER WITH 9 A.M. ACTUAL VAPOUR PRESSURE WITHIN SPECIFIED CLASSES FOR ROMA, 1957–69 INCLUSIVE

Quarter	Actual vapour pressure at 9 a.m. (mb)					
	≤5·00	5·01–10·00	10·01–15·00	15·01–20·00	20·01–25·00	25·01–30·00
MAM	0·8	20·4	31·9	37·4	8·4	0·9
JJA	2·8	18·8	34·3	4·1	0·0	0·0
SON	2·9	33·2	35·3	25·2	3·1	0·2
DJF	0·2	6·1	15·4	45·0	30·5	2·8
Year	1·7	29·7	29·2	27·8	10·5	1·0

(*d*) *Humidity*

An indication of the seasonal trend in actual atmospheric water vapour content is given in Figure 12, in which mean weekly actual vapour pressure at 9 a.m. for Roma has been plotted, with its standard deviation. A maximum of $19 \cdot 43 \pm 4 \cdot 10$ mb is recorded between February 5 and 11, whereas a minimum value of $8 \cdot 46 \pm 2 \cdot 60$ mb is observed between July 20 and 30. Annual regimes of 9 a.m. vapour pressure and rainfall follow each other closely. The percentage frequency of days per quarter with 9 a.m. vapour pressure falling within specified intervals has been calculated for 13 years at Roma and is shown in Table 12.

Data presented in Table 13 show the seasonal trend in the relative humidity index for six stations in the area. This index, calculated at the ratio of 9 a.m. vapour pressure to saturated vapour pressure at daily mean temperature, is a good approximation to mean daily relative humidity (Bureau of Meteorology 1956). Highest values are found for May, June, and July and lowest values between October and January. The mean annual relative humidity index lies between 52% at St. George and 61% at Miles and Surat. The annual range is smallest at Surat (14%) and greatest at St. George and Bollon (21%). These data illustrate the regional trend of decreasing humidity to the west and to the south (Fitzpatrick 1967*a*, 1968).

(*e*) *Cloudiness and Radiation*

Cloudiness data included in Table 13 illustrate that, especially during the six summer months, cloudiness decreases toward the south (cf. Miles *v*. Mungindi) and west (cf. Miles *v*. Mitchell), although with respect to Bollon this trend seems to be reversed somewhat in winter. Cloudiness at 3 p.m. is greater in summer but seasonal variation is much less pronounced for 9 a.m. observations (e.g. Mungindi).

Unfortunately no radiation records are available for the area. Maps prepared by the Bureau of Meteorology (1954) show the annual total hours of bright sunshine at Roma to be 3250 hr with a maximum of about 310 hr in December (10 hr/day) and a minimum of 212 hr in June (7 hr/day). Mean global radiation estimates for Roma (Bureau of Meteorology 1964) range from 650 Ly/day in December to 290 Ly/day in June. In December mean global radiation increases from 600 Ly/day in the far north (near Mt. Moffat H.S.) to 675 Ly/day near Mungindi in the south. In June global radiation decreases from an estimated 315 Ly/day in the far north to 280 Ly/day in the south.

(*f*) *Evaporation*

Monthly totals of tank evaporation calculated from weekly totals as estimated from mean maximum temperature and vapour pressure (Fitzpatrick 1963; Keig and McAlpine, unpublished data*) for five stations in the area have been included in Table 13. Monthly totals are lowest in June, ranging from 64 mm to 78 mm, and highest in December and January (257 mm–294 mm). Annual totals are greatest for Bollon (2046 mm) and smallest for Surat (1880 mm). Although areal variation is relatively small it would appear that evaporation in summer increases toward the south-west but this trend is reversed in winter.

Also included in Table 13 are mean monthly totals of Australian standard tank evaporation observations made at St. George for 36 years by the Irrigation and Water Supply Commission of Queensland. The annual total of 2060 mm is slightly higher than the estimated total of 1943 mm.

Maps of average monthly and annual evaporation prepared by the Bureau of Meteorology (1968) for the Australian sunken standard tank show isolines of evaporation in January running NW.–SE. with totals of 230 mm in the north-east and 300 mm in the far south-west. December shows a stronger N.–S. component with 230 mm on the eastern and 300 mm on the western boundary. Gradients in evaporation are much smaller in June. The 50-mm isoline is situated in the far south-east corner of

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TABLE 13

OTHER CLIMATIC CHARACTERISTICS

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Years
						Average index of mean relative humidity (%)								
Bollon	48	52	55	59	62	68	69	63	53	53	47	49	55	25
Miles	59	61	63	65	70	70	66	63	59	54	54	54	61	29
Mitchell	49	52	56	58	62	66	63	57	51	47	47	48	53	28
Roma	51	54	56	58	57	66	64	57	62	48	48	50	55	26
St. George	45	51	51	55	61	66	65	58	51	47	46	47	52	29
Surat	56	57	61	63	68	70	69	64	59	57	56	56	61	28
						Average index of cloudiness (%)								
Bollon	29*–48†	32–45	28–45	24–36	28–38	35–38	30–30	23–29	21–26	26–40	27–38	29–42	28–38	40–16
Miles	38*	39	32	26	25	33	27	23	21	27	30	33	29	45
Mitchell	29 –46	32–46	28–41	23–34	25–33	32–35	26–28	20–25	17–24	22–33	24–39	36–43	25–35	50–49
Mungindi	20	25	21	18	21	26	26	29	15	20	18	17	20	28
Roma	33 –47	37–49	30–44	25–37	28–36	34–37	28–32	22–28	19–30	25–38	29–43	30–44	28–38	50–45
St. George	27	35	25	23	24	28	29	23	17	26	22	22	25	18
						Total evaporation (mm/month)								
Bollon	294	217	187	126	99	72	77	103	143	192	254	283	2046	25
Goondiwindi‡	258	200	170	117	89	69	74	94	128	181	223	247	1850	29
Mitchell	262	199	172	132	102	78	87	113	148	205	237	266	2001	28
Roma	265	205	180	135	111	69	87	113	149	205	242	273	2035	26
St. George	264	219	198	141	94	64	63	91	137	194	221	257	1943	29
St. George§	304	214	195	137	98	73	78	85	142	201	249	284	2060	36
Surat	256	198	164	121	93	72	79	102	136	184	219	256	1880	28

* 9 a.m. observation. † 3 p.m. observation. ‡ Outside survey area. § Measured with Australian standard tank.

the State and the 75-mm isoline runs SE.–NW., west of Charleville. Taken over a complete year the area lies between approximately N.–S.-running isolines of 1780 mm in the east and 2150 mm in the west.

III. Climate in Relation to Agriculture

Available soil moisture is generally regarded as the major limiting factor for pasture growth in semi-arid and subhumid environments. This has been recognized in a climatic classification of eastern Queensland by Nix (Gunn and Nix, unpublished data) based on rainfall probabilities for the summer season (November–April) and the winter season (May–October). In the present context we refer to this classification, which covers the Balonne–Maranoa area as well, as a useful example of agro-climatic zonation for the area. According to the classification the survey area falls partly in the subhumid zone and partly in the semi-arid zone. The boundary between these zones runs from Glenmorgan in the east, past Mitchell to Babbiloora in the north. Within the major zones subdivisions reflect varying proportions of summer and winter rainfall and variations in total rainfall amount, as depicted in Figures 10 and 11.

In studies of the agricultural climatology of the Yass valley and of the Katherine area, N.T., Slatyer (1960*a*, 1960*b*) has applied a generalized water balance model that has since been used amongst others by Fitzpatrick (1965) and McAlpine and Yapp (1969). A recent general discussion of the program has been given by McAlpine (1970), while Keig and McAlpine (unpublished data*) provide a detailed technical description of the computer system. This generalized model has been used to study the soil moisture regime for six stations in the Balonne–Maranoa area, for Goondiwindi, and for Charleville with, as data inputs, observed weekly rainfall for 65 years and long-term estimated averages of mean weekly evaporation from an open water surface (Fitzpatrick 1963). Week-to-week changes in available soil moisture content are estimated from weekly inputs of observed rainfall and weekly water withdrawals by evapotranspiration. The maximum soil moisture storage capacity is assumed to be 100 mm on the basis of a water retention capacity of 25 mm/30 cm and an average rooting depth for most non-woody plants down to 120 cm. Other assumptions made in the model are as follows.

(i) No run-off or deep drainage occurs at actual soil moisture storage below 100 mm.

(ii) Actual evapotranspiration $= 0 \cdot 8 \times$ tank evaporation when the sum of soil moisture storage for the week prior to that for which calculations are being made and actual rainfall exceed 50 mm. Below this level actual evapotranspiration $=$ $0 \cdot 4 \times$ tank evaporation.

(iii) A pasture growth period is defined as a consecutive series of two or more weeks with soil moisture storage greater than zero. Drought periods are defined as a consecutive series of two or more weeks with soil moisture storage equal to zero.

In Figure 13 average weekly soil moisture storage for 1901–65 has been given for the eight stations. The results clearly show a maximum in winter centred around July 12, a secondary maximum in the second half of March, a minimum in November

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and early December, and a secondary minimum around May 10. Up to early May, Surat is wettest and Bollon driest. After that date all six Balonne–Maranoa stations are being enclosed by Goondiwindi as the wettest and Charleville as the driest station.

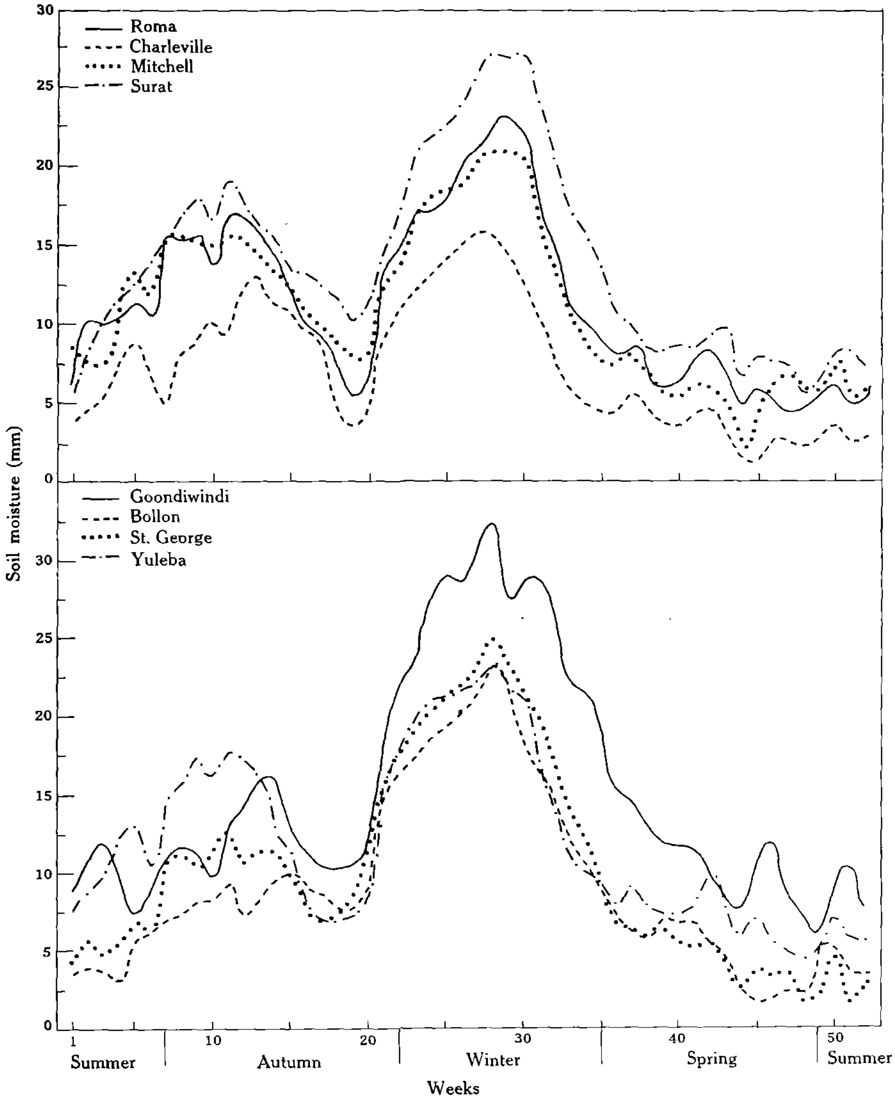

Fig. 13.—Average weekly soil moisture storage (1901–65 inclusive) for eight selected stations (maximum soil moisture storage is 100 mm).

Spatial heterogeneity within the area is greatest in early autumn, mid winter, and late spring. For all stations seasonality in mean soil moisture storage is the reverse from that in rainfall.

The information in Figure 13 is complemented by the frequency distribution of various soil moisture levels for all four seasons for the six stations within the area (Table 14). A striking feature is the relatively low frequency percentage (< 12%) of weeks with the soil moisture storage more than half full for all stations.

TABLE 14

PERCENTAGE FREQUENCY OF WEEKS WITH SOIL MOISTURE STORAGE AT SPECIFIED LEVELS: SEASONAL AND ANNUAL SOIL MOISTURE STORAGE INDICES

Station and quarter	Soil moisture storage (mm) 0	1–25	26–50	51–75	76–100	> 100	Seasonal index	Annual index
Bollon								
MAM	62·1	22·8	9·5	2·8	1·7	1·1	10·8	9·8
JJA	39·5	31·1	20·4	6·0	2·1	0·8	18·0	
SON	75·4	18·6	4·7	0·8	0·4	0·1	5·0	
DJF	75·9	17·4	4·9	0·9	0·5	0·5	5·5	
Mitchell								
MAM	52·1	29·0	13·7	3·1	1·2	0·9	12·7	11·6
JJA	40·3	33·3	18·9	4·1	2·0	1·4	17·0	
SON	72·0	21·1	4·7	1·3	0·6	0·4	6·2	
DJF	63·6	22·7	7·5	2·8	1·3	2·1	10·6	
Roma								
MAM	53·8	27·4	12·8	3·2	1·4	1·5	13·0	12·0
JJA	38·6	33·4	20·0	4·3	2·7	1·1	17·8	
SON	68·3	23·4	5·7	1·5	0·5	0·6	7·1	
DJF	64·8	22·8	5·2	4·0	1·9	1·2	10·2	
St. George								
MAM	55·4	27·0	12·4	3·9	0·9	0·4	11·7	10·8
JJA	32·8	34·1	24·4	5·2	1·9	1·7	20·0	
SON	73·9	20·1	4·9	0·9	0·2	0·0	5·0	
DJF	74·6	18·4	3·7	1·9	0·9	0·6	6·3	
Surat								
MAM	46·5	29·1	17·9	4·5	1·2	0·8	15·0	14·5
JJA	30·2	32·1	25·9	6·3	3·8	1·8	22·8	
SON	65·2	22·6	8·0	3·0	0·5	0·7	8·8	
DJF	61·7	23·8	7·7	3·6	1·1	2·2	11·3	
Yuleba								
MAM	49·9	31·0	13·7	3·0	2·0	0·5	13·2	12·7
JJA	37·3	34·1	18·2	6·0	2·8	1·5	18·8	
SON	65·2	24·3	8·3	1·4	0·6	0·2	7·8	
DJF	62·3	23·6	7·5	3·6	1·7	1·5	11·0	

In order to facilitate inter-seasonal and areal comparison of soil moisture storage levels, relative frequencies in per cent of all classes except the 0 mm class have been multiplied by their respective mid-range values (i.e. 13, 38, 65, 90, and 100 mm).

TABLE 15

ACTUAL AND CUMULATIVE NUMBER OF OCCURRENCES OF DROUGHT OF SPECIFIED DURATION COMMENCING PER SEASON AND TOTAL NUMBER OF OCCURRENCES PER YEAR FOR STANDARD PERIOD 1901–65 INCLUSIVE

Station and quarter	Length of drought period (weeks) ≤4	5–8	9–12	13–16	17–20	21–26	27–32
Bollon							
MAM	60	17(77)	4(81)	1(82)	0(82)	2(84)	0(84)
JJA	47	13(60)	8(68)	8(76)	4(80)	0(80)	2(82)
SON	36	27(63)	9(72)	9(81)	4(85)	2(87)	4(91)
DJF	57	26(83)	11(94)	9(103)	3(106)	1(107)	1(108)
Year	200	83(283)	32(315)	27(342)	11(353)	5(358)	7(365)
Mitchell							
MAM	55	20(75)	10(85)	0(85)	3(88)	0(88)	1(89)
JJA	41	10(51)	16(67)	8(75)	2(77)	5(82)	0(82)
SON	53	27(80)	12(92)	4(96)	2(98)	0(98)	0(98)
DJF	70	22(92)	7(99)	5(104)	2(106)	1(107)	1(108)
Year	219	79(298)	45(343)	17(360)	9(369)	6(375)	2(377)
Roma							
MAM	51	19(70)	8(78)	4(82)	1(83)	0(83)	1(84)
JJA	34	19(53)	7(60)	4(64)	6(70)	1(71)	0(71)
SON	57	20(77)	8(85)	7(92)	3(95)	2(97)	0(97)
DJF	78	25(103)	8(111)	4(115)	1(116)	0(116)	2(118)
Year	220	83(303)	31(334)	19(353)	11(364)	3(367)	3(370)
St. George							
MAM	62	23(85)	8(93)	0(93)	0(93)	0(93)	0(93)
JJA	41	12(53)	8(61)	4(65)	2(67)	2(69)	2(71)
SON	49	30(79)	11(90)	9(99)	6(105)	3(108)	1(109)
DJF	53	27(80)	6(86)	7(93)	1(94)	1(95)	1(96)
Year	205	92(297)	33(330)	20(350)	9(359)	6(365)	4(369)
Surat							
MAM	55	17(72)	5(77)	1(78)	0(78)	1(79)	0(79)
JJA	29	12(41)	7(48)	4(52)	1(53)	3(56)	0(56)
SON	60	25(85)	12(97)	5(102)	3(105)	0(105)	0(105)
DJF	67	23(90)	12(102)	4(106)	1(107)	1(108)	2(110)
Year	211	77(288)	36(324)	14(338)	5(343)	5(348)	2(350)
Yuleba							
MAM	59	28(87)	9(96)	2(98)	0(98)	1(99)	0(99)
JJA	35	12(47)	10(57)	4(61)	2(63)	1(64)	0(64)
SON	68	21(89)	14(103)	5(108)	3(111)	3(114)	0(114)
DJF	77	23(100)	7(107)	4(111)	1(112)	0(112)	2(114)
Year	239	84(323)	40(363)	15(378)	6(384)	5(389)	2(391)

These values have been added and divided by 4 to give a seasonal soil moisture index as indicated in Table 14. The average of the four seasonal soil moisture indices is defined as mean annual soil moisture index. An index of 0 indicates that the store was empty at all times and an index of 100 indicates that soil moisture depletion has never occurred. Soil moisture conditions at all stations are most favourable in winter and least favourable in spring; summer conditions are better than those in spring but drier than autumn conditions. On an annual basis Roma, Mitchell, and Yuleba are comparable whereas Surat is slightly wetter and St. George and Bollon drier. Differences between spring and summer are less marked for the drier stations.

From an agricultural point of view the risk of drought is of extreme importance. In Table 15 actual and cumulative frequencies of occurrences of drought of specified length during the period 1901–65 for all six stations per season and per year have been given. Droughts are listed in the season in which they commenced. In the majority of cases this is also the season in which the greatest part of a drought occurs. However, some overlap is possible.

At all stations the least number of individual droughts commences in winter, followed by autumn and spring in that order; droughts commencing in summer are most frequent except at St. George where droughts commence more frequently in spring. It can be seen from Table 15 that with a decreasing annual soil moisture index the number of individual droughts of more than 12 weeks' duration increases from 26 at Surat to 50 at Bollon for the standard period, such droughts being especially frequent in winter and spring.

Run-off and deep drainage, occurring when a surplus of rain is present after evapotranspiration requirements have been met and the soil water storage has been refilled to full capacity of 100 mm, is combined in a water surplus term. Mean annual water surplus for 1901–69 has been calculated to be for Surat 22 mm, Roma 17 mm, Mitchell 25 mm, Yuleba 17 mm, St. George 8 mm, and Bollon 10 mm as compared with Charleville 13 mm and Goondiwindi 18 mm.

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PART V. GEOLOGY OF THE BALONNE–MARANOA AREA

By R. W. GALLOWAY*

I. INTRODUCTION

This brief account of the geology of the Balonne–Maranoa area is concerned primarily with aspects particularly relevant to understanding the land forms, soils, and natural vegetation. It has been compiled from reports and publications by officers of the Bureau of Mineral Resources, Geology and Geophysics and of the Geological Survey of Queensland. Readers seeking fuller information on the rocks of the area are referred to these authorities and in particular to the explanatory notes accompanying the relevant 1 : 250,000 geological maps (Exon 1968, 1971*a*, 1971*b*; Graham 1972; Reiser 1971; Senior 1971; Senior 1972) and to the forthcoming bulletin and geological map on the Surat basin (Exon, personal communication). Some of the stratigraphic nomenclature is being reviewed and consequently not all names used here may be finally acceptable (Exon and Vine 1970).

II. MAJOR STRUCTURAL FEATURES

Most of the Balonne–Maranoa area lies in the north-western part of the Surat Basin but in the north and west it extends over the Nebine Ridge into the Eromanga Basin. Both the Surat and Eromanga Basins contain sequences of gently dipping Mesozoic rocks. The Nebine Ridge is an intervening rise in the basement which crops out in a small area in the centre of the Eddystone 1 : 250,000 geological sheet area. The very gentle regional dips, southward into the Surat Basin and westward into the Eromanga Basin, are modified in the northern part of the area by broad folds which strike roughly perpendicular to the margins of the basins and by faults which generally run about north-east or north-west. The presence of these fold structures causes the outcrop of the gently dipping Mesozoic sedimentary units to swing northwards on synclines and southwards on anticlines.

III. STRATIGRAPHY

The generalized distribution of major lithologies is illustrated in Figure 14. The distribution of stratigraphic units is described in relation to the 1 : 250,000 geological map sheets which cover the area and to the main railway line passing east–west through Roma. The most varied rocks with the best exposures occur north of the railway line and here the geology is known in considerable detail. South of the railway line the solid rocks are less varied, deeply weathered, and largely concealed by younger superficial sediments.

For the present purpose the consolidated sedimentary rocks can be divided into two major groups of quartzose and labile following the classification of arenites of Crook (1960). The quartzose rocks are comparatively little affected by weathering

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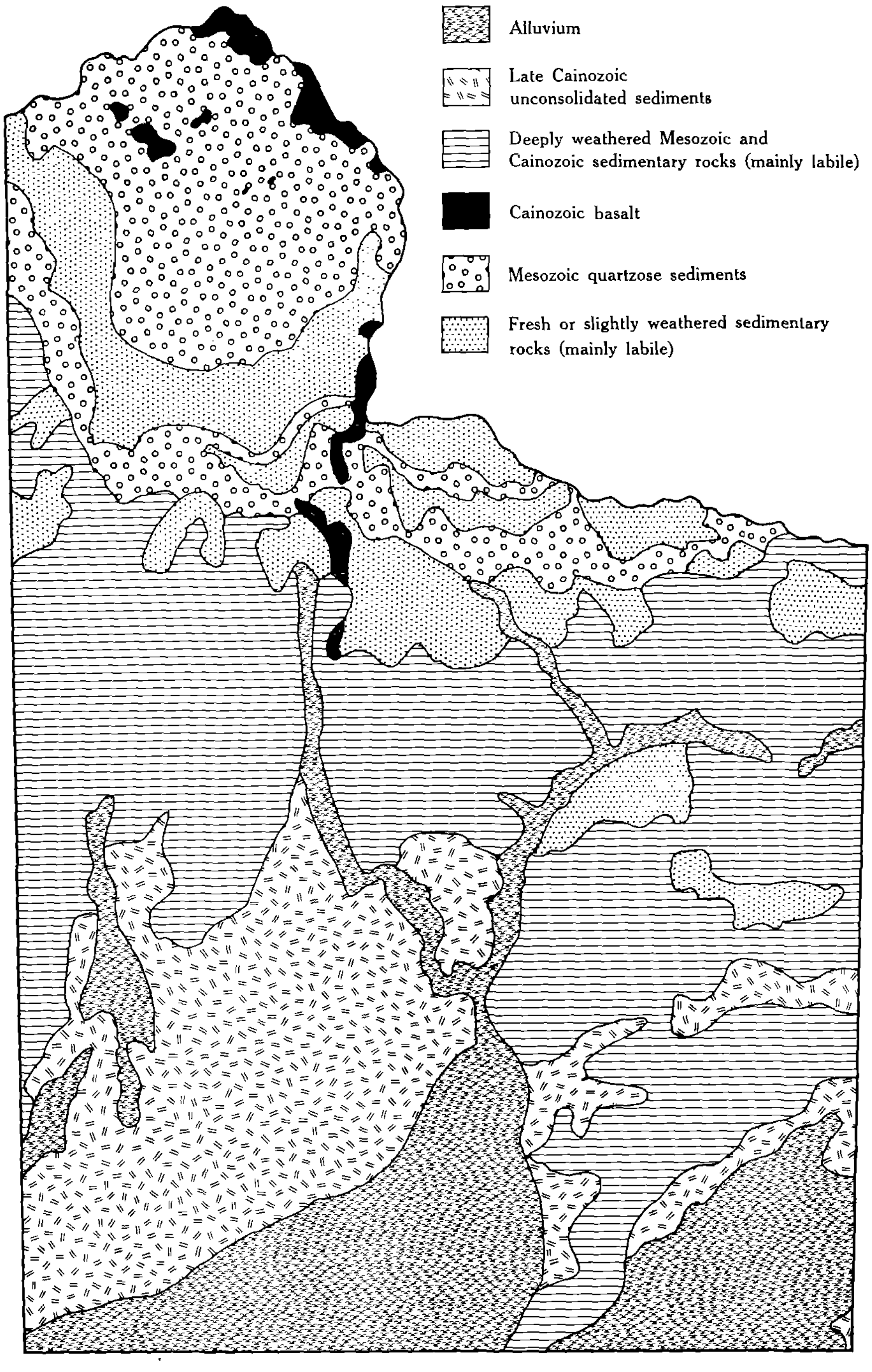

Fig. 14.—Lithology.

and consequently are associated with soils and vegetation which differ from those on the labile rocks which weather easily and contain a wider range of minerals. This lithologic distinction is one of the bases for classification of materials in Part VI.

(*a*) *Pre-Lower Jurassic*

A small patch of Palaeozoic ultrabasic rocks and pre-Jurassic sediments crops out in the crest of an anticline in the centre of the Eddystone sheet area. Further north, on the Springsure sheet area a small area of the shaly Triassic Moolayember Formation is exposed.

(*b*) *Lower Jurassic*

The Lower Jurassic Precipice Sandstone is exposed in the north-central part of the Eddystone map sheet. It is a coarse cross-bedded fluviatile quartzose sandstone 75–150 m thick.

The Evergreen Formation, like the Precipice Sandstone which it overlies, is exposed only in the north of the area. This formation up to 120 m thick is here dominated by the quartzose Boxvale Sandstone Member and the thin Westgrove Ironstone Member.

The Hutton Sandstone, more than 120 m thick, is quartzose to sublabile sandstone with considerable feldspar content which crops out in a great arc across the Eddystone sheet area.

(*c*) *Middle–Upper Jurassic*

The Injune Creek Group occupies the southern margin of the Eddystone sheet area and the northern margin of the Mitchell sheet area and extends eastward into the Roma sheet area. Its composition changes from west to east. West of the Maranoa River the Injune Creek Group includes the Birkhead Formation, the Adori Sandstone, and the Westbourne Formation. The Birkhead Formation, 150–300 m thick, is generally sublabile to labile sandstone, partly calcareous, and with some carbonaceous siltstone and minor coal. The Adori Sandstone, up to 60 m thick, is a pebbly, cross-bedded, quartzose to sublabile sandstone with minor siltstone. The Westbourne Formation consists of siltstone and mudstone, in part carbonaceous and calcareous, plus very fine-grained, friable, quartzose or sublabile sandstone; it is about 120 m thick over most of the Mitchell sheet area but thins eastward.

For some distance east of the Maranoa River the upper part of the Birkhead Formation is known as the Springbok Sandstone Member. Further to the east, the Birkhead Formation and the Springbok Sandstone Member are not recognized as separate units within the Injune Creek Group. In this area the group has become sandier and less labile than to the west but the Westbourne Formation is still recognizable until it pinches out north-east of Roma.

(*d*) *Upper Jurassic–Lower Cretaceous*

The Hooray Sandstone, a cross-bedded quartzose to sublabile sandstone with some siltstone, is about 120 m thick and conformably overlies the Westbourne Formation. It crops out over extensive areas in the west of the Eddystone sheet area and the north-west of the Mitchell sheet area. East of the Maranoa River the lower part of the Hooray Sandstone gives way eastwards to the quartzose Gubberamunda Sandstone, while the middle part of the Hooray Sandstone merges into the partly calcareous labile and argillaceous Southlands Formation. In turn, the Southlands Formation grades eastwards into the lithologically similar Orallo Formation and the quartzose Mooga Sandstone. The upper part of the Hooray Sandstone also grades eastwards into the basal part of the Lower Cretaceous Bungil Formation (Exon and Vine 1970).

(*e*) *Lower Cretaceous*

The Bungil Formation incorporates most of the rocks formerly known as the Blythesdale Formation and consists of fine lithic sandstone, siltstone, and mudstone with subordinate sublabile sandstone and calcareous beds. It can be divided into several members east of the eastern edge of the Mitchell sheet area though not all occur at any one locality. As a whole the Bungil Formation and its constituent members become less quartzose eastwards.

In the western sector of its occurrence the Bungil Formation is split into a thin arenite, the Claravale Sandstone Member (cross-bedded, coarse, quartzose sandstone), and the more important Nullawart Sandstone Member (very fine-grained, sublabile to quartzose sandstone) and the Minmi Member (lithic to quartzose sandstone).

Further east the Claravale Sandstone Member disappears but the Nullawart Sandstone Member and Minmi Member continue on to the Roma sheet area where they are underlain by the Kingull Member (soft muddy siltstone and carbonaceous mudstone) and the sublabile sandstone and mudstone of the Mooga Sandstone. These elements of the Bungil Formation extend across the Roma map sheet area not far north of the railway line and pass out of the survey area north of Dulacca.

South of the Great Western railway line the solid geology is simpler and dominated by the Rolling Downs Group which has been extensively weathered. TheWallumbilla Formation, made up of the Doncaster Member (mudstone and minor siltstone) and the Coreena Member (labile sandstone, siltstone, and mudstone), is overlain by the Surat Siltstone (known only in section) and the shaly Gorman Creek Formation. The latter is the youngest Cretaceous formation in the area and outcrops sporadically as far south as the New South Wales border.

(*f*) *Cainozoic*

The Cainozoic rocks consist of volcanics, consolidated and unconsolidated terrestrial sediments, and alluvium. Deep weathering significantly altered the labile sediments but had little effect on quartzose rocks.

The volcanics are predominantly basalts which now cap plateaux in the extreme north and fill an old valley which extends well south of the railway line on the Mitchell sheet area. The basalt has a radiometric date of about 23 million years (Exon *et al.* 1970) and is the remnant of a formerly more extensive sheet. Small intrusions of gabbro occur in the north of the Eddystone sheet area.

The consolidated terrestrial sediments include a wide variety of lithologies. They are widely exposed across the centre of the area but are only patchy on the steeper country north of the railway line and have been buried by younger unconsolidated sediments in the south. Thicknesses are generally of the order of 10–25 m, but up to 220 m have been recorded in a broad trough west of the Balonne River (Senior 1970). Lithologies include poorly bedded, poorly sorted muddy sandstone and conglomerate and quartzose sandstone and pebble conglomerate.

Unconsolidated late Cainozoic sediments ranging in texture from clay to sand form extensive plains in the south-west and narrower plains in the south-east. They were deposited by rivers which followed essentially the same courses as the modern major streams of the area.

Alluvium of late Quaternary age occurs along all the creeks and in the south of the area it forms extensive alluvial plains. Silt and clay predominate though sand and gravel do occur, especially in the steeper northern part of the area. Minor sand dunes formed by wind reworking old levees occur south-west of St. George.

Deep weathering with formation of mottled and pallid zones has been widespread and its effects have been noted to depths of more than 30 m although the usual depth is considerably less. Pisolitic ironstone laterite horizons are practically absent. Deep weathering has more effect on the Cretaceous labile sediments than on the Jurassic quartzose sediments.

IV. Economic Geology

In the south-western third of the area artesian and subartesian bores produce considerable quantities of stock and domestic water. Hydrostatic heads have decreased substantially since the first bores were put down and output will probably continue to decline for many years before a steady yield is achieved (Ogilvie 1955).

The Surat Basin has been prospected for hydrocarbons and Australia's first commercial oil field was discovered at Moonie, just east of the survey area. Gas fields with estimated total reserves of 250,000,000,000 ft^3 (7,000,000,000 m^3) exist near Roma and gas is supplied to Brisbane by pipeline (Traves 1971).

V. Geology and the Land Systems

As there is no hard-and-fast distinction between geology and geomorphology in relation to land systems, these aspects will be considered jointly in Part VI.

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PART VI. GEOMORPHOLOGY OF THE BALONNE–MARANOA AREA

By R. W. GALLOWAY*

I. INTRODUCTION

The basic relief of the Balonne–Maranoa area is fairly simple. It consists of a long, extremely gentle slope which falls southward from a maximum altitude of about 1000 m in the extreme north to about 140 m in the south-west. The relief in the north is rolling to mountainous, in the centre it is rolling to undulating, in the south it is mainly gently undulating to level. The underlying sedimentary rocks dip southwards rather more steeply than the land surface which consequently cuts across the geologic strata (Fig. 15). A deep weathering profile which formed during late Cretaceous and Cainozoic time was subsequently partially removed and unconsolidated sediments were spread over lower parts of the landscape.

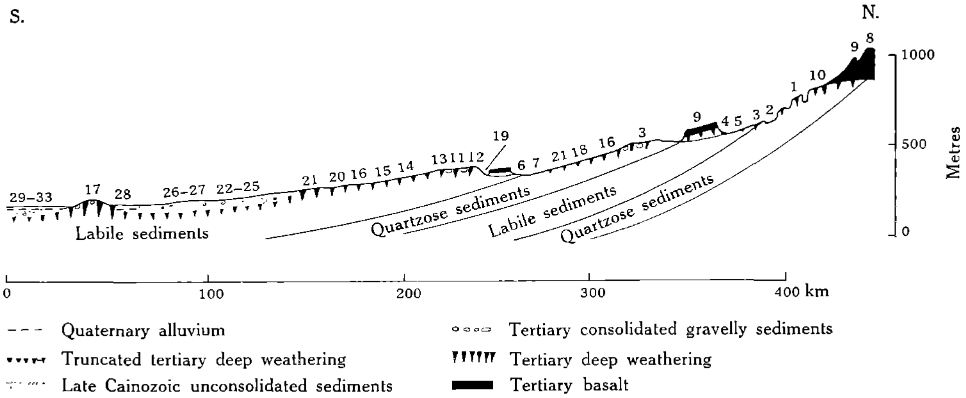

Fig. 15.—Diagrammatic north–south section showing dominant location of land systems in Balonne–Maranoa area. Land systems: 1, QhMe; 2, QuA; 3, QrCp; 4, ShSw; 5, SrX; 6, SuMe; 7, SuD; 8, BtS; 9, BhMc; 10, Bul; 11, (S)rNi; 12, (S)rBe; 13, (S)rXM; 14, (S)uM; 15, (S)uXM; 16, (S)uX; 17, (S)ulX; 18, (S)uBu; 19, (S)hY; 20, (S)uXB; 21, (S)uBl; 22, CpCp; 23, CpXM; 24, CpM; 25, CpBXM; 26, CpBl; 27, CpG; 28, ACp; 29, AXM; 30, AX; 31, AC; 32, ABb; 33, Af.

II. MAJOR TYPES OF COUNTRY AND ASSOCIATED LAND SYSTEMS

The major types of country correspond to ten major classes of material and have been named after them (Table 16). Their generalized distribution is shown on Figure 16 and they form the basis for grouping the land systems on the land system map and its accompanying reference.

(a) *Quartzose Sediments*

Quartzose sediments, mainly sandstone, occupy a compact area of some 20,000 km^2 in the north. On account of the predominance of quartz this rock was little

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affected by deep weathering, though it has been bleached to considerable depths and minor shale beds have been kaolinized or otherwise modified. A further local effect connected with deep weathering was the formation of a resistant sheet of silcrete ("billy") on sandstone overlain by basalt in the north of the area.

Three land systems occur on the quartzose sediments in the north. Undulating to rolling country with deep sandy-surfaced duplex soils and cypress pine forest developed on the quartzose and micaceous Hutton Sandstone is mapped as QrCp land system which is dominated by land units 7 and 8. Rocky dissected plateaux rising from 20 to 200 m above their surroundings comprise QhMe land system which occurs on the Precipice Sandstone and Boxvale Sandstone Member and whose vegetation is mixed layered eucalypt woodland (land unit 1). Between these dissected plateaux lie wide valleys with undulating floors with deep sands and smooth-barked apple woodland comprising QuA land system dominated by land unit 5.

TABLE 16

RELATIONSHIP OF MATERIALS AND LAND SYSTEMS

Major class of material	Associated land systems	Relation to deep weathering
Quartzose sediments	QhMe, QuA, QrCp	Not seriously affected because of quartzose lithology or complete stripping of the profile or relatively young age
Fresh labile sediments	ShSw, SrX, SuMc, SuD	
Basalt	BtS, BhMc, BuI	
Indurated deeply weathered sediments	(S)rNi, (S)rBe, (S)rXM	Deeply weathered, then stripped to varying degrees
Moderately resistant deeply weathered sediments	(S)uM, (S)uXM, (S)uX, (S)uIX, (S)uBu	
Unresistant deeply weathered sediments	(S)hY, (S)uXB, (S)uBl	
Unconsolidated late Cainozoic mixed sediments	CpCp, CpXM, CpM	Post deep weathering
Late Cainozoic clay	CpBXM, CpBl, CpG	
Coarse alluvium	ACp, AXM, AX	
Fine alluvium	AC, ABb, Af	

Quartzose sediments also crop out in an irregular belt from north of Morven in the west to north of Yuleba in the north-east. Apart from small areas of steep dissected country with mixed eucalypt woodland on the most quartz-rich rocks, this belt is cypress pine country of QrCp land system. Because of the gentle dips and the alternation of hard and soft beds low indistinct scarps are a common feature.

(b) *Fresh Labile Sediments*

These materials and the associated types of country form an irregular belt running north-west to south-east from north of Morven to south-east of Surat. They occur where erosion has removed the deep weathering profile to expose the underlying fresh rocks and Cainozoic sediments of the Rolling Downs group. Removal has often been incomplete and traces of the basal portion of the former deep weathering

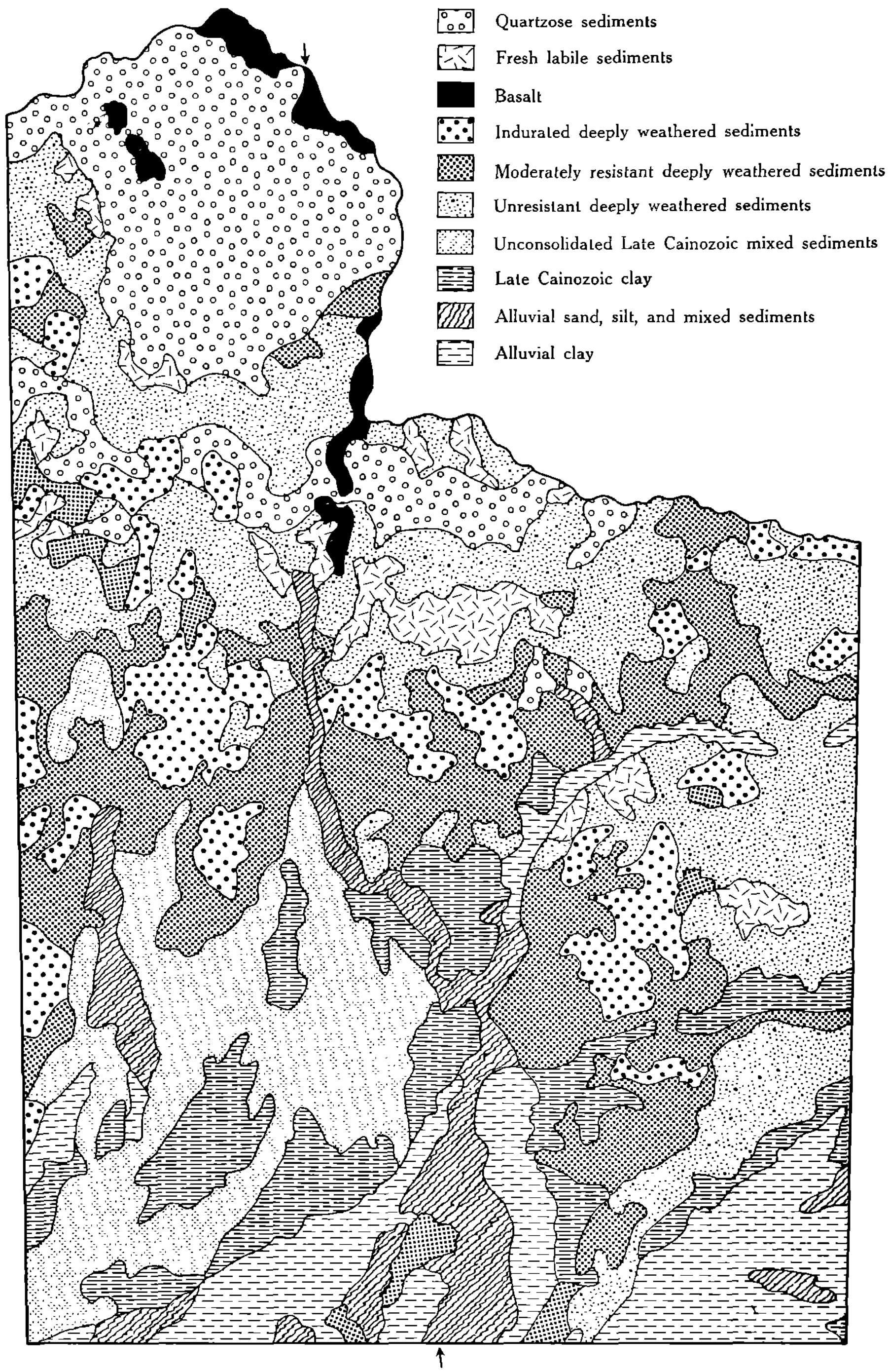

Fig. 16.—Generalized distribution of major types of material. The arrows indicate the approximate location of the profile in Figure 15.

zone survive with different soils and vegetation. The relief on fresh labile sediments is generally undulating and soils are moderately deep clays supporting grassland (SuD land system) or mountain coolibah open-woodland (SuMc land system). Smaller areas of these labile rocks, somewhat affected by deep weathering, occur on scarps and rolling country below basalt caps north-east of Roma and comprise ShSw land system. A small area of rolling relief with poplar box open-woodland (SrX land system) occurs on part of the Orallo Formation. North of Roma the country on fresh labile sediments is unusually steep for this type of material, with slopes up to 10%; consequently soil erosion is particularly acute in this locality.

(*c*) *Basalt*

The basalt is restricted to high ground in the extreme north and to a ridge that widens locally to a narrow plateau running north to south near the eastern edge of the Mitchell 1 : 250,000 map sheet area. The basalt ranges from moderately weathered to fresh. It mainly forms stony country with frequent outcrop supporting mountain coolibah open-woodland interspersed with grassland (BhMc land system). A very small tableland at about 1000 m above sea level in the extreme north forms BtS land system, while colluvial foot slopes with rather deeper soils generally support silver-leaved ironbark open-woodland and have been mapped as BuI land system.

(*d*) *Indurated Deeply Weathered Sediments*

Deeply weathered rocks occupy nearly half the area and predominate in the centre and south-east. Selective induration with iron and silica has occurred and in places reworked surface gravel has been cemented by iron solutions. Such resistant material now comprises only a fraction of the total extent of deeply weathered rocks.

Ferruginous induration predominates in the north-east, east, and centre where it now forms cappings to low plateaux of weathered rock rising 10–50 m above the surrounding lowlands. The induration is not especially resistant and true laterite crusts are absent. Only where the induration coincides with sandstone members of the bed-rock (e.g. south and east of Surat) are distinct breakaways developed. The summits of the plateaux tend to be rather sandy country forming (S)rNi land system, while the eroded margins with very shallow soils and bendee forest have been mapped as (S)rBe land system.

The silcrete layers are mainly confined to the drier western half of the area and probably formed in subsurface situations and at various times (Exon *et al.* 1970). On the Homeboin sheet area silcrete is at or near the surface over extensive areas forming undulating or rolling country with shallow soils ((S)rXM and parts of (S)uM and (S)uXM land systems). On the Mitchell sheet area, on the other hand, the silcrete layers cap plateaux rising to as much as 100 m above the surrounding lowlands east of the Maranoa River.

Silcrete ("billy") pebbles and cobbles are a common surface feature around Roma where they have possibly been derived from a silcrete layer which underlay a former extensive basalt cover. Silcrete pebbles are a significant element in limited gravel terraces occurring along the middle Maranoa and also in Tertiary conglomeratic sandstones.

(e) *Moderately Resistant Deeply Weathered Sediments*

This class of material and the associated land systems form extensive lowlands across the centre of the area. Slopes rarely exceed 4%. In the very rare exposures the rock is yellowish, heavily weathered, with occasional ferruginous mottlings and segregations, and the original lithology is practically unrecognizable. A characteristic feature of the surface is a sparse lag gravel derived from the ferruginous mottlings and segregations, or from a former overlying ferruginous indurated layer. Locally the lag gravel is colluvially derived from adjacent low mesas still capped by the indurated layer.

Five land systems comprising 16% of the Balonne–Maranoa area are dominantly developed on this class of material. (S)uM, (S)uXM, and (S)uX form a rough climatic sequence with the proportion of mulga to box and red earth to texture-contrast soils decreasing from drier to moister environments. (S)uIX is a combination of two types of country which are too small to map separately: broad interfluves on indurated Tertiary gravel or Cretaceous sediments with ironbark woodland and adjacent slopes on moderately resistant weathered sediments with poplar box woodland. (S)uBu land system with bull oak forest on texture-contrast soil is confined to two limited areas in the east and may possibly be related to some unrecognized features of the bed-rock lithology.

In addition, part of ShY land system (rolling or hilly country with yapunyah) occurs on this class of materials.

(f) *Unresistant Deeply Weathered Sediments*

This class of material and the associated major types of country form gently undulating lowlands and plains, mainly in the east. Slopes rarely exceed 2% except in narrow scarp-foot zones. The drainage pattern is integrated and occasional angular fragments of the underlying labile Cretaceous rocks are found on the surface. Clay soils predominate and gilgai structures are common.

The dominant land system, and the largest in the entire survey area, is (S)uBl comprising undulating lowlands with belah or brigalow open-forest and deep clay or texture-contrast soils. (S)uXB land system is transitional between brigalow or belah open-forest and poplar box woodland developed on moderately resistant weathered sediments ((S)uX land system). (S)hY land system is fairly small and confined to foot slopes of scarps and adjacent rolling country; only part falls into this category of materials, the remainder consisting of moderately resistant weathered sediments. Despite the weak nature of the rock, slopes in (S)hY land system often exceed 6% because a lag gravel of silcrete inhibits erosion.

As a rule, the indurated, the moderately resistant, and the unresistant deeply weathered rocks correspond to the upper, middle, and lower portions of the former deep weathering profile but this simple relationship is not universally valid. In places, as on the eastern side of the Thomby Range, belah forest associated with unresistant weathered rocks ((S)uBl land system) stands upslope from poplar box woodland of (S)uX land system developed on the moderately resistant weathered material. This juxtaposition may possibly be related to initial steep slopes or warping of the deep weathering profile. South of Delacca moderately resistant weathered sediments with bull oak and texture-contrast soils occur downslope from belah forest on unresistant weathered sediments. The reason for the unusual relationship is probably that the effect of deep weathering has been insufficient to mask a strong contrast of initial lithology (apparently easily weathered mudstone over micaceous sandstone).

(*g*) *Late Cainozoic Mixed Sediments*

An extensive fan was deposited on the Dirranbandi and Homeboin sheet areas by the Maranoa River during the late Cainozoic. The material is gravelly upstream but mostly consists of sand, silt, and clay in varying proportions. The clay occurs in irregular radial belts and also fringes the distal edge of the fan; it is discussed in subsection (*h*) below. Broad low rises of sand, several kilometres wide and rising to a few metres above the level fan surface, are levees of former courses of the Maranoa now modified by wind action with the development of low dunes and deflation hollows. The fan falls some 60 m over its exposed length of 150 km to give an overall gradient of 0·04%. Local slopes rarely exceed 0·9%. The Maranoa now skirts the eastern edge of the fan and the drainage is poorly integrated with surface streams absent over large areas. The lower end of the fan is overlain by younger alluvium.

The land systems on the fan are simple. The old levees form CpCp land system and have coarse sandy soils and a distinctive vegetation of cypress pine, rough-barked apple, and shrubs. The rest of the fan, other than the clayey portions considered below, is mapped as CpXM land system where both poplar box and mulga are present or as CpM where mulga is dominant. These land systems resemble (S)uXM and (S)uM on moderately resistant weathered sediments but have lower gradients, deeper soils, and no surficial ferruginous gravel.

(*h*) *Late Cainozoic Clay*

Late Cainozoic clays were laid down not only by the Maranoa River as part of the above-mentioned fan but also by the Balonne and Moonie Rivers. This material forms plains with deep clay soils which are often gilgaied and which support belah or gidgee forest (CpBl and CpG land systems). A small area with poplar box, brigalow, and mulga in the extreme south-west includes some younger alluvial silts and clays. The plains have very low gradients, rarely exceeding 0·8% except at dissected margins where they may fall somewhat more steeply to younger alluvial flats. The drainage is poorly integrated and surface stone is absent.

(*i*) *Coarse Alluvium*

In the north and centre of the area most alluvium is sand and silt with clay confined to limited tracts along the major streams. There are also minor gravel terraces. In the south of the area, on the other hand, sand and silt form only relatively restricted levee and channel tracts, sometimes modified by wind action, and most of the alluvium is clayey. The levees form a noticeable axial belt in the alluvium south of St. George with lower clay plains on either flank.

Three land systems have been recognized on coarser alluvium: ACp consists mainly of cypress pine open-forest or woodland on deep sandy soils, AX is mostly poplar box woodland on duplex soils, while AXM is similar country with mulga in the dry south-west.

(*j*) *Fine Alluvium*

Alluvial clay forms extensive plains in the extreme south of the area and also along the Balonne River. Smaller clay tracts occur along the Maranoa River south of Mitchell and in narrow valleys draining basalt uplands in the north. Except in the last situation, gradients are extremely low and rarely exceed 0·5%. Most areas of fine alluvium are subject to flooding by run-on or as a result of the very slow run-off. Fine alluvium differs from late Cainozoic clay in the complete absence of gilgai. Where gilgai does appear to occur in the extreme south-west, in fact, there is only a thin layer of alluvial clay over late Cainozoic clay in which the gilgais have really formed. The reason for this contrast in gilgai occurrence between the two types of clay is unknown.

By far the largest land system on fine alluvium is AC (alluvial clay plains with coolibah open-woodland) occupying 10% of the entire survey area. Restricted areas in the extreme south are very similar but have black box instead of coolibah (ABb land system). The lowest areas, most liable to flooding, comprise Af land system.

III. Evolution of the Landscape

The evolution of the landscape falls into three major phases, each of which was undoubtedly far more complex than can be indicated here. The first phase lasted from about the middle of the Cretaceous to the middle of the Tertiary and resulted in the smooth Tertiary weathered land surface. During the second phase, which occurred in the middle Tertiary, this surface was dissected and basalt was extruded in the north of the area. In the third phase (late Tertiary and Quaternary) there was extensive deposition of unconsolidated material on the lower parts of the landscape. The distribution of the land systems in relation to the landscape formed by this history is shown on Figure 15.

(*a*) *Formation of the Tertiary Weathered Land Surface*

This complex phase began with the retreat of the Cretaceous sea from the north of the area, presumably as a result of uplift. Erosion started on the newly exposed landscape and extended southwards as the sea withdrew. Erosion was accompanied by deposition of sandy and gravelly sediments in lower parts of the landscape which were consolidated to form the Tertiary deposits now widely exposed in the centre of the area (Mitchell sheet area in particular) and in the south where silicified quartz gravels occur between Mungindi, Dirranbandi, and Bollon. Deep weathering accompanied and followed the erosion of the bed-rock and deposition of the Tertiary sediments with the formation of indurated ferruginous and siliceous horizons and alteration of labile sediments to depths of 30 m or more. At times weathered material was eroded, deposited again, and reweathered as shown by the presence of rolled silcrete pebbles in the consolidated Tertiary sediments.

By mid-Tertiary time the landscape was reduced to a gently sloping plain, mainly erosional in the north and depositional in the south with widespread indurated crusts and probably with low rises such as the Thomby Range associated with more resistant rocks. This Tertiary weathered land surface, equivalent to the "upper pediplain" of Exon *et al.* (1970), is a fundamental geographic feature of the northern two-thirds of Australia.

(*b*) *Dissection of the Tertiary Weathered Land Surface*

Dissection of the Tertiary weathered land surface commenced in the latter part of the Tertiary. At a fairly early stage of the dissection a north–south valley at least 120 km long to the east of Mitchell was filled by basalt which has a radiometric date of approximately 23 million years (Exon *et al.* 1970). Subsequent further dissection of the weaker surrounding rocks has left the basalt as a broken sinuous ridge, standing some 200 m above the surrounding lowlands in the north and descending to merge with the general land surface at its southern end. Sporadic deep weathering of the basalt shows that this process continued into the late Tertiary although the greater part had taken place before the emission of the basalt. Continuing erosion stripped the Tertiary weathered land surface entirely from the northern third of the area though small outliers still cap isolated hills such as Mt. Eumamurrin north of Roma. Relics also survive on the Great Divide which forms the north-eastern boundary of the Balonne–Maranoa area and in the Warrego catchment which drains the extreme north-west corner. Small basalt caps on summits north-east of Roma (e.g. Mt. Bassett) are probably survivals of an extensive sheet removed by erosion during this phase.

In the centre of the area, particularly towards the west, removal of the Tertiary weathered land surface was less complete, probably because of reduced uplift and the development of resistant indurated layers. Dissection here seems to have occurred by valley incision followed by scarp retreat to give valley plains overlooked by mesas with indurated caps on top of which the Tertiary weathered land surface is more or less preserved, e.g. north and south of Morven. East of Surat there are indications that dissection led to inversion of relief with former valley floors now forming low linear plateaux 10–30 m higher than the surrounding lowlands.

In the south of the area the extent of dissection during this phase is obscured by younger deposits. A wide trough, up to 200 m deep, has been proved to underlie the plain between St. George and Bollon (Senior 1970). It has been ascribed to tectonic downwarping but there are indications that a similar buried trough, filled by late Cainozoic sediments, extends far into New South Wales under the Darling River system (Hind and Helby 1969) and the whole may form a large buried valley system. Weathered bed-rock rises capped with silicified gravel on the margin of the trough in the Hebel–Dirranbandi area are the summits of an erosional landscape now almost entirely buried by alluvium.

Where removal of the Tertiary weathered landscape and the underlying deep weathered profile was complete, undulating lowlands with clay soils lacking melon-hole gilgai but sometimes with linear gilgai formed on the fresh labile rocks (Fig. 17). Partial removal produced gently undulating country dominated by poplar box woodland or belah and brigalow open-forest and minor yapunyah woodland. Where removal was slight, bloodwood and bendee vegetation predominates.

(*c*) *Late Cainozoic Deposition*

During the prolonged period of dissection just discussed the products of erosion were exported from the area by the major rivers draining to the south-west. In the late Tertiary and Quaternary, on the other hand, while erosion continued much of the material was re-deposited within the area. In the north and centre these deposits were confined to colluvial aprons below hills and narrow alluvial tracts in the valleys but in the south they spread over extensive areas.

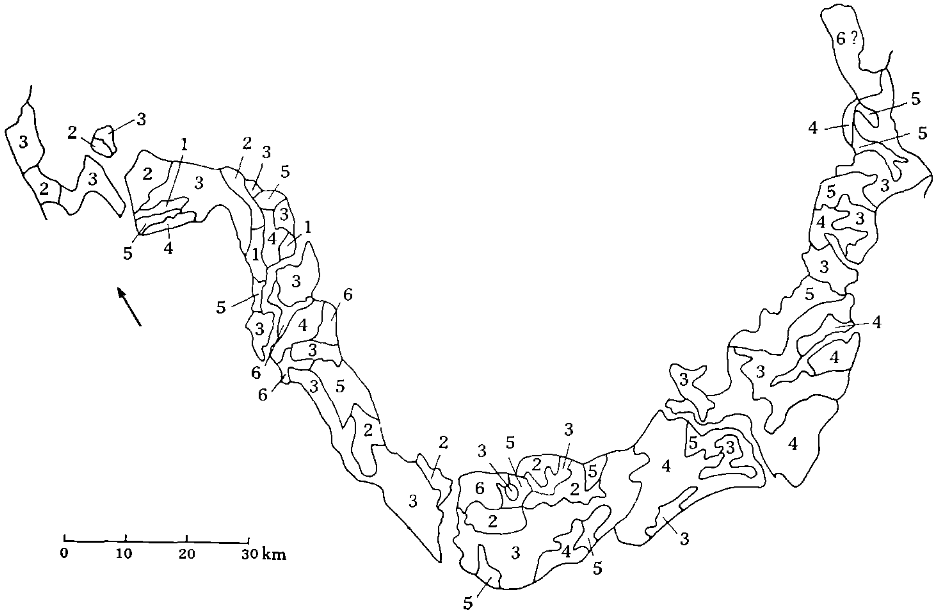

Fig. 17.—Vegetation and land systems on the labile Birkhead Formation showing effects of varying preservation of deep weathering profile.

Geology	Vegetation	Land system
(1) Fresh labile sediments, deep weathered profile entirely stripped	Grassland	SuD
(2) Vestiges of deep weathered profile	Mountain coolibah open-woodland	SuMc
(3) Soft lower part of deep weathered profile	Belah and brigalow forest	(S)uBl
(4) Lower to middle part of deep weathered profile	Poplar box and brigalow woodland	(S)uXB
(5) Middle part of deep weathered profile	Poplar box woodland	(S)uX
(6) Overlying sandy deposits	Cypress pine forest	QrCp

In the earlier part of the late Cainozoic the trough between St. George and Bollon was filled by up to 220 m of sand and gravel now consolidated into sandstone and conglomerate (Senior 1970). Subsequently, extensive but fairly thin spreads of sand, silt, and clay were laid down in the southern half of the area. The Maranoa River, which drains a wide variety of rocks with a large sandstone component, laid down an extensive fan with its apex about 80 km south of Mitchell and extending at least as far south as the New South Wales border. In keeping with the lithology of the source area this fan is dominantly sandy but with considerable proportions of mud-sized material, some gravelly areas near the head, and clay spreads particularly on the distal margin. Old sandy levee tracts a few metres high and up to several kilometres wide are plainly visible on the surface of the fan and support distinctive heath and *Angophora* vegetation. Wallam Creek, south of Bollon, draining indurated and moderately resistant weathered fine-textured rocks formed a smaller fan of dominantly mud-sized material. The Moonie River, draining soft weathered sediments, deposited mainly clay during this phase as did the Balonne River which derived its material primarily from weathered basalt of the Darling Downs. A few kilometres above the Maranoa–Balonne confluence clays deposited by the Balonne River (Fig. 18; Plate 5, Fig. 1) interfinger with sandy material from the Maranoa.

Deposits in the north corresponding to these fans consist of sandy colluvial spreads best developed north-east of Morven where they extend for several kilometres below dissected weathered sandstone mesas.

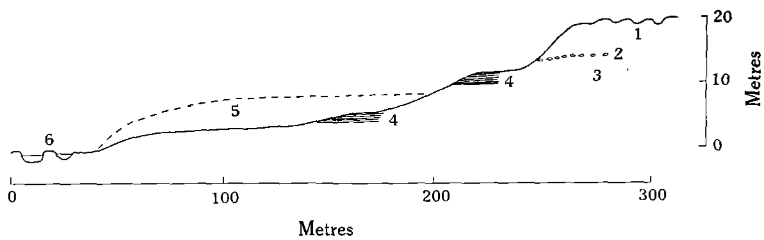

Fig. 18.—Section on west bank of Maranoa River, 4 km north of 'Wycombe'. Dimensions are approximate. (1) Grey clay with minor sand; red mottling in lower 1–2 m; gilgai on surface. (2) Ferruginous concretions and rolled quartz pebbles forming horizon 10–20 cm thick. (3) Cretaceous labile sediments weathered to sandy red-yellow mottled clay. (4) Lenses and layers of less weathered sandstone. (5) Dissected terrace of gravelly sandy clay; includes silcrete pebbles. (6) Modern channel of the Balonne River.

In the later part of the Quaternary alluvial plains developed along the major streams. In the north and centre these were restricted to fairly narrow valley floors, but in the south they spread widely and covered the southern end of the fans already laid down by the Maranoa River and Wallam Creek. The alluvium tends to reflect the nature of the source rocks, being sandy in valleys draining sandstone country in the north and finer-textured where draining labile siltstones and shales. Alluvial relief of terraces, levees, and back swamps is well developed.

There is evidence that some of this alluvium was deposited at a time when stream discharge was higher than it is today. Abandoned levees and channels, in the Boomi area for instance, consist of coarse sand and fine gravel whereas their modern equivalents are medium sand to silt. Furthermore, abandoned meanders and channels are larger than the modern ones and this also points towards former higher discharges. Where the alluvium lapped against bed-rock rises in the Dirranbandi–Hebel area, drainage was restricted and shallow lakes were formed. The largest is Lake Bokhara, which covers some 15 km^2 and which is still marshy in wet seasons.

Wind action in the drier south-west of the area probably occurred many times during the Quaternary. The levee tracts on the old fans and sandy or silty levees on younger alluvium have blow-outs, dunes, and lunettes, all now stabilized and no longer developing. Aeolian sands were encountered below 8 m of fluvial sands on the Maranoa fan 40 km south-west of St. George, so it is likely that several phases of aeolian activity occurred.

Throughout the area younger alluvium is often capped by thin silty layers with well-preserved alluvial microstructures. This points to recent acceleration of erosion as a result of grazing and cultivation. Sheet erosion by wind and water is locally severe on silty levees in the far south-west (Plate 6, Fig. 2).

IV. Slopes

(a) *Available Data*

Considerably more data are available than for previous surveys and consequently more precise information can be given on some aspects of the slopes. In the field the mean slope over a distance of about 60 m was determined by levelling two short traverse lines intersecting at right angles (Fig. 19). Data were available

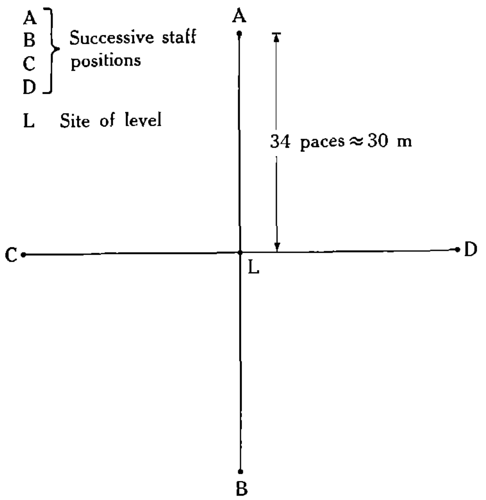

Fig. 19.—Method of slope measurement. Height differences *A–B*, *C–D* calculated; compass orientation of line *AB* determined; gradient and direction of maximum slope then deduced by inspection.

from 720 sites. Following Speight (1971), the slope values were grouped into classes where each class was twice as steep as the preceding one and each class was then weighted according to the estimated area it occupied. When classified in this way the slope populations of various types of country were found to be almost normally distributed with similar standard deviations on all types of relief from plains to mountains.

Unfortunately areas with gilgaied soils, totalling some 10,000 km^2, could not be incorporated in this analysis because the steep microrelief made overall slope measurements impossible in the available time. Undoubtedly overall slopes of gilgaied areas are low and probably rarely exceed 1%. Data are also inadequate for the steep country in the north. Most of the few observations made here were on gentler foot slopes, giving a poorly representative sample.

Little information is available on the length or plan-form of slopes. Generally it can be said that slopes are fairly long to long in all but the steepest parts of the area.

(b) *Slopes and Relief Categories*

The Balonne–Maranoa area is dominated by gentle slopes. Fully half the area has slopes less than 2% and barely one-tenth of the area has slopes in excess of 10%. Two-thirds of all slopes lie between 0·7% and 6·0%. On the alluvial clay plains in the south average slopes can be as low as 0·1%.

TABLE 17

ESTIMATED SLOPES FOR VARIOUS RELIEF CATEGORIES IN THE BALONNE–MARANOA AREA

Relief category	Mean slope (%)	Slope range included within one standard deviation (%)
Level	0·4	0·2– 0·8
Undulating	1·3	0·7– 2·5
Rolling	2·4	1·2– 5·0
Hilly*	15·0	7·0–40·0
Mountainous†	?	?

* Rough estimates; few data. † Inadequate data.

The relief was classified in the field and during air-photo interpretation into level, undulating, rolling, hilly, and mountainous categories. Table 17 indicates the dominant slopes in the lower three categories, expressed as the mean slope plus or minus one standard deviation on a logarithmic scale, i.e. including about two-thirds of all slopes. It is noteworthy that these categories are less steep than those defined by the United States Department of Agriculture (1951) which, in turn, are less steep than those used by the New Zealand Soil Bureau (Taylor and Pohlen 1962) (Table 18). Evidently concepts such as "rolling" vary with the geographical context.

TABLE 18

UPPER LIMIT OF MOST SLOPES IN THREE RELIEF CATEGORIES ACCORDING TO THREE AUTHORITIES

Relief category	Authority: U.S. Dep. Agric. (1951) (Soil survey manual)	N.Z. Soil Bureau Taylor and Pohlen (1962)	This report
Level or nearly level	2%		
Flat to gently undulating		—	
Level			1%
Undulating	7%		
Easy rolling		9%	
Undulating			3%
Rolling	13%		
Rolling		21%	
Rolling			6%

There is a considerable overlap in slope values between the undulating and rolling categories and these were the most difficult to define in the field and on the air photographs; many of the land units had to be classified as both undulating and

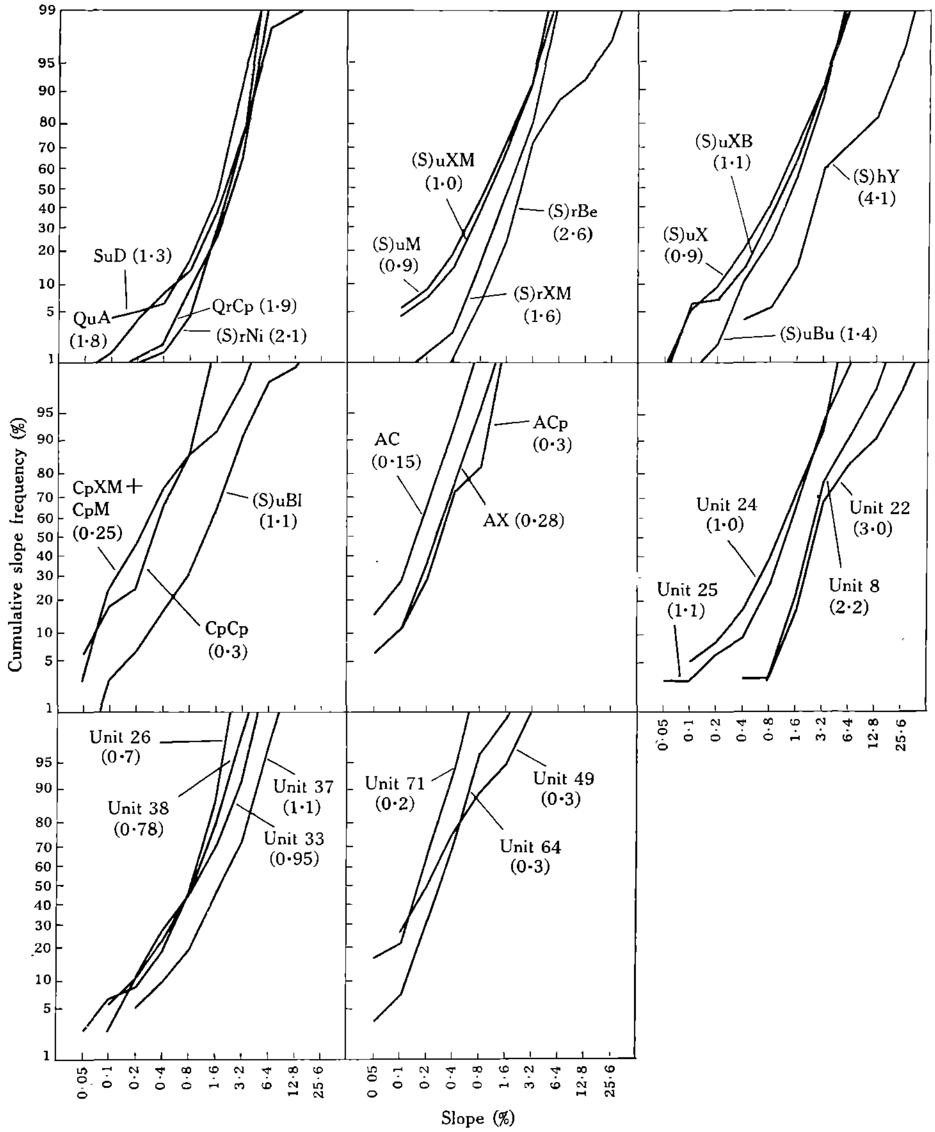

Fig. 20.—Slope frequency distributions for major land systems and land units. Percent mean slope given in parentheses.

rolling. Nevertheless, field experience indicated considerable differences between these categories in terms of degree of erosion, stoniness, and amount of outcrop so the distinction between them has been retained in the land unit descriptions (Part IV).

Distinction between hilly and mountainous terrain was also not very clear and rested on estimates of local relief (greater than or less than 200–300 m) rather than on recognized differences in slope.

On the other hand, the distinction between undulating and level terrain was clear, consistent, and significantly expressed in the landscape. Slopes steeper than about 0·8–1·0% generally comprised undulating erosional terrain with occasional surface stones or lag gravel, whereas most slopes below this value occurred on depositional plains of late Cainozoic sediments or alluvium and had no surface gravel. Slopes around 0·8–1·0% are also about the gentlest that can be definitely identified stereoscopically on the available air photographs. The distinction in types of country with slopes above and below this slope value is also reflected in drainage patterns and the associated distribution of farm dams. On slopes greater than about 0·8% the drainage is organized and dams succeed each other down the main drainage lines. On less steeply sloping country the drainage pattern is disorganized and dams are more randomly distributed.

(c) *Slopes and Land Units or Land Systems*

Sufficient information was obtained to estimate slope distributions for the 19 largest land systems, covering 84% of the area, and for the 11 most important land units, covering 49% of the area (Fig. 20). Rougher estimates were also made for the remaining 64 land units. Slopes given in the land unit descriptions (Part III) are estimates of the range lying within one standard deviation of the mean.

The information presented in Figure 20 can be used to estimate the area of a unit or land system which is steeper or less steep than any nominated slope value. For instance, 20% of unit 38 (gently undulating plains, belah open-forest, texture-contrast soils) has slopes greater than 1·6% and 10% has slopes less than 0·2%. If research or experience should indicate that a proposed land use on this type of country causes unacceptable soil erosion on slopes in excess of 1·6% and drainage problems occur on slopes less than 0·2%, it is at once apparent that 70% of this type of country is potentially usable, subject of course to other limitations such as fertility and access. In using the graphs in Figure 20 it should be borne in mind that the scale on the x-axis is logarithmic.

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PART VII. SOILS OF THE BALONNE–MARANOA AREA

By R. H. Gunn*

I. Introduction

The main objective in this Part is to describe the soils that have been identified in the area and to define the criteria used to differentiate between them. Some of the relationships between the soils and other features of the landscapes are indicated and their distribution is shown on the soil map included with this report. Alluvial soils are not shown as their occurrences are too small to map. Further information on the soils is given in the land unit descriptions in Part III where the photographic patterns reflected by the various soil landscapes are also illustrated. During the survey samples were collected from 55 profiles later allocated to 18 families and the analytical data on exchangeable cations, soluble salts, and clay minerals have been recorded in an unpublished technical memorandum which is available on request.

Although climate has exerted an overall controlling influence over the nature and distribution of soils in the area, the local distribution is controlled mainly by the lithology and weathering status of parent rocks and materials and the geomorphic history of the landscapes. Remnants of a mantle of deeply weathered rocks are widespread and indicate an almost complete cover at one time. Red massive earths occur on intact remnants of the old surface and on extensive depositional plains where reworking has occurred. Duplex and cracking clay soils, some of which are salt-affected, have formed on the exposed weathered zones or on redistributed materials derived from them. Where the weathered mantle has been removed by erosion, soil formation has been influenced directly by the lithology of the exposed "fresh" rocks. Cracking clay soils formed on soft labile sediments and basalt, uniform sands and sandy duplex soils developed on quartzose sandstones, and a range of soils occurs on mixed sedimentary rocks. In the south of the area and near major streams various soils, dominantly deep cracking clays, have formed on alluvial materials. This broad pattern of soil distribution, in which catenary or topographic sequences are generally evident in uplands, is similar to but less complex than that which occurs in the Fitzroy basin to the north.

Prior to the survey, soil information was available from various sources. The area is included in Sheets 3 and 4 of the Atlas of Australian Soils (Northcote 1966; Isbell *et al.* 1967) which map associations of principal profile forms (Northcote 1971) at 1:2,000,000 scale. In a reconnaissance survey, Holland and Moore (1962) mapped and described the soils and vegetation in 55,600 km^2 of the Bollon district of which about 7000 km^2 are in the survey area. Isbell (1957*a*) mapped and described 17 soil associations in an area covering 23,600 km^2 of which 7800 km^2 are in the south-east of this area. Most of the observations made by Isbell are directly applicable to many of the soils considered in this Part. Isbell (1957*b*) also carried out detailed soil work in the area proposed for extension of the St. George irrigation scheme where ten

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associations of great soil groups were identified. Sedentary and gilgaied clay soils under brigalow in the area were mapped and described by Isbell (1962).

II. Soil Groups and Families

Grouping of the soils is based on profile descriptions at 962 sampling sites. These sites were selected as being representative of the various landscapes in the area as reflected by distinctive patterns and their component elements on 1 : 85,000 scale aerial photographs. Generally, these more-or-less homogeneous landscapes recur wherever the genetic factors (lithology and geomorphic history) are similar. There was some bias in selecting the sampling sites in terms of potential land use. For example, very few observations were made in hilly dissected terrain on quartz sandstone but numerous observations were made in most landscapes on plains and gently undulating terrain under belah or acacia forests and eucalypt woodlands. The main objective was to group the soils (1) in a similar order of detail in relation to other features of the landscapes in which they occur and (2) by soil properties judged to be most significant to land use (mainly for agriculture, pastures, or forestry). The classification may be useful for other purposes such as engineering, provided that soil tests for engineering purposes can be correlated with the soils that have been identified and mapped. According to Thornburn (1969) considerable progress has been made in this field in the U.S.A.

The soils of the area have been arranged in 7 major groups and 40 families. The major groups are differentiated mainly on the basis of texture following the uniform, gradational, and duplex divisions of Northcote (1971) and these are further subdivided according to the lithology, weathering status, or mode of formation of parent materials. Family groups are defined mainly according to differences in effective depth of sola, thickness and texture of surface horizons, and reaction, structure, and colour of subsoils. The major groups and families are denoted by lettered symbols as shown in Table 19.

III. Soil Descriptions

(*a*) *Alluvial Soils* (A)

The soils of this group occur on recent alluvial deposits which are generally stratified and show little or no profile development apart from slight humic staining at the surface. They occur mainly on lower terraces near present stream channels and are not extensive. Three families have been identified on the basis of differences in texture.

Aa (2 obs.).—These soils are uniform clay loams to silty clays or clays and are underlain by sand at depths ranging from 75 to 100 cm. Colours are dark brown to dark grey-brown in the upper layers and brown or yellowish brown in the underlying sandy materials. They are massive throughout and reaction is slightly acid to mildly alkaline.

Ab (6 obs.).—These soils are characterized by upper layers of uniform medium to fine texture (sandy clay loam to light or medium clay) which are underlain by alternating layers of various textures (sands, loams, and clays) at depths of 35–75 cm. They are massive and reaction is neutral throughout.

TABLE 19

MAJOR SOIL GROUPS AND FAMILIES IN THE BALONNE–MARANOA AREA

Major group	Family	Summary description	Appropriate or approximate equivalent name (Stace *et al.* 1968)	Principal profile form (Northcote 1971)
Alluvial soils	Aa	Uniform medium- to fine-textured soils on sandy substrata	Alluvial soils (Aa–Ac)	Um 5·5
	Ab	Uniform medium- to fine-textured soils on layered materials		Um 1
	Ac	Uniform coarse-textured soils on clayey substrata		Uc 1
Brown and grey-brown soils	Formed on weathered zone materials			
	Ba	Moderately deep to deep, uniform or gradational, reddish brown, neutral to acid throughout	Euchrozems	Uf 6·31, Gn 3·12
	Bb	Moderately deep to deep, uniform or gradational, reddish brown, strongly alkaline subsoils		Uf 6·31, Gn 3·13
	Bc	Moderately deep to deep, uniform or gradational, dark brown to grey-brown, strongly alkaline subsoils	Prairie soils (Bc–Be)	Uf 6·31, 6·51, Gn 3·23
	Formed on various sedimentary rocks			
	Bd	Moderately deep to deep, uniform gradational, dark brown to grey-brown, strongly alkaline subsoils		Uf 6·31, 6·32, Gn 3·93
	Formed on alluvium			
	Be	Deep, uniform or gradational, dark brown to grey-brown, strongly alkaline subsoils		Uf 6·32, 6·51
	Shallow soils on various parent rocks			
	Bf	Shallow (< 60 cm) grey, brown, and red soils		Uf 6·31, 6·32, Gn 3·23
Cracking clay soils	Formed on weathered zone materials			
	Ca	Gilgaied, very deep, mainly grey, alkaline–acid, less commonly brown or reddish brown	Grey, brown, or red clays (Ca–Cb)	Ug 5·24, 5·34
	Cb	Moderately deep to deep, grey, brown or reddish brown, alkaline at or near the surface and acid beneath		Ug 5·24, 5·34, 5·16
	Formed on "fresh" argillaceous sedimentary rocks			
	Cc	Moderately deep to deep, grey or brown, strongly alkaline subsoils with carbonate and/or gypsum	Grey or brown clays	Ug 5·32, 5·22, 5·12

	Formed on basalt			
	Cd	Moderately deep, dark grey, strongly self-mulching, alkaline subsoils	Black earths	Ug 5·12
	Formed on alluvium			
	Ce	Deep, grey and brown, strongly alkaline subsoils	Grey or brown clays	Ug 5·24, 5·16
	Shallow soils on various rocks			
	Cf	Shallow (< 60 cm) grey and brown	Grey or brown clays	Ug 5·12
Duplex or texture-contrast soils	Weakly solonized soils formed mainly on weathered argillaceous sediments			
	Da	Thin sandy or loamy surface horizons over strongly alkaline red or brown blocky subsoils	Red-brown earths/solodic soils	Dr 2·23, 2·13, Db 1·23, 1·33
	Db	Thin sandy or loamy surface horizons over strongly alkaline yellow or dark blocky subsoils	Solodic soils	Dy 2·23, 2·33, Dd 1·13, 1·23
	Dc	Thin sandy or loamy surface horizons over neutral to acid, mainly red or brown, blocky subsoils	Red or brown podzolic soils	Dr 2·21, 2·22, Db 1·21, 1·22
	Halomorphic soils with columnar structure formed mainly on weathered sediments			
	Dd	Thin sandy or loamy surface horizons over strongly alkaline mainly brown subsoils	Solodized solonetz or solodic soils	Db 1·23, 1·43, 2·43
	De	Mainly thin sandy or loamy surface horizons over neutral to acid mainly yellow subsoils	Soloths	Db 1·21, Dy 3·41
	Soils formed on quartzose materials			
	Df	Thick sandy surface horizons over strongly alkaline red or yellow blocky subsoils	Solodic soils	Dr 3·23, 2·23, Dy 3·43, 3·23
	Dg	Thick sandy surface horizons over neutral to acid mainly mottled blocky to massive subsoils	Yellow podzolic soils	Dy 3·42, 3·82, Dr 3·26
	Soils formed on alluvial materials			
	Dh	Mainly thin sandy or loamy surface horizons over strongly alkaline red or brown subsoils	Solodic soils	Dr 2·23, 2·43, Db 1·23
	Di	Mainly thin sandy or loamy surface horizons over strongly alkaline yellow or dark subsoils	Solodic soils	Dy 3·23, Dd 1·13, 1·43
	Dj	Thick sandy surface horizons over neutral to acid mainly yellow subsoils	Yellow podzolic soils	Dy 3·42, 5·82
Massive earths	Ea	Loamy red earths, gravelly, mainly on reworked materials, neutral to acid	Red earths	Gn 2·12, 2·11
	Eb	Loamy red earths on Cainozoic deposits, neutral to acid	Red earths	Gn 2·12, 2·11

TABLE 19 (*Continued*)

Major group	Family	Summary description	Appropriate or approximate equivalent name (Stace *et al.* 1968)	Principal profile form (Northcote 1971)
Massive earths (*continued*)	Ec	Loamy red earths, strongly alkaline subsoils	Calcareous red earths	Gn 1·23
	Ed	Sandy red earths, neutral to acid throughout	Red earths	Gn 2·12, 2·11
	Ee	Loamy yellow or brown earths, neutral to acid throughout	Yellow earths	Gn 2·81, 2·42
	Ef	Alluvial red earths, neutral reaction	Red earths (Ef–Eh)	Gn 2·12, 2·15
	Eg	Shallow red earths (< 60 cm), generally gravelly and acid throughout		Gn 2·11, 2·41
	Eh	Humic red earths on elevated basalt tablelands		Gn 2·11
Uniform sandy soils	Deep soils on transported materials			
	Fa	Red sands, acid to neutral	Siliceous sands (Fa–Fb)	Uc 1·23
	Fb	Yellow and brown sands, acid to neutral		Uc 1·21, 1·22
	Formed on materials derived from quartzose sediments			
	Fc	Shallow sands (< 90 cm)		Uc 1·21
	Fd	Moderately deep to deep red sands	Siliceous sands (Fd–Fe)	Uc 5·11, 1·23
	Fe	Moderately deep to deep yellow or brown sands		Uc 5·11, 4·2
Skeletal soils	Ga	Very shallow uniform coarse textures, generally gravelly or stony	Lithosols (Ga–Gb)	Uc 1·21, 1·23
	Gb	Very shallow uniform medium- to fine-textured, generally gravelly or stony		Um 1·43

Ac (2 obs.).—Surface layers of sand to sandy loam, 35–50 cm thick, underlain by layered clays, sandy clays, or silty clays are the main properties of these soils. Reaction is neutral at the surface and strongly alkaline in the underlying strata where small quantities of carbonate or gypsum may be present.

(*b*) *Brown and Grey-brown Soils* (B)

The soils of this group have uniform fine textures (light to heavy clays) or gradational textures (clay loams grading to medium or heavy clays). Varying grades of blocky structure are present either throughout the profiles or in the subsoils. On the basis of 123 profile examinations, six families have been identified according to differences in parent materials, depth, colour, and reaction. Some of these soils may be equated with euchrozems and prairie soils (Stace *et al.* 1968) but generally their affinities lie more with the grey, brown, and red clays into which they commonly intergrade.

(i) *Soils formed on Weathered Zone Materials*

Ba (16 obs.).—The soils of this family are moderately deep to deep (65– > 105 cm) and occur mainly on middle to lower slopes in undulating to rolling terrain under woodlands or open-forests of poplar box and/or brigalow and belah. They have either uniform clay textures or gradational texture profiles in which the clay content gradually increases from clay loam to medium or heavy clay. Varying quantities (3–20 %) of fine gravel in the profiles and a gravel or stone surface strew are commonly present. Colours range from dark brown or reddish brown at the surface to reddish brown or dark red in subsoils. Analytical data for one profile indicate that the soil is salt-affected (exchangeable sodium percentage (E.S.P.) 25, chloride 750–985 p.p.m.). Soil reaction ranges from neutral to medium acid. They are moderately to severely eroded on some steeper slopes.

Bb (19 obs.).—These soils are similar to those of Ba family but soil reaction is generally neutral in surface horizons and becomes strongly alkaline in subsoils. Analytical data for one profile indicate that the soil is salt-affected (E.S.P. 20–40, chloride 1440–2000 p.p.m.). Less commonly, reaction is strongly alkaline throughout. Small to moderate (3–15 %) accumulations of soft carbonate and/or gypsum occur in subsoils and gravel is commonly present on the surface and in upper horizons. Shrub woodlands or open-forests of box, or less commonly yapunyah, and/or brigalow and belah predominate.

Bc (33 obs.).—The main characteristics of these soils are their dark brown to dark grey-brown colours and strongly alkaline reaction in subsoils where small to moderate (3–15 %) accumulations of soft carbonate and/or gypsum are almost invariably present. Depths range from 80 to > 120 cm and blocky structure is present throughout profiles or in subsoils. Analytical data for one profile indicate that the soil is salt-affected (E.S.P. 20, chloride 887–1064 p.p.m.). Gravel and stone commonly occur on the surface and in upper horizons. These soils have formed in materials derived from weathered argillaceous sediments and they occur on all parts of slopes in gently undulating terrain but mainly on middle and lower segments. Shrub woodlands of box with varying proportions of brigalow or belah, or open-forests of brigalow and/or belah are characteristic.

(ii) *Soils formed on Labile Sediments*

Bd (9 obs.).—These soils have similar properties to Bc family but they have formed on materials derived from fresh or only slightly weathered rocks and they commonly intergrade with the cracking clay soils of Cc family. They occur mainly on middle and lower slopes under shrub woodlands of box. Colours range from dark brown to very dark grey and small to moderate (3–20%) accumulations of soft carbonate are present below about 35 cm.

(iii) *Soils formed on Alluvium*

Be (27 obs.).—These soils have formed in alluvial materials on lower terraces and flood-plains and in some locations are subject to flooding by overflow. Uniform silty clay or light to heavy clay textures, dark to very dark brown or grey colours, and depths exceeding 90 cm are the main characteristics. Soil reaction is generally neutral at the surface and becomes strongly alkaline below about 50 cm where small accumulations of soft carbonate are present. Occasionally they are strongly alkaline throughout. The vegetation is mainly box woodland with varying proportions of coolibah or belah.

(iv) *Shallow Soils on Various Rocks*

Bf (19 obs.).—Shallow soils less than 60 cm in depth with uniform fine or gradational textures have been placed in this family. They have formed in materials derived from various argillaceous rocks, both weathered and fresh, mainly on crests and upper slopes in hilly to undulating terrain. Colours are mainly dark brown to brown, less commonly dark red or reddish brown. Reaction is neutral to mildly alkaline at the surface and becomes strongly alkaline beneath. Vegetation is highly variable; woodlands of silver-leaved ironbark, poplar box, and mountain coolibah predominate.

(*c*) *Cracking Clay Soils* (C)

The soils of this group are characterized by uniform medium to heavy clay textures, marked shrinking and swelling properties, and imperfect to impeded drainage. Six families have been identified according to differences in the nature and mode of formation of parent materials, microrelief, and effective depth. They correspond to the grey, brown, and red clays of Stace *et al.* (1968) and have been described by various authors in Queensland (Hubble 1961; Isbell 1962; Beckmann and Thompson 1960; and others).

(i) *Soils formed on Weathered Zone Materials*

Ca (42 obs.).—These soils have strongly developed gilgai microrelief (60–180 cm) and have formed on deeply weathered materials in erosional and depositional situations. They are more than 150 cm deep and commonly much deeper (>5 m). Colours are mainly dark grey or brown, less commonly yellowish red or reddish brown, and prominent red or yellow mottling is usual below about 90 cm. A surface strew of stones and gravel occurs in some locations. Soil reaction is generally about neutral at the surface, becomes strongly alkaline between 60 and 90 cm, and then grades to medium or very strongly acid in the lower profiles. Less commonly reaction is strongly acid throughout. Small to moderate (3–15%) accumulations of carbonate generally occur in the upper 90 cm and gypsum is present in some profiles at slightly greater depths. Analytical data in respect of six profiles indicate high E.S.P. (15–50) and high to very high contents of chloride (500–3400 p.p.m.) at depths generally below 30 cm. Clay mineral analysis indicates that kaolin is dominant and montmorillonite subdominant. Brigalow and/or belah open-forests are characteristic, but gidgee occurs in the drier south-west of the area.

Cb (28 obs.).—These soils are similar to those of Ca family but depths range from 80 to >150 cm and gilgais are absent or only slightly developed.

(ii) *Soils formed on "Fresh" Labile Sediments*

Cc (22 obs.).—These soils occur mainly on undulating Mitchell grass "downs" underlain by "fresh" argillaceous sediments which have had little or no alteration by deep weathering. Linear gilgai with stones or gravel on the mounds occur on some steeper slopes (5–10%). The average effective depth is 105 cm (range 65–>150 cm), the deeper soils occurring generally on lower slopes. Deep wide cracks and a granular self-mulching layer at the surface form on drying. Colours range from brown to very dark grey in the upper horizons and grade to brown or yellowish brown beneath. Soil reaction is neutral to mildly alkaline at the surface and strongly alkaline below about 30 cm; occasionally the soils are strongly alkaline throughout. Small accumulations of carbonate and/or gypsum are almost invariably present in the lower profiles.

Analytical data on three profiles indicated medium to high cation exchange capacity (C.E.C.) (23–36 m-equiv./100 g), 100% base saturation, predominantly with calcium and magnesium, low E.S.P. (<10), low to medium chloride (65–473 p.p.m.), and very low to medium phosphorus (8–30 p.p.m.). X-ray diffraction analysis on samples from two profiles indicated (1) kaolin dominant, montmorillonite subdominant, and illite and randomly interstratified material accessory, (2) randomly interstratified material dominant, kaolin and illite subdominant, and montmorillonite accessory.

(iii) *Soils formed on Basalt*

Cd (2 obs.).—Dark, strongly self-mulching, moderately deep to deep cracking clay soils have formed on fresh basalt in small scattered areas. Up to 30% of the surface is covered with stones (10–15 cm diam.) in places. Similar soils are extensive in the Fitzroy basin to the north.

(iv) *Soils formed on Alluvium*

Ce (61 obs.).—The soils of this family occur extensively on alluvial plains under coolibah open-woodland or grassland mainly in the south of the area. They are very deep (>150 cm) grey and brown medium to heavy clays which are poorly drained. They are subject to overflow flooding of varying frequency, depth, and duration over wide areas. Soil reaction is generally neutral to mildly alkaline at the surface and becomes strongly alkaline below about 30 cm where accumulations of carbonate and/or gypsum (from trace amounts to 15%) are almost invariably present. Less commonly soil reaction is strongly alkaline throughout.

Analytical data in respect of six profiles indicate medium to high C.E.C. (20–45 m-equiv./100 g), 100% base saturation, calcium and magnesium dominant and subdominant respectively, E.S.P. 10–20, and variable chloride contents (120–1360 p.p.m.) below 30 cm, and fair to very high phosphorus status (20–200 p.p.m.).

(v) *Shallow Soils on Various Parent Rocks*

Cf (8 obs.).—All shallow cracking clays less than 60 cm in depth have been grouped in this family. They have formed mainly on labile sediments and basalt and occur on crests or upper slopes. Grassy open-woodlands of silver-leaved ironbark or mountain coolibah are characteristic.

(*d*) *Duplex Soils* (D)

The main characteristic of this group of soils is the clear to abrupt boundary between sandy or loamy surface horizons and clayey subsoils. These soils are widely distributed throughout the area on various materials, generally in level to gently undulating terrain. Subdivision into four subgroups and ten families is based on the examination of 298 profiles. The subgroups are defined according to differences in the nature and mode of formation of parent materials and at family level, differentiae are the thickness and texture of surface horizons and the reaction, structure, and colour of subsoils.

(i) *Weakly Solonized Soils formed mainly on Weathered Argillaceous Sediments*

Da (82 obs.).—The main features of these soils are thin loamy surface horizons over dark reddish brown to dark brown strongly alkaline medium to heavy clay subsoils. Profiles are generally more than 90 cm deep but some shallower soils are underlain by hard weathered zone materials. Surface horizons are predominantly dark reddish brown to dark brown massive clay loams or sandy clay loams, 5–38 cm thick (average 18 cm). Colour A_2 horizons are generally present, less commonly these are sporadically or conspicuously bleached or are absent. Reaction in the surface horizons is medium acid to neutral. The clay subsoils have medium to coarse blocky structure, hard to very hard consistence, and small to moderate (3–15%) accumulations of soft or concretionary carbonate. Gypsum commonly occurs in the deeper horizons. Reaction grades from strongly alkaline to moderately acid in the deeper layers of some profiles.

Chemical analyses on three profiles indicate 100% base saturation predominantly with calcium and magnesium, but sodium comprises 30–40% of the exchange capacity at depths below 36 cm. Subsoils are slightly affected by soluble salts (0·10–0·15% NaCl). In surface horizons available phosphorus is low (15–20 p.p.m.) and organic carbon ranges from 1·2 to 2·3%. Clay mineral analyses of three subsoil samples indicate that kaolin is dominant and illite, montmorillonite, and randomly interstratified material are accessory. Traces of calcite, haematite, and feldspar were also reported.

These soils occur most extensively in (S)uBl and CpBl land systems on plains or gently undulating terrain in the east of the area under belah, brigalow, and/or box forests or woodlands. Large areas have been cleared for grain cultivation or improved pastures. They commonly occur in catenary sequences or in mosaics with gilgaied clays (Ca family) and in places they intergrade with the solodized solonetz and related soils of Dd and De families.

Db (32 obs.).—These soils are very similar to those of Da family apart from subsoil colours which range from dark grey or grey-brown to dark brown or very dark grey-brown (i.e. Dy and Dd subdivisions of Northcote 1971). The average thickness of the predominantly loamy surface horizons is 23 cm (range 6·5–51 cm). Most of these soils occur on lower slopes in gently undulating terrain under poplar box woodland with a shrub understorey.

Dc (39 obs.).—Thin acid sandy clay loam to clay loam surface horizons underlain by medium to heavy clay, very strongly acid to mildly alkaline subsoils are characteristic features of this family. They are generally more than 91 cm deep but a shallow phase (9 obs.) occurs in which sola are less than 60 cm deep and are underlain by hard weathered zone materials. Subsoils have blocky structure and generally hard to very hard consistence and colours are mainly red or brown, less commonly yellow or dark. Shrub woodlands of poplar box or silver-leaved ironbark are most common but open-forests or woodlands of gum-topped box, spotted gum (in the north-east), and narrow-leaved ironbark also occur.

Analytical data for one profile indicate properties similar to those of Da family (i.e. 100% base saturation, mainly calcium and magnesium; E.S.P. 35; 0·13% NaCl in B_2 horizon; low phosphorus and organic carbon contents (12 p.p.m. and 0·9% respectively)). Clay minerals in the B_2 horizon of this profile were found to be dominantly kaolin with montmorillonite and randomly interstratified material subdominant and accessory respectively.

(ii) *Halomorphic Soils with Columnar Structure*

Dd (25 obs.).—The soils of this family have thin (<38 cm) sandy or loamy surface horizons, generally with a pale-coloured or bleached A_2 horizon over clayey strongly alkaline subsoils with columnar structure (Plate 4, Fig. 1). Consistence in the columnar B_2 horizons is very hard to extremely hard when dry. These soils have formed mainly in materials derived from weathered sediments in the north-east and less commonly in alluvial materials. Subsoil colours are mainly brown (16 obs.) but yellow (6 obs.) and red (3 obs.) also occur and mottling is uncommon. Most of these soils occur in (S)uBu land system on lower slopes under woodland of box or narrow-leaved ironbark with an understorey of bull oak. Cypress pine and brigalow and/or belah open-forests are less common.

Chemical analyses on samples from two profiles indicate 100% base saturation with calcium and magnesium co-dominant and E.S.P. 30. The soils are not affected by soluble salts but up to 0·10% NaCl occurred in the subsoil of one profile.

De (14 obs.).—These soils are similar to those of Dd family but they have strongly acid to mildly alkaline reaction in subsoils. Almost invariably a conspicuously bleached A_2 horizon is present above the columnar B_2 horizons. They occur mainly on upper or middle slopes in very gently undulating terrain. Shrub woodlands of poplar box, cypress pine, and narrow-leaved ironbark are characteristic, generally with a high proportion of bull oak in the understorey.

Analytical data on one profile indicate low exchange capacity (5·0–8·4 m-equiv./100 g) and magnesium and sodium are the dominant and subdominant cations respectively (E.S.P. 40) in the lower subsoil (60–90 cm).

(iii) *Soils formed on Quartzose Materials*

Df (16 obs.).—The distinctive features of these soils are thick (38–76 cm) massive sand to sandy loam surface horizons over strongly alkaline red or yellow clayey subsoils. They are generally more than 90 cm deep, occasionally less, and have formed mainly on middle to upper slopes in gently undulating terrain on quartzose sandstone in the north. Surface horizons are dark grey-brown to dark reddish brown and A_2 horizons are generally present and occasionally bleached. There is an abrupt boundary to the clayey subsoils which range in texture from sandy clay loam to medium-heavy clay. Colours range from grey-brown to dark red and prominent mottling is common (8 profiles). Structure is blocky and consistence is commonly hard to very hard. Woodlands of poplar box or silver-leaved ironbark and cypress pine, with or without shrubs, predominate.

Dg (35 obs.).—These soils have similar properties to those of Df family but subsoil reaction is medium acid to neutral and they occur mainly on middle to lower slopes. Surface horizons have sand to loamy sand textures, occasionally sandy loam, and the average thickness is 63 cm (range 38–107 cm). Colours range from brown to dark grey-brown at the surface and A_2 horizons are pale brown to white (50% with a conspicuous bleach). Surface soil reaction is slightly to medium acid. Subsoils are mainly yellowish brown to grey-brown and less commonly yellowish red, and nearly all are mottled prominently. Subsoils have massive to weak subangular blocky structure. The vegetation reflects the sandy nature of the surface soils. Cypress pine open-forest with scattered ironbarks, bull oak, and tumbledown gum are about as common as poplar box woodland with varying proportions of all the previously mentioned species in the understorey. Cypress pine occurred at 30 of the sites.

(iv) *Soils formed on Alluvial Materials*.—The soils of the three families in this subgroup are similar to Da, Db, and Dg soils. They differ in respect of (*a*) depth, all being deep to very deep, (*b*) parent materials, which are derived from various sources, and (*c*) their location, generally near major streams, where they are subject to flooding or waterlogging in places. In the semi-arid extreme south-west of the area the soils of Dh and Di families on broad levees and plains have been very severely eroded in places by water and wind action (land unit 66).

Dh (22 obs.).—These soils have thin (5–25 cm) loamy or sandy surface horizons overlying red or brown medium clay subsoils with moderately to strongly alkaline reaction. Surface soil colours are mainly dark brown to dark reddish brown and there is generally a well-defined brown, reddish brown, or yellowish brown A_2 horizon. Surface soil reaction is slightly acid to neutral. Subsoils are dark brown to reddish brown and a few are mottled. They have blocky structure and generally hard consistence. Small to moderate (3–20%) amounts of soft carbonate accumulations are common in the upper subsoils and gypsum sometimes occurs at greater depths. These soils have formed mainly on well-drained levees and terraces and poplar box woodland with or without a shrub layer occurred at 17 of the sites. A low open-woodland of whitewood and leopardwood with sparse short grasses occurred at the remaining sites. Analytical data in respect of one profile indicate a C.E.C. of 6·6 and 10·5 m-equiv./100 g in the silty loam A_1 and silty clay B_2 horizons respectively. The soil is 100% base saturated with calcium (dominant) and magnesium (subdominant). The E.S.P. is 10 in the B_2 horizon and soluble salts are negligible. Available phosphorus in the surface soil is 57 p.p.m. and organic carbon is 0·5%.

Di (22 obs.).—These soils have yellow or dark subsoil colours but in other respects they have similar morphology to those of Dh family. Analytical data on samples from two profiles indicate that the soils are slightly affected by soluble salts (0·23–0·29% NaCl) in the subsoils. They are 100% base saturated predominantly with calcium and magnesium and the E.S.P. ranges from 30 to 38 at the depths of 30–60 cm. At one site in a back plain, available phosphorus was 60 p.p.m. and organic carbon was 1·5% and at the other site on a levee, available phosphorus was 12–18 p.p.m. and organic carbon was 0·6% in the upper 30 cm.

Dj (11 obs.).—Massive sandy surface horizons 30–80 cm thick, underlain by mainly yellow, less commonly brown or red, mottled sandy to medium clay subsoils with neutral to slightly acid reaction are the main characteristics of these soils. Subsoils have mainly blocky structure, occasionally massive, and generally hard consistence. Poplar box shrub woodland predominates in which cypress pine and tumbledown gum are common associates.

(*e*) *Massive Earths* (E)

The soils of this group have gradational texture profiles in which the clay content gradually increases with depth, and massive structure with earthy or porous fabric. These soils have formed mainly in strongly weathered labile sediments and less commonly in alluvium. They occur either in erosional landscapes underlain by the weathered zones of lateritic profiles or on depositional plains where reworked materials were laid down over stripped weathered zones or very deep alkaline/acid clays. Occurrences in the latter situations are extensive in the south-west of the area. The group comprises eight families differentiated according to variations in texture, gravel content, reaction, colour, depth, and mode of formation. The term "sandy" used in respect of these soils denotes sandy loam or coarser textures to a depth of 60 cm or more and "loamy" denotes sandy clay loam or finer textures at depths of less than 60 cm in the profiles. These criteria are somewhat arbitrary, but differences in natural vegetation between sandy and loamy massive earths support the validity of this division. Descriptions are based on the examination of 254 profiles.

Ea (106 obs.).—The soils of this family have dark reddish brown to dark brown sandy clay loam to clay loam surface horizons which grade to red, reddish brown, or yellowish red light to medium clays in the subsoils. In some situations they form a more-or-less intact cover to lateritic profiles; in other locations small weathered zone residuals at higher elevations indicate that these soils have formed in locally reworked materials. Profiles are generally more than 90 cm deep but some range between 60 and 90 cm in depth and are underlain by weathered zone materials. The soils contain varying amounts (range 5–50%, average 10–20%) of fine gravel, 6–25 mm in diameter, consisting of fragments of ferruginized sedimentary rocks. The gravel content generally increases with depth and in a few profiles a hard ferruginized pan occurs. Where the soils are sheet eroded, a thin lag of glazed fine gravel occurs at the surface. Soil reaction is mainly slightly to medium acid throughout but occasionally is mildly alkaline in the subsoils. The soils have massive structure and earthy porous fabric. In the drier western parts of the area, a forest or woodland of mulga with scattered poplar box, silver-leaved ironbark, and/or forest gum occurs. In other parts, woodlands of poplar box or silver-leaved ironbark occur, generally with a moderately dense shrub understorey of sandalwood, wilga, red ash, quinine, and other species.

Analytical data on two profiles indicate considerable variation in chemical properties. In one profile which was acid throughout, the C.E.C. was less than 5 m-equiv./100 g and calcium and magnesium were co-dominant in the exchange complex. Available phosphorus was 5 p.p.m. and organic carbon 0·5%. Clay mineral analysis indicated that kaolin was dominant and illite and randomly interstratified material were accessory. In the other profile which was mildly alkaline in the subsoil, the C.E.C. increased from 5·4 at the surface to 15·1 m-equiv./100 g in the subsoil where magnesium was dominant and sodium subdominant.

Eb (42 obs.).—These soils are similar to those of Ea family but they have formed on almost level depositional plains and are gravel-free. Profiles are more than 100 cm deep and borings to 150 cm at a few sites indicate that they are probably very deep. Surface horizons are dark reddish brown sandy loams to sandy clay loams and these grade to dark red or yellowish red clay loams or light clays in the subsoils. Soil reaction is generally medium to slightly acid at the surface and grades to neutral or occasionally mildly alkaline at depth. Woodlands of poplar box and mulga with a moderately dense shrub layer of wilga and sandalwood predominate. Less common are woodlands of silver-leaved ironbark generally with associated cypress pine and mulga.

Ec (32 obs.).—The soils of this family are loamy red earths with strongly alkaline reaction in the subsoils where small to moderate (3–20%) accumulations of soft or concretionary carbonate are common. The soils are generally more than 90 cm deep but included are shallower soils (40–70 cm) which are underlain by a thin layer of gritty material, usually with mottling and iron-manganese staining, over calcareous clay D horizons. These soils are most extensive on depositional plains underlain by calcareous clays but they have also formed in reworked red earths overlying weathered zones and in alluvium. They commonly occur in mosaics with gilgaied cracking clays (Ca family) where they are occasionally calcareous throughout. In other respects they are similar to the soils of Ea and Eb families, with and without fine gravel respectively. Shrub woodlands of poplar box are characteristic but low open-forests of brigalow or gidgee also occur in the extreme south-west of the area.

Analytical data on two profiles indicate low C.E.C. in surface horizons (4·6–7·1 m-equiv./100 g) and an increase with depth (6·3–14·1 m-equiv./100 g), and calcium is the dominant metal ion throughout. The soils are low in soluble salts (EC_e 1·98 mmhos/cm at a depth of 60–106 cm in one profile). Clay mineral analysis in the subsoil of one profile indicates that kaolin is dominant and illite and randomly interstratified material are accessory. The $CaCO_3$ content in this sample was 0·83%.

These results indicate that the strongly alkaline reaction in the subsoils is due to the high calcium status.

Ed (13 obs.).—The main characteristics of these soils are sand to sandy loam textures in the upper 60 cm and a gradual increase in clay content to sandy clay loam or light clay. Surface horizons are dark brown to dark red which grade to red or yellowish red in the subsoils. Most profiles were examined to depths of 90 cm and a few to 150 cm. At three sites the soils were underlain by weathered zone materials between 90 and 120 cm. Soil reaction is medium to slightly acid. The soils occur in both erosional and depositional situations and the characteristic vegetation comprises woodlands of silver-leaved ironbark, cypress pine, and mulga in varying proportions.

Ee (20 obs.).—These soils have yellowish brown or brown commonly mottled subsoils. They have formed mainly in materials derived from weathered sedimentary rocks on lower or middle slopes in gently undulating terrain. They are generally more than 90 cm deep but at five sites the depth ranged between 70 and 90 cm. Soil reaction is slightly acid to neutral throughout. Woodlands of silver-leaved ironbark or poplar box with varying proportions of mulga and/or cypress pine are characteristic.

Ef (9 obs.).—The soils of this family have formed in alluvial materials mainly on levees and terraces. Sandy and loamy soils are included and subsoil colours range from yellowish red to brown. They are generally gravel-free but moderate contents (5–20%) of fine gravel occurred at two sites. Woodlands of poplar box predominate.

Eg (31 obs.).—These soils are underlain by weathered zone materials at depths ranging between 30 and 60 cm. They occur mainly on crests and upper slopes in gently undulating to rolling terrain and generally contain varying proportions (10–60%) of gravel and stone. Surface horizons are dark brown to dark reddish brown sandy clay loams which grade to brown, reddish brown, or red light to medium clay in subsoils. Soil reaction is generally medium acid throughout but some profiles are neutral. Forests or woodlands of mulga and bendee usually with scattered silver-leaved ironbark and/or poplar box are the main vegetation types but narrow-leaved ironbark, gum-topped box, and yapunyah woodlands also occur.

Eh (1 obs.).—Moderately deep (110 cm) loamy red earths with well-defined humic surface horizons up to 30 cm thick and containing up to 10% organic matter have formed on elevated basalt tablelands in the north of the area under tall open-forest. They are underlain by ferruginized basalt. Weak subangular blocky structure is present in the surface horizons but clayey subsoils are massive. Reaction is slightly to medium acid throughout.

(*f*) *Uniform Sandy Soils* (F)

The soils of this group have uniform sand to loamy sand textures, single-grain structure, and neutral to medium acid reaction throughout. Two subgroups are identified according to differences in the nature and mode of formation of parent materials. The first, comprising two families, is formed of soils on transported materials on levees near major streams, some of which have been modified by wind action, and on levee remnants on old depositional plains. In the second group, consisting of three families, the soils have formed *in situ* or in materials which have accumulated by colluvial shift and are underlain by quartz sandstones. Criteria used to differentiate between families are depth and colour.

(i) *Soils on Transported Materials*

Fa (31 obs.).—These soils are generally more than 150 cm deep but are underlain by clayey D horizons at depths exceeding 105 cm in places. Colours in surface horizons are dark brown or red and grade to reddish brown, yellowish red, or red below about 60 cm. Single-grain structure and loose to soft consistence are usual but some soils become massive and firm in the deeper horizons. Soil reaction is neutral to medium acid throughout. Silver-leaved ironbark woodland and/or cypress pine open-forest with varying proportions of Moreton Bay ash, tumbledown gum, or rusty gum are characteristic.

Fb (10 obs.).—These soils are similar to those of Fa family but colours are brown to yellowish brown in the lower horizons.

(ii) *Soils formed on Quartz Sandstone*

Fc (13 obs.).—Depths to bed-rock range between 35 and 80 cm and colours are mainly dark brown to brown, less commonly reddish or yellowish brown. These soils generally occur on crests and upper slopes in undulating to rolling terrain under cypress pine open-forest or woodlands of silver- or narrow-leaved ironbark, tumbledown gum, or grey gum.

Fd (13 obs.).—These soils are similar to those of Fa family but they occur in gently undulating terrain underlain by quartz sandstones. Depth to bed-rock ranges from 115 to >150 cm. The characteristic vegetation is cypress pine open-forest or woodlands of rusty gum or rough-barked apple.

Fe (16 obs.).—These soils are similar to those of Fd family but colours in lower horizons are brown to yellowish brown.

(*g*) *Skeletal Soils* (G)

The soils of this group show little or no profile development apart from humic staining in the surface horizons. They are generally less than 35 cm in depth and have moderate to high contents (10–50%) of gravel and stones. They occur mainly on crests and upper slopes in undulating to hilly terrain under woodlands of narrow-leaved ironbark, yapunyah, and Queensland peppermint or forests of bendee and lancewood. Two families are differentiated on the basis of texture, one having coarse and the other medium to fine textures.

Ga (4 obs.).—These are very shallow sandy soils underlain by weathered zone materials or sandstone at depths mainly less than 30 cm.

Gb (27 obs.).—These are mainly shallow uniform loams or clays generally less than 35 cm deep.

IV. Relationships between Soils and Other Landscape Features

The distribution of the 76 land units in the 33 land systems that have been identified in the area is shown in the land system map reference. Some land systems, e.g. ShSw and BtS, are either small or very uniform and can be described in terms of only one or a few component land units. Others such as AX and (S)uBl land systems have complex assemblages of land units, some of which recur widely in other land systems, generally in different proportions. Some land units differ only in respect of vegetation in accordance with climatic changes, particularly the decrease in rainfall from north-east to south-west. These recurring landscapes, which have been subjected to the same geomorphic processes, therefore resulted in the development of similar land forms and soil parent materials and hence similar assemblages of soils.

The 11 land systems on weathered rocks (groups of materials 4–6, see Fig. 16), consisting dominantly of 25 land units (20 to 44), cover about 45% of the area. Recognition of the main features and some of the factors leading to the development of these landscapes on variously denuded deep weathering profiles is therefore important in understanding the distribution of soils and vegetation over extensive areas. As explained in Part VI, a deep weathering profile with a surface cover of massive earths and underlying weathered zones extended over most of the area. Subsequent dissection and bevelling left variously denuded remnants of the old surface on high ground and exposed the weathered zones on which a range of duplex and cracking clay soils developed. These soils with associated land-form elements and vegetation generally occur in catenary sequences similar to that described in the Fitzroy region (Gunn 1967). Soil landscapes on extensive depositional plains were formed largely from materials stripped from the cover of weathered rocks and were laid down by the two main streams in the area. They have similar assemblages of soils but have been modified by sorting and the addition of materials derived from fresh rocks.

Where the cover of weathered rocks was completely removed, a range of fresh rocks was exposed and the nature and distribution of soils are directly related to the underlying lithology. Extensive alluvial plains were formed in the major valleys from various source materials.

The assemblages of soils in these landscapes are described briefly in the following sections and illustrated diagrammatically in Part III.

The soil map shows the distribution of 26 associations or mapping units, the boundaries of which are those of the land systems. In 13 of the associations 1 soil family is dominant, i.e. it occupies 40% or more of the area in a mapping unit. In 9 of the associations 2 or more families in the same major group occur in about the same proportions. The remaining 4 associations have complex assemblages of several soil families in 2 or more major groups. The soils shown in the map reference generally cover 80% or more of the mapping units and minor occurrences of other soils are not included. Estimations of the extent of all soils in the land systems are given in Tables 20–22. Land clearing has obscured the photo patterns in extensive areas and it was not possible to map all the areas of gilgaied soils (Ca family). Most of the main occurrences, however, are indicated by the symbol "g" within associations Nos. 19 and 25.

(*a*) *Soil Landscapes on Quartz Sandstones* (Land units 1–8)

Resistant quartz sandstones in the north of the area form extensive tracts of hilly terrain with some colluvial spreads bordering the larger valleys. Indications of deep weathering are evident in the form of bleaching or occasional pallid clay strata and ferruginization along joints and fissures but, because they consist largely of quartz, these rocks have been little altered and derived soils are mainly acid and sandy. Quartzose to sublabile sandstones also give rise to dominantly sandy soils but there

TABLE 20

ESTIMATED AREAS OF SOILS (KM^2) IN THE LAND SYSTEMS OF THE QUARTZ SANDSTONE, LABILE SEDIMENTS, AND BASALT LITHOLOGICAL GROUPS

Major group and family	Quartz sandstone			Labile sediments					Basalt	
	QhMe	QuA	QrCp	ShSw	SrX	SuMc	SuD	BtS	BhMc	BuI
Alluvial soils										
Aa										
Ab										2
Ac										
Brown and grey-brown soils										
Ba										
Bb										
Bc						7	21			
Bd					90	134	125		31	10
Be		37	88						13	8
Bf				120	156	126	105	15	20	
Cracking clay soils										
Ca										
Cb						44	167			
Cc						370	1567			
Cd									31	85
Ce							63			
Cf					45	15	42		63	85
Duplex soils										
Da			528			15				
Db			88							
Dc	58		264			15				
Dd		18	176							
De		18	88							
Df		55	528							
Dg		148	3256							
Dh		37	88		6	7				
Di		37	88		3	7				
Dj	58									
Massive earths										
Ea		55	440							
Eb										
Ec										
Ed		18								
Ee	117	18								
Ef										
Eg		18								
Eh								45		
Uniform sandy soils										
Fa			88							
Fb			88							
Fc	642	185	880							
Fd	146	460	880							
Fe	205	736	1232							
Skeletal soils										
Ga	1694									
Gb									472	
Total	2920	1840	8800	120	300	740	2090	60	630	190

are enough clay-forming minerals in these rocks for sandy duplex soils to develop on middle and lower slopes. The eight land units in this category occur mainly in land systems QhMe, QuA, and QrCp but land units 5, 7, and 8 also occur in other land systems (Fig. 6).

Land units 1–4 occur in hilly terrain in QhMe land system only. Shallow skeletal sandy soils (Ga family) with extensive rock outcrops in land units 1 and 3 cover 60% of this land system. Minor areas of moderately deep soils (Ee and Fc families) in land units 2 and 4 occur on some upper and middle slopes below scarps. In the larger valleys mapped in QuA land system, moderately deep to deep sandy soils (dominantly Fd and Fe families) with some shallow soils (Fc) on ridge crests occur mainly under an open woodland of rusty gum on extensive colluvial spreads below scarps and sandstone hills (land units 5–7). In the extreme north there is a striking change in texture on the valley floors where deep uniform clay soils (Be family) carrying silver-leaved ironbark woodland have formed in alluvium derived from basalt which caps the sandstone in the upper reaches of stream catchments (land unit 67). Further south, duplex soils (Dh and Di families) have formed in medium-textured alluvium (land unit 64).

Land unit 8 is estimated to cover 40% and 15% of land systems QrCp and QuA respectively which form rolling to gently undulating terrain on quartzose to sublabile sandstones. It occurs mainly on middle and lower slopes and has dominantly sandy duplex soils with mottled sandy clay to light clay subsoils (Dg family). Minor occurrences of similar soils with alkaline reaction and occasionally with columnar structure suggest the accumulation of sodium salts in some situations. Prominent mottling and commonly bleached A_2 horizons indicate seasonal waterlogging and lateral movement of water above the clayey B horizons, particularly on lower slopes.

(*b*) *Soil Landscapes on Fresh Labile Sediments* (Land units 9–14)

Where the cover of weathered rocks and materials has been stripped off, a range of fresh rocks has been exposed. Landscapes formed on labile sandstones, siltstones, and mudstones have been mapped in four land systems (ShSw, SrX, SuMc, and SuD) consisting mainly of land units 9–14. ShSw and SrX land systems are not extensive and occur only in the north and north-east of the area. Occurrences of SuMc land system form an irregular belt in the north-west between Radford and Babbiloora, mainly fringing QrCp land system. The undulating "downs" in SuD land system are most extensive in an irregular belt between Roma and Mitchell, north of Morven, and to the south of Surat. These areas are generally bordered by (S)uBl and (S)uXB land systems on weathered materials, and SuMc and SuD land systems include small areas of cracking clays and brown and grey-brown soils on weathered rocks. The geographic distribution of these land systems reflects minor differences in the residual effects of deep weathering (Fig. 17).

Land units 9–12 occur on crests and upper slopes in rolling to hilly terrain and shallow brown and grey-brown soils predominate (Bf family). Both natural and accelerated erosion is reflected in the shallow depths of soils in these landscapes on basic sediments. The subsoils have strongly alkaline reaction and accumulations of soft carbonates in the soils and underlying rocks probably reflect the leaching and translocation of soluble materials in a cover of weathered rocks that lay above them at one time. Moderately deep to deep cracking clay soils (Cc family) occur on gentler slopes in land units 13 and 14 with open-woodlands and grassland respectively. These differences in vegetation almost certainly reflect variations in soil drainage and moisture availability where the well-drained ridges and crests are better suited to tree growth. The cracking clay soils of land unit 14 also show slight residual effects of deep weathering in the upper slopes of some occurrences in their reddish brown colour, greater depth, higher contents of soluble salts, more acid reaction, and dominance of kaolinite clay minerals. Soils formed on fresh rocks are generally dark grey-brown or dark brown in colour and a few analyses indicate that randomly interstratified material with properties similar to montmorillonite may be dominant. They also have low contents of chloride and exchangeable sodium. Linear gilgai with stones or gravel on the mounds commonly occur on the steeper mid slopes.

(*c*) *Soil Landscapes on Basalt* (Land units 15–19)

Compared with the Fitzroy basin to the north, only small areas of formerly extensive basalt flows remain but have given rise to similar landscapes and assemblages of soils. The areas have been mapped in three land systems (BtS, BhMc, BuI) consisting of varying proportions of land units 15–19. These land systems are most extensive in the extreme north on the Great Dividing Range, near Dooloogarah, and to the north of Mt. Tabor. Smaller areas occur near Kilmorey and to the north and east of Mitchell. The most extensive occurences in the north form mountainous to hilly terrain where steep slopes and natural erosion permit only the development of shallow skeletal soils. In small areas on elevated plateaux and tablelands with gently undulating to almost level relief, shallow to moderately deep soils have formed. Most of the basalt is fresh but small areas on weathered rock are included (Fig. 7).

Land units 15 and 16 are of small extent and occur only on elevated tablelands about 900 m a.s.l. They are representative of much larger areas on the Consuelo Tableland which drains into the Fitzroy basin. Land unit 15 covers 75% of BtS land system and has moderately deep weakly structured to massive humic red earths (Eh family) which are underlain by ferruginized basalt. The humid conditions are reflected in thick well-defined dark brown surface horizons containing up to 10% organic matter and in the tall forest which these soils support. Stripped margins of these tablelands (land unit 16) have shallow, commonly stony, uniform clay soils (Bf family). Land unit 17 with shallow skeletal loams (Gb family) and extensive outcrop is dominant in hilly terrain (BhMc land system) with steep slopes, and shallow cracking clay soils (Cf family) occur on more gentle slopes in undulating terrain in land unit 18. Areas of moderately deep self-mulching dark clay soils (Cd family) under grassland occur on some plateau remnants and are generally stony (land unit 19).

The effects of deep weathering on basalt are reflected in small areas of very deep cracking clay soils (Cb family) which are strongly alkaline at or near the surface and strongly acid and mottled beneath. They have moderately high levels of exchangeable sodium and medium to high contents of soluble salts. These soils support brigalow open forest. There has been carbonate enrichment in some of the shallow clay soils in land unit 18 which are calcareous throughout, and thick C horizons indicate more intense weathering than in profiles derived from fresh rock.

(*d*) *Soil Landscapes on Indurated Weathered Rocks* (Land units 20–34)

A relatively simple assemblage of soils occurs in land units 20–23 included in this category. The landscapes have formed chiefly in the more elevated parts of rolling to hilly terrain underlain mainly by weathered rather quartzose sediments but some labile rocks are included. The generally steep slopes and rapid run-off have resulted in the development of mainly shallow, gravelly or stony, massive earths or, alternatively, they are truncated phases of soils that were much deeper at one time.

Land unit 20 occurs mainly in the north-east of the area under narrow-leaved ironbark woodland and shallow gravelly massive earths (Eg family) predominate. Some deeper soils (Ea family) on more gentle slopes are included. These soils are all strongly leached and acid and are underlain by weathered zones. In similar situations, land unit 21 has moderately deep acid duplex soils (Dc family) with thin loamy surface horizons over medium to heavy clay subsoils. These soils have clearly formed in materials derived from shaly strata. Land unit 22 includes scarps, steep slopes, and denuded areas mainly with skeletal very shallow loamy soils (Gb family) and shallow massive earths (Eg family) which are generally gravelly or stony; outcrops of weathered rocks are common. Forests of lancewood in the more humid north-east of the area and bendee in the drier parts are indicative. Shallow to moderately deep gravelly massive earths (Ea and Eg families) and skeletal soils predominate in land unit 23. Extensive areas of these soils are underlain by stones and gravel of silcrete or "billy" and they occur below the levels of weathered zone outcrops indicating development in redistributed materials.

The soils of land units 24–34 occur mainly in undulating to nearly level terrain with more gentle slopes and they are deeper than those in the previous group. They generally occur in catenary sequences with massive earths in more elevated sites and a range of duplex soils on middle and lower slopes. The soils in some land units are located in specific parts of the area and their distribution appears to be related to particular rock lithologies (e.g. land unit 31).

Land units 24–27 have similar soils, mainly massive earths (Ea family) with minor occurrences of other soils in this group. Large uniform areas of land unit 24, the dominant unit in (S)uIX land system, occur on nearly level plains in the west. Land unit 28 occurs sporadically on steeper slopes and has shallow to moderately deep duplex soils (Dc family) which are strongly to extremely acid. They are underlain by weathered zone materials commonly with moderately high contents of soluble salts. Duplex soils with thick sandy surface horizons (Dg and Df families) in land unit 29 occupy small areas on some mid slopes. Land units 30, 32, and 33 have dominantly duplex soils with thin sandy or loamy surface horizons over clay subsoils (Da, Db, and Dc families). They occur most extensively on lower slopes in (S)uXM land system in this geomorphic category. Some of these soils are almost certainly affected by soluble salts and/or exchangeable sodium and differentiation between the red-brown earths and solodic soils is not clear-cut.

Land unit 31 has duplex soils with columnar structure (Dd and De families) which belong to the solodized solonetz, solodic, and soloth groups as defined by Hallsworth *et al.* (1953). Although these soils occur sporadically elsewhere, they are most extensive in (S)uBu land system in the north-east of the area between Yuleba

TABLE 21

ESTIMATED AREAS OF SOILS (KM^2) IN THE LAND SYSTEMS OF THE WEATHERED SEDIMENTS LITHOLOGICAL GROUP

Major group and family	Weathered sediments										
	(S)rNi	(S)rBe	(S)rXM	(S)uM	(S)uXM	(S)uIX	(S)uX	(S)uBu	(S)hY	(S)uXB	(S)uBl
Alluvial soils											
Aa											
Ab											
Ac											
Brown and grey-brown soils											
Ba						17			133	237	534
Bb					80	13			133	237	178
Bc						13			133	198	1780
Bd											356
Be											
Bf											
Cracking clay soils											
Ca							86			198	3204
Cb									200	198	2848
Cc											
Cd											
Ce											178
Cf											
Duplex soils											
Da	20	35	80		437	86	1726	133		1185	3916
Db	10	35	80		358	22	518	22		1185	2848
Dc	657	450	80		119	22	518	67	252		178
Dd						4	173	600		118	890
De						4	173	578		118	
Df						9	86				
Dg					199	39	345	111		79	
Dh			80		80	4	86	22		40	178
Di			39		40	4	86	22		39	178
Dj							86				
Massive earths											
Ea	78	347	1711	1710	2308	64	3366	44	13		
Eb				68			431				
Ec			40	137	40		259				
Ed	10	35					173	111			
Ee	78	35	159	114	119		259	44	27		
Ef											
Eg	78	1214	796	114	80	129	259	22			
Eh											
Uniform sandy soils											
Fa											534
Fb											
Fc		35						67		118	
Fd		35			80			244			
Fe		35						133			
Skeletal soils											
Ga											
Gb	49	1214	915	137	40				439		
Total	980	3470	3980	2280	3980	430	8630	2220	1330	3950	17800

and Wallumbilla Creeks and south of the Moonie River. The origin of the high proportions of exchangeable sodium leading to their formation is thought to be the deeply weathered marine sediments in these areas.

Land unit 34 included in this category has dominantly dark brown and grey-brown soils (Ba, Bb, and Bc families) which have formed on labile sandstones and some shaly rocks mainly in (S)uM land system.

(*e*) *Soil Landscapes on Unresistant Weathered Labile Sediments* (Land units 35–44)

The ten land units included in this category occur in varying proportions on landscapes underlain by labile sandstones, siltstones, and mudstones which have been subjected to deep weathering. Most of the soils in these landscapes are affected by soluble salts and/or exchangeable sodium which are believed to have their origin in the underlying weathered zones in these rocks. They are most extensive in (S)hY, (S)uXB, and (S)uBl land systems which occur in a broad belt following the distribution of these rocks. Small remnants of a former cover of hard rocks are present in the upper segments of some occurrences. Each land unit is characterized by the occurrence of a dominant soil group of which a particular soil family is generally most extensive. The soil landscapes commonly occur in a catenary sequence and are correlated with specific plant communities (Fig. 8). In some areas (e.g. west of Meandarra) gilgaied clay soils occur in both elevated and bottom land situations in a topographic sequence. This distribution may be related to the occurrence of remnants of a cover of Tertiary sediments overlying weathered shaly strata where conditions were suitable for the development of gilgaied soils in both materials.

Land unit 35, generally on crests and steeper upper slopes, has dominantly shallow skeletal loams and clays (Gb family) and weathered zone outcrops commonly containing soluble salts are common. Woodlands of yapunyah or gum-topped box are indicative. Land unit 36 on shallower slopes has moderately deep to deep brown and grey-brown soils (Bb, Bc, and Ba families) under similar vegetation. A surface strew of stones or coarse gravel is common and may prevent cracking in some soils with uniform heavy clay textures. In other respects these soils have similar properties to the cracking clay soils of land units 41–43 which are commonly strongly alkaline at or near the surface and acid beneath or, alternatively, are neutral to acid throughout.

Land units 37 and 38 under brigalow and/or belah–box shrub woodland and belah open-forest respectively have duplex soils, predominantly Da and Db families, with minor proportions of other soils in this major group. These soils occur on middle and lower slopes below land units 35 and 36 where these are present. Although they lack the columnar structure of the soils of Dd and De families with which they commonly intergrade in some occurrences, their development has been influenced by moderately high levels of exchangeable sodium and soluble salts, but to a lesser degree. Clay mineral analyses indicate that kaolin is dominant and montmorillonite, illite, and randomly interstratified clay are accessory, pointing to moderately weathered parent materials. The reasons for the differences in vegetation are not clear, but there is a tendency for land unit 37 to occur on lower slopes which receive run-off in gently undulating terrain. The duplex soils of these land units grade to dark brown and grey-brown soils (dominantly Bc family) on very gentle slopes below with similar vegetation (land units 39 and 40). Analytical data indicate exchangeable sodium percentages up to 20–30 and soluble salts comprising up to 2000 p.p.m. chloride.

The four lowermost land units, 41–44, all have cracking clay soils on weathered zones or materials derived from them, with minor inclusions of brown and grey-brown soils (Bc, Bd, and Bf families). The soils in land unit 44 have well-developed gilgai microrelief and a few analyses indicate high levels of exchangeable sodium and chloride contents of up to 3400 p.p.m.

(*f*) *Soils of the Depositional Plains* (Land units 45–59)

Extensive depositional plains in the centre and south of the area have been mapped into six land systems in which land units 45–59 are the main components. The largest occurrences are in a fan-shaped area on the Maranoa with Albany Downs, Mulga Downs, and St. George at the apices. The source materials were derived mainly from the cover of weathered rocks in the catchment and partly from zones of enrichment at the base of weathering profiles and fresh rocks which supplied carbonates and gypsum. Textures range from sands to clays and the absence of ironstone gravel in the relatively young soils of these plains is the major difference between these and similar soils underlain by weathered zones. The distribution of these soils is shown diagrammatically in Figure 9.

Land units 45–47 on slightly elevated, elongated old levees broadly oriented in a north–south direction have very deep well-drained sandy soils (Fa and Fb families) with only weakly differentiated colour horizons. These soils are soft, loose, and structureless and numerous ant-holes are common. They absorb water readily and there is little or no run-off even during heavy rainfall. Remnants of old channels with duplex soils are present in some occurrences, for example near Quandong.

The most extensive soils on the plains are the loamy massive earths of Eb family (land units 48 and 49) with minor occurrences of other soils in this group (Ec and Ed families). They are similar to those of Ea family but are very deep and contain none of the fine gravel characteristic of the sedentary or locally reworked soils from which they are derived. Interspersed with and adjoining these massive earths are areas of duplex soils (land units 50–52) mainly with thick sandy surface horizons and strongly alkaline subsoils, some of which may have formed by deposition of sandy layers over loamy massive earths.

Also extensive on these plains are mosaics of massive earths, duplex, and/or brown and grey-brown soils which are interspersed with areas of gilgaied cracking clays (land units 53–56). These mosaics have formed either on lenses of loamy and clayey materials or on layers where the coarser-textured soils have been irregularly stripped off to expose the underlying clays in which gilgai microrelief has formed. A "stoneline" of fine subangular gravel is frequently present above the clay which is generally strongly alkaline and calcareous. It is considered that the alkaline massive earths (Ec family) have commonly formed in these situations where the subsoils have been influenced by the underlying calcareous clay layer. The gilgaied clays (Ca family in land units 58–59) in these situations generally have higher contents of carbonates and/or gypsum and are strongly alkaline to greater depths than similar soils on weathered sediments. The most likely explanation is that they have formed in materials derived from both weathered and fresh calcareous rocks on these depositional plains. Similar soils (Cb family) occur under low brigalow woodland in the south-west of the area (land unit 57) but gilgais are absent.

(*g*) *Soil Landscapes on Alluvium* (Land units 60–76)

Alluvial lands are estimated to cover more than 25,000 km^2 in the area. They have been mapped in six land systems and described in terms of 17 land units, many of which occur as small components in other land systems. These landscapes have been differentiated mainly on the basis of texture, according to the nature of source materials and mode of deposition, and vegetation, which reflects not only variations in climate and soils but also flooding regimes. The soils in these landscapes generally have well-developed profiles and recent alluvial soils cover small areas only on lower terraces near major stream channels.

Land units 60 and 61 have deep uniform sandy soils (Fa and Fb families) which occur mainly on old levees, modified by wind action in places, on the upper reaches of the Maranoa, on Mungallala Creek, and between Thallon and Dirranbandi where the Maranoa has deposited coarse materials on the extensive plain in the south. These materials consist mainly of medium to fine quartz sand and profile development is reflected only in gradual colour changes. Small areas of sandy massive earths are present in some occurrences. Land unit 62 occurs in the south-west of the area and has loamy massive earths with strongly alkaline subsoils.

Duplex soils supporting various plant communities have formed on medium-textured alluvium on levees, plains, and valley floors. Land unit 63 has dominantly sandy duplex soils with acid mottled subsoils (Dj family), but alkaline and columnar-structured soils (Dh, Di, and De families) also occur, and indicate that they are salt-affected in places. Land unit 64 with poplar box woodland on duplex soils, mainly with strongly alkaline subsoils (Dh and Di families), is very extensive along the upper Maranoa, the Warrego and its tributaries in the north-west, and on old levees on the plains in the south. This land unit is dominant in AX land system but it recurs as a small component in 16 other land systems. Similar soils and vegetation occur in small rounded depressions (land unit 65) predominantly in AXM land system. Many of these areas are subject to flooding or waterlogging. Duplex soils (Dh and Di families) under low open-woodlands of leopardwood and whitewood and short grass occur extensively in the south-west of the area. Analytical data indicate that they are salt-affected (E.S.P. >15 and chloride contents >1000 p.p.m.) in places. These soils have been very severely eroded and the surface soils have been completely removed by run-off and/or wind action in some areas (Plate 6, Fig. 2).

Land units 67–74 occur on back plains and valley floors and all have uniform clay soils. Land unit 67 occurs specifically in the extreme north where the soils of Be family have formed in fine-textured alluvium derived from basalt.

Land units 68–74 all have cracking clay soils (Ce family) interspersed with non-cracking clays (Be family) in some of the units. They occur mainly on extensive back plains on the Condamine, the lower Balonne, and the Macintyre–Barwon system in the south and south-east. These soils generally become strongly alkaline at depths below about 50 cm where small accumulations of carbonate and gypsum occur. The few analytical data available indicate moderately high levels of exchangeable sodium

TABLE 22

ESTIMATED AREAS OF SOILS (KM^2) IN THE THE LAND SYSTEMS OF THE TRANSPORTED DEPOSITS AND ALLUVIUM LITHOLOGICAL GROUPS

Major group	Transported deposits								Alluvium			
and family	CpCp	CpXM	CpM	CpBXM	CpBl	CpG	ACp	AXM	AX	AC	ABb	Af
Alluvial soils												
Aa							98	8	119			
Ab							98	16	119	338	4	30
Ac								8	119	113		
Brown and grey-brown soils												
Ba												
Bb					434							
Bc				6	434	147						
Bd												
Be				12			65	8	300	1690	141	76
Bf												
Cracking clay soils												
Ca				6	2892	588						
Cb				14	362	221						
Cc												
Cd												
Ce				11	72	44		40	717	7889	196	1359
Cf												
Duplex soils												
Da		490	29	3	578	147						
Db		196		116	723							
Dc					216							
Dd		98			72							
De							33	8				
Df		587	29	58								
Dg		587										
Dh	9		12		72		262	128	1791	563	7	30
Di	9			6	72		262	112	1791	451	22	15
Dj	17	98					458	104	597			
Massive earths												
Ea	9		17			74						
Eb	25	5678	389		578							
Ec	9	685	17	58	723	220	98	320				
Ed	9											
Ee												
Ef							196	16	119	113		
Eg						29						
Eh												

TABLE 22 (*Continued*)

Major group and family	Transported deposits						Alluvium					
	CpCp	CpXM	CpM	CpBXM	CpBI	CpG	ACp	AXM	AX	AC	ABb	Af
Uniform sandy soils												
Fa	551	1371	87				850	16	179	113		
Fb	212						850	16	119			
Fc												
Fd												
Fe												
Skeletal soils												
Ga												
Gb												
Total	850	9790	580	290	7230	1470	3270	800	5970	11270	370	1510

(E.S.P. 10–20) and chloride contents ranging between 700 and 1360 p.p.m. at depths below 50 cm. Many areas of these soils are subject to flooding by overflow, particularly in land units 71 and 74.

V. LAND USE ASPECTS

(*a*) *Soil Moisture*

Owing to low and very variable rainfall over much of the area and high rates of potential evaporation, particularly during the summer months, lack of adequate moisture is one of the main limitations to crop and pasture growth in the area. From Table 14 in Part IV it can be seen that average levels of soil moisture, based on an assumed capacity of 100 mm in the root zone, are well below 25% of the total storage capacity for most of the year. Levels are most favourable during the period June/August and bare fallowing of cultivated lands during summer is commonly practised to augment soil moisture for growing winter cereal or fodder crops. Apart from irrigation, fallowing, and the selection of suitable soils, other management practices such as deep ploughing, ripping, contour ridging, and stubble mulching (Paull *et al.* 1971; MacCartney *et al.* 1971) are relevant, but few or no quantitative data are available with regard to rates of run-off, water entry and movement, and the water availability and storage capacities of the various soils in the area. Little is known of the possible long-term effects of large-scale clearing on soil moisture regimes. Clearly there is a need for further work in this field.

Preliminary observations made during a study of the moisture characteristics of selected soils in the area indicate:

(1) Marked variations in the rates at which water enters and permeates surface soils may be caused by differences in surface crusting, organic matter content, the occurrence of faunal channels and holes, root densities, and presence of mosses and lichens.

(2) The clayey substrata of duplex soils are very slowly permeable when moist.

(3) The initial infiltration rate into dry or only slightly moist cracking clays is very rapid but decreases to almost nil after about 5 min.

In this section some of the factors that affect the moisture characteristics of the soils are considered in terms of four broad groups.

(i) *Uniform Fine-textured Soils*.—These include the cracking clay soils and most of the brown and grey-brown soils which are used extensively for crop production and established pastures in the east and north of the area. These soils all have moderate to high clay contents (40% or more) but some soil families differ markedly in respect of other physical and chemical properties.

Differences in self-mulching properties and aggregation in surface horizons may also cause variations in rates of infiltration. The soils of Cc and Cd families, for example, form strongly self-mulching layers when dry but most of the Ca soils have weak surface crusts. Stirk (in Reeve *et al.* 1963) found moderate to low macroporosities in clay soils derived from both weathered materials and sediments, indicating low permeability rates. The moderate to high levels of exchangeable sodium generally present at depths of 30 cm or more in the soils of Ca and Cb families would result in very slow permeability. In alluvial landscapes, cracking and non-cracking clays (Ce and Be families) with self-mulching to non-self-mulching properties form mosaics in some situations.

Owing to the high clay contents these soils have potentially high capacities for storing plant-available water. These capacities would vary, however, with the content and mineralogy of the clay as well as with porosity and depth. Coughlan (1969) found strong correlations between clay percentage and 15-atmosphere moisture percentage in a range of Queensland soils and that predictions were improved by dividing the soils into groups according to clay mineralogy. The cracking clay soils on weathered materials (Ca and Cb families) have dominantly kaolinite clay minerals in the upper profiles but proportions of montmorillonite increase at lower levels. In soils derived from fresh argillaceous sediments and basalt, X-ray diffraction data on a few samples indicate that montmorillonite or randomly interstratified minerals with properties similar to those of swelling clays are dominant. Stirk (in Reeve *et al.* 1963) found higher retention values in black earths, with predominantly montmorillonite clay, than in the alkaline/acid kaolin-dominant brigalow soils and assumed that the water was present mainly in the adsorbed phase and reflected a greater surface area of the clay. In general, however, Stirk found little difference between the clay soils he studied and he determined average available water storage capacities of between 0·16 and 0·21 cm/cm (2 and 2·5 in./ft) soil depth.

The marked differences between the natural vegetation found on clay soils derived from fresh sediments and basalt (i.e. grassland) and weathered materials with belah, brigalow, or gidgee forests reflect variations in soil properties, particularly those which affect the moisture characteristics. The grassland soils with higher proportions of swelling clays are poorly aerated when moist, they form strongly self-mulching surface layers and extensive deep cracks on drying, and water is held at higher tensions at the lower levels of the available moisture range. These conditions appear to be generally unsuitable for the growth of trees. The higher macroporosity and less marked cracking in soils derived from weathered materials, particularly those on the mounds of gilgais where there is good surface drainage, seem to offer more suitable conditions. The gilgai mounds appear to be stable in undisturbed sites under present climatic conditions. In addition, the moderate to high levels of soluble salts (predominantly sodium chloride) with resultant higher osmotic pressures as well as possible toxicity may permit only tolerant species to become established and grow.

According to the United States Department of Agriculture (1954), it is the total concentration of solute particles in the soil solution rather than their chemical nature which is mainly responsible for the inhibitory effects of saline solutions on the growth of crop plants. The equivalent negative pressure as soil moisture tension increases as the soil becomes drier is apparently additive to the osmotic pressure of the soil solution in limiting the availability of water to plant roots. Osmotic pressures of saturation extracts range between about 3 and 6 atmospheres with electrical conductivities of 4–12 mmhos/cm. These properties almost certainly offset some of the advantages of high clay contents and potential water storage capacities.

(ii) *Duplex Soils*.—Subdivided into four subgroups and ten families, these vary considerably in respect of the texture, consistence, and thickness of surface horizons, the structure and mineralogy of clayey subsoils, and the nature and content of the exchange complex and soluble salts. As a result their moisture characteristics are also likely to be very variable. In the first subgroup (Da, Db, and Dc families) the surface horizons are mainly clay loams with an average thickness of 18 cm and they are hard-setting and massive. Estimated infiltration rates are moderate to moderately slow and available water storage capacities in the range 0·10–0·17 cm/cm (1·5–2·0 in./ft) soil depth. The blocky structured subsoils have light to medium clay textures (40–60 % clay) with dominantly kaolinite clay minerals, and potential storage capacities of the order of 0·17 cm/cm (2·0 in./ft) soil depth would be expected although moderate levels of exchangeable sodium and soluble salts would affect permeability and availability.

Duplex soils with columnar structure (Dd and De families) have hard very slowly permeable clayey subsoils and moderately high proportions of exchangeable sodium and magnesium. During wet periods the thin sandy or loamy surface horizons become saturated and thixotropic owing to shallow perched water-tables. These conditions, together with the barrier to root penetration, provide poor media for plant growth and are regarded as unsuitable for cultivation.

Soils formed on quartzose materials and sandy alluvia (Df, Dg, and Dj families) have thick sandy surface horizons. These soils have moderately rapid to rapid infiltration rates depending on whether or not they are hard-setting, but water storage capacities are judged to be low (0·04–0·08 cm/cm or 0·5–1 in./ft of soil) and they are prone to seasonal waterlogging and drought. Alluvial soils with thin sandy or loamy surface horizons would be expected to have moisture characteristics similar to those of the first subgroup but they are subject to waterlogging or flooding by run-off from higher ground or overflow from rivers and creeks in some occurrences.

(iii) *Massive Earths*.—These are generally enriched by sesquioxides and have earthy porous fabric, free drainage, and dominantly kaolinoid clay minerals. McIntyre (1956) found that macroporosity increased with increasing content of free iron. The loamy soils of Ea and Ee families on deeply weathered materials have large pores which, together with their moderate to high gravel contents and kaolinite clay minerals, result in low water storage capacities (estimated 0·04 cm/cm or 0·5 in./ft depth). Similar soils but free of gravel (Eb, Ec, and Ef families) are likely to have somewhat higher storage capacities. The alkaline red earths (Ec family) are commonly underlain by clay layers and probably become seasonally saturated in the lower profiles in these situations. The sandy red earths with sand to sandy loam textures in the upper 60 cm are very permeable and water storage capacities are estimated to be about 0·04 cm/cm or 0·5 in./ft depth. In view of their shallow depths and high gravel contents the shallow red earths (Ee) have very low storage capacities and high run-off rates on the steeper slopes.

(iv) *Uniform Sandy Soils*.—Grouped into five families, all have similar physical and chemical properties apart from variations in depth and colour. Water enters and moves through these soils rapidly and storage capacities are very low (estimated average 0·04 cm/cm or 0·5 in./ft depth). On the other hand, soil moisture tensions are low, most of the stored water is readily available to plants, and they respond more rapidly even to light showers than those in more fine-textured soils. In areas with marked seasonal rainfall, the first growth of pastures in early spring occurs in these sandy soils and they are favoured for this reason. In other respects they tend to be droughty for all except deep-rooting plants and the wide spacing of both native trees and grasses is a possible reflection of these conditions.

(*b*) *Accelerated Erosion*

From the description of the geomorphic history in Part VI it is clear that natural erosion has occurred extensively in the area since the Tertiary. Most of the surface cover and a large part of the underlying zones of the weathered mantle have been stripped off and removed or redeposited. Accelerated as well as natural erosion is occurring at present, but it is impossible for us to differentiate between the two forms or to determine rates. Natural erosion is most evident in the form of shallow skeletal soils and rock outcrops on steep hill slopes where the effects of land use are also minimal. On rolling and undulating terrain, however, where more intensive land use is possible, it is believed that most of the erosion which is evident in the form of gullying or sheeting has been caused by destruction of the ground cover by grazing and, to a lesser extent, cultivation.

The survey was carried out during and just after the break of a prolonged drought and most of the area was desiccated and severely overgrazed. In many parts only a sparse ground cover of *Bassia* spp. remained and native fodder trees and shrubs were being cut to provide feed for stock. Under these conditions, the effects of erosion could be clearly observed and estimates were made of the depth of surface soil removed and the percentage of the area affected in the immediate vicinity of sampling sites. Most of the erosion was caused by run-off, but evidence of deflation and accumulation of fine sand along fence lines and around the base of trees and shrubs was observed in the south and west of the area. In general, wind erosion appears to be of minor importance.

Clearly some landscapes are more susceptible to erosion than others, but drought, overgrazing, and the reduction in the ground cover of grasses, particularly in the more delicately balanced communities in the drier areas, appear to be the prime causes in grazing land. Old levees adjacent to Wallam Creek near Homeboin and on the alluvial plains south of the Thallon–Dirranbandi railway line (land unit 66) have been severely eroded. Slopes range from almost level to about 2% on the steeper margins. Duplex soils with thin silty loam or fine sandy loam surface horizons over red silty clay to heavy clay subsoils predominate and over extensive areas the surface horizons have been completely removed (Plate 6, Fig. 2). Some local reworking by wind action was also observed. These soils support a sparse cover of short minute grass with scattered whitewood and leopardwood and analytical data indicate that in places they have high levels of exchangeable sodium which lead to dispersion and slaking of the clay subsoils. An estimated area of 800 km^2 is affected to varying degrees and, if these lands are to be reclaimed, complete protection from grazing, contour ripping at intervals, and seeding with suitable grass species would appear to be necessary.

Red massive earths generally with gravel increasing in size and quantity with depth (Ea family) under box–ironbark–mulga open-forest (land unit 24) have also been severely sheet-eroded over extensive areas. Observations indicate that 3–8 cm of the surface soil has been removed over 30–70% of the area in the vicinity of numerous sites even on very gentle slopes (<1%). These soils, particularly at sheet-eroded sites, tend to form hard surface crusts or flakes and a surface lag of fine gravel commonly occurs. These properties almost certainly reduce water entry and promote run-off. Analytical data on a few profiles indicate that surface soils contain less than 1% of organic matter and following erosion, regeneration of a ground cover is likely to be retarded by the reduction of the naturally low content of nutrients in organic form. Charley and Bowling (1968) have pointed out the seriousness of such erosional losses. In similar terrain but with steeper slopes (land unit 23) a higher proportion of shallow gravelly soils (Eg family) occurs owing to more severe natural as well as accelerated erosion. Sandy soils, particularly those with high proportions of fine sand, and some duplex soils with fine sandy surface horizons appear to be the most susceptible to wind erosion (e.g. land units 47, 60, 66) where the ground cover is reduced.

Land units 10 and 11 in SrX land system and land unit 43 in (S)uBl land system in the north-east of the area have also been severely eroded over extensive areas. Shallow cracking clay soils (Cf) and brown and grey-brown soils (Bf) formed on basic sediments and cracking clay soils (Cb) on weathered materials predominate. Moderately steep slopes (5–10%) combined with calcareous soils, in which the cohesiveness and stability of aggregates are reduced, and grazing pressure have led to sheet and gully erosion in these landscapes. Deep and extensive gullying in parts of land unit 31 in (S)uBu land system also indicates the susceptibility to erosion of the columnar-structured duplex soils (Dd and De) with moderately high levels of exchangeable sodium.

(c) Salinity

Soils with moderate to high contents of soluble salts (EC_e >4 mmhos/cm) and/or exchangeable sodium (E.S.P. >15) occur extensively in the area. These properties affect plant growth by causing strongly alkaline reaction, nutrient imbalances, and/or toxicity as well as by influencing the movement and availability of soil water. Columnar structure and hard consistence in the solodized soils of Dd and

De families impede root development markedly. They therefore restrict the choice of crop or pasture species and limit the development of potential irrigable lands. On the basis of field observations and the few analytical data available, the distribution of salt-affected soils in the principal land systems and land units is shown in Table 23. These soils occur mainly in landscapes classified in groups of materials as shown in Figure 16 in the lower zone of a catenary sequence on weathered sediments (Fig. 8). They also occur on depositional plains derived largely from the stripping of weathered landscapes (Fig. 9), and sporadically on alluvium.

TABLE 23

DISTRIBUTION OF SALT-AFFECTED SOILS

Soil family	Electl. conduct. (mmhos/cm)	Cl (p.p.m.)	Exch. Na (%)	Principal land systems	Principal land units
Ba, Bb, Bc	4–10	750–2000	10–30	(S)hY, (S)uXB, (S)uBl	34, 36, 39, 40, 41, 55
Ca	4–12	650–2800	15–50	(S)uBl, CpBl, CpG	44, 53–56, 58, 59
Cb	4–12	500–3400	15–50	(S)hY, (S)uBl, CpG	41–43, 57
Ce	4–10	500–1360	10–20	Parts of AC, ABb, Af, AX	69–72, 74
Da, Db	4– 8	600–1250	10–25	(S)ulX, (S)uX, (S)uXB, (S)uBl	30, 32, 33, 37, 38, 52, 55
Dd, De	4– 8	400–600	15–30	(S)uBu	31
Dh, Di	4– 8	1000–1730	10–20	Parts of AX, AXM, ACp	64–66

The soils classified as salt-affected are those with appreciable quantities of readily soluble salts, mainly sodium chloride. Some soils in the area contain appreciable quantities of other salts with low solubility, such as gypsum and the carbonates of calcium and magnesium (e.g. Cc and Cd families), but their effects on crop or pasture growth are probably negligible provided that adapted species are selected. Sodic soils are defined as those in which exchangeable sodium comprises 15% or more of the exchange capacity. It is stressed that the occurrence of these soils may be sporadic in some landscapes and their extent can only be determined by detailed survey.

(*d*) *Other Aspects*

Gilgai microrelief, generally between 60 and 90 cm but up to 150 cm in places, occurs in the soils of Ca family in land units 44, 58, and 59 and in soil mosaics in land units 53–56. Although some areas of these soils are being used for crop production, the more extreme forms present difficulties in the use of machinery and crop growth is generally uneven owing to ponding and/or exposure of subsoils. The use of areas of soil mosaics for other than improved pastures presents similar problems. Excessive contents of stones or gravel in some soils restrict the use of machinery for cultivation or pasture improvement. These and other limitations imposed by soils on the more intensive forms of land use are indicated by the land capability symbols given for each land unit and in Table 31 in Appendix I.

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PART VIII. VEGETATION OF THE BALONNE–MARANOA AREA

By L. Pedley*

I. Introduction

(a) Environmental Influences

Climatic, edaphic, and topographic factors determine the composition and distribution of plant communities within the Balonne–Maranoa area, though over a large proportion of the area the communities have been influenced directly or indirectly by the activities of man. As in other parts of Australia, climatic factors determine what plants occur in the area but edaphic and topographic factors to a large extent control the distribution of plants within the area.

The rainfall and its seasonal distribution are important controls on plant distribution, but because rainfall decreases gradually from the north-east to the south-west and its winter component declines gradually from south to north the changes in vegetation occur over large distances and are complicated by more abrupt changes in edaphic factors. *Acacia harpophylla* open-forests which predominate in the east and north-east are replaced by *Casuarina cristata* open-forests in the centre of the region, which are in turn replaced by open-forests of *Acacia cambagei* in the south-west. Such definite replacement is unusual. The absence of *Eucalyptus microtheca* in the north of the area, for example, is due to absence of suitable soils rather than to any climatic factor.

Though a significant amount of rain falls in the winter, particularly in the south of the region, plants of the ground layer are mainly summer-growing perennial grasses. It is likely that the winter component is not sufficiently reliable to have enabled winter-growing herbaceous perennials to have evolved or to have become adapted, although winter-growing annual forbs are sometimes major components of the ground layer of woodlands and in grassland. The incidence of winter rain may determine the distribution of some trees, though temperature may also have an effect. *E. intertexta* and *E. largiflorens* are restricted to the south of the area though suitable soils exist elsewhere.

The effect of temperature is even more difficult to determine. Everist (1949) noted a correlation between the eastern limit of *Acacia aneura* and the isotherm for January of mean screen temperatures between 27·8°C and 28·3°C but low temperatures may also be significant. The incidence of frost in the south-western half of the area is high and the paucity of trees on alluvial plains may be due to the killing of seedlings by frost. In rolling or hilly areas cold air drainage may also influence the distribution of trees.

Differences in soil often result in abrupt changes in vegetation. The change from open-woodland of *Eucalyptus tessellaris* and *Callitris columellaris* on coarse-textured soil to open-woodland of *E. microtheca* on fine-textured soil, both on

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alluvium, is pronounced but transitions from open-forest of *Acacia harpophylla* to woodland of *E. populnea* or to grassland are equally marked and quite common. As well as these local changes which are often due to changes in lithology there is a noticeable regional effect. In the headwaters of the Maranoa, Merivale, and Warrego Rivers there is a floristically rich shrub woodland which I have called "mixed layered eucalypt woodland". It occurs on coarse-textured soils derived from quartzose sandstone. This community does not occur elsewhere in the area but similar communities are common on quartzose sandstone in the Nogoa–Belyando (Pedley 1967), Isaac–Comet (Story 1967), and Dawson–Fitzroy areas (Speck 1968).

In many cases the correlation of vegetation with soil and climate may be interpreted in terms of the water available to the plants.

The vegetation of the area has been modified by the activities of man—especially since the introduction of exotic grazing animals within the last 120 years. Some anthropogenic effects are direct and obvious, but others are indirect and quite subtle.

Much of the vegetation has been cleared, either wholly or in part, for cultivation or grazing. Cultivations result in the complete destruction of the vegetation but often in grazing areas not all the woody vegetation is removed and the herbaceous plants are not disturbed except when the area is burnt to reduce dead woody material. After clearing, however, grazing and changes in water relations and shading often lead to marked changes in the ground flora. Some species such as *Paspalidium* spp., *Rhagodia nutans*, and *Abutilon oxycarpum* often disappear, and unpalatable species increase at the expense of more palatable ones. Grazing also affects regeneration of some woody species. Sheep have been used deliberately to destroy young regrowth of *Acacia harpophylla* (Johnson 1964) with varying success; and regeneration of *A. aneura* may be prevented by grazing at even normal stocking rates. Many eucalypts, particularly *E. populnea*, are difficult to kill by ring-barking or pushing with heavy machinery. They regenerate from adventitious buds on stems and lignotubers and some woodland communities are now denser because of regrowth after clearing than they were initially.

Fire has probably been part of the environment at least since human occupation, though in the more arid parts of the area burning must always have been sporadic as sufficient fuel would be available only occasionally. The effect of fire on some woody species is known. *Callitris columellaris* and *Casuarina cristata* are susceptible to fire and in many cases it is difficult to determine in what quantities they originally occurred in some communities. On the other hand, aerial parts of *Acacia harpophylla* are killed by fire, usually after pulling but occasionally by wild fires, but regrowth from root suckers is so vigorous as to exclude other woody species. Many stands of the *A. harpophylla* examined showed signs of disturbance by fire and it is suspected that many formerly contained some *Casuarina cristata*.

If for some reason an area formerly subject to fire is protected, significant changes may occur. If *Callitris columellaris* seedlings are not destroyed they often form dense thickets 2 m or more high. There is then no ground cover and because of this fires will not spread. The thickets are therefore fireproof except on their edges. Such dense impenetrable stands of *Callitris* are common in the northern part of the area. The dense stand of shrubs in some communities, particularly open-woodland of *E. populnea*, may also be related to protection from fire. Following above average rain in the 1950s a large number of shrubs, especially *Eremophila mitchellii*, became established, possibly because grazing had reduced the competition of perennial grasses. Since that period the shrubs have excluded grasses and consequently there has not been enough material on the ground to carry a fire to reduce the shrubs.

Besides its direct effect on the composition of the ground layer and its ability to carry fire, grazing has probably contributed to soil erosion in the area. This is most marked in woodlands of *Eucalyptus populnea* and *E. populnea–A. aneura*. Grazing by sheep has in many cases led to the elimination of all but the most unpalatable perennials. Topsoil and organic material have been eroded by wind and/or water, leaving a hard-setting surface where regeneration of perennials is impossible. The growth of shrubs on lower slopes may also be increased because of run-on from these bared surfaces.

(*b*) *Major Forms*

Because there is no great variation in climate across the area and because large areas are uniform topographically and geologically there is not a great diversity of vegetation types. The formations range from grassland to tall open-forest but the most extensive are grassland, open-woodland, woodland (covering more than half the area), and open-forest. These formations are defined according to Specht's (1970) scheme which is discussed in subsection (*d*) below. Areas of low woodland, tall open-forest, and softwood scrub, which approximates to semi-evergreen vine-thicket of Webb (1959), are so small that they could well be omitted from this account.

(*c*) *Plant Geography*

Eucalypts are the commonest trees in the area, 25 species being of ecological significance. They predominate in all but one of the open-woodland and woodland communities recognized. Of these, *Eucalyptus populnea* is the commonest and most wide-ranging. As well as its wide geographic range it tolerates a wide range of soils. It is probably most common on duplex soils but is also common on massive earths and is found on brown and grey-brown soils and cracking clay soils. *E. melanophloia* is widely distributed but does not tolerate as wide a range of climatic and soil conditions as *E. populnea*. In the east it tends to be replaced by *E. drepanophylla*.* *E. maculata* occurs with *E. drepanophylla* in the eastern portion. *E. microtheca* is widely distributed mainly in the south of the area. It is confined to alluvial cracking clay soils or occasionally brown and grey-brown soils. Associated with *E. microtheca* in the south but occurring also on duplex soils is *E. largiflorens*, a species much more common in New South Wales. *E. orgadophila* is sporadic in its distribution. It occurs on soils derived from basalt or shales. The range of *E. intertexta* is unusual. It occurs on massive earths and solodic soils in the south of the area (south of a line between "Southwood" and "Tongy") but its range does not coincide with any climatic province.

The genus *Acacia* is almost as important as *Eucalyptus*, not only in the number of species but also in the area in which they predominate. *Acacia harpophylla* is

*Identification of narrow-leaved ironbarks both in the herbarium and in the field is difficult. Specimens of both *E. crebra* and *E. drepanophylla* were collected but the species could not be distinguished with certainty in the field and the name *E. drepanophylla* has been used for both.

dominant in open-forest in the central part of the region and occurs sporadically elsewhere usually on fine-textured soils. *A. aneura* forms open-forest or a distinct layer in woodland of *E. populnea* or *E. melanophloia* on massive earths over about one-third of the area. *A. cambagei* is also a species which forms open-forests but it is confined to the driest part of the region. *A. catenulata* forms open-forests and is confined to shallow soils usually associated with scarps. It is replaced to the north and north-east by *A. shirleyi*. Within the region there are two other species, *A. microsperma* and *A. aprepta*, in pure stands on shallow soils.

Casuarina cristata occurs in open-forest associated with *A. harpophylla* or alone.

There are some species which are of some phytogeographical interest. *Eucalyptus saligna*, *E. melliodora*, and *E. eugenioides* occur on soils derived from basalt at the head of Carnarvon Creek (altitude *c.* 900 m). They reflect the more humid conditions of the area, and their isolation from their nearest stations on the eastern edge of the Darling Downs suggests they are relics of previously more widely ranging populations. *Cadellia pentastylis* is a minor constituent of the vegetation being confined to scarps on weathered rocks south of Morven, near "Amboola", with minor occurrences *c.* 40 km west of Surat and in the Maranoa Range south of Amby. It is the only member of the Simaroubaceae, an Indo–Malesian family, found in arid or semi-arid parts of Australia.

Eremophila mitchellii is common and widespread in a number of communities and is absent only from those occurring on sand. It has probably increased greatly since disturbance by grazing animals. *Geijera parviflora* is also widespread, but is more susceptible to fire and grazing when young and is nowhere a problem.

(*d*) *Classification of Vegetation*

In classifying the vegetation, emphasis has been placed on the distribution of taller woody species rather than on herbaceous species. The distribution of woody species reflects gross factors of the environment such as rainfall and parent material of soils, whereas herbaceous species are influenced to a greater extent by factors, often local in their effect, such as texture of surface soil, degree of shading, and amount of leaf litter. They are also more likely to be eliminated by grazing.

Groups of species, more or less equivalent to formations of Beadle and Costin (1952), are described. The associations recognized are not perfect because species overlap to some extent and some occur across entire environmental gradients. That species respond individually and not as members of groups does not preclude treating the vegetation from the association standpoint. In general, if vegetation is sampled over some environmental gradient it will be possible to demonstrate significant association or dissociation between species. Using the pattern of interspecific associations it is possible to treat the species as members of classes or as continuous variables. One can regard each species either as being a member of a class (e.g. mulga as a member of the class box–mulga woodland or the class mulga open-forest), or as a variable changing in value in relation to some environmental factor (e.g. its distribution could be discussed in terms of soil moisture or soil texture, rainfall, temperature, etc.). The first method is more appropriate to the present survey.

In an account such as this where a large region is covered it is more convenient to discuss associations rather than individual species. That there are well-defined species groups is confirmed by analysis of floristic data from the whole area. Computer classification of the vegetation data using only the species lists from field observations was undertaken in collaboration with Dr M. P. Austin and confirmed the subjectively recognized vegetation associations with very few minor exceptions.

The associations have been arranged in formations according to a scheme proposed by Specht (1970). To avoid a lengthy and complex account unusual vegetation types, either associations or formations, have been treated in related more common types. There are several difficulties in using Specht's classification. The accurate measurement of projective canopy cover would require considerably more time at each sampling site than allowed and consequently this was estimated, drawing on experience in classification of vegetation types in other parts of Queensland. Communities in which there is an upper open tree layer and a dense lower layer present another problem. In general they can be regarded as either layered open-woodland with a dense lower stratum or as open-forest with emergents. If there are fewer than 25 emergent trees per hectare these communities have been classed as open-forest, if more than 25, as woodland. The distinction between grassland and grassy open-woodland depends on grassland having fewer than 25 trees per hectare.

Because of this arbitrary decision the structural and floristic differences between some communities are slight. This is especially true of woodland and open-forest communities in which *Acacia aneura* or *Callitris columellaris* predominates.

The classification of layered communities is further complicated by the fact that the composition of the lower tree layer often shows continuous variation. This is most obvious in communities containing *Acacia aneura* with *Callitris columellaris* and *C. columellaris* with *Casuarina luehmannii.* The distinction between a woodland with a lower stratum of *A. aneura* and one with a lower layer of *Callitris columellaris* or between one with a lower layer of *C. columellaris* and one with a lower layer of *Casuarina luehmannii* is sometimes quite arbitrary. I have been guided by my estimates of the biomass contributed to the community by each species.

(*e*) *Vegetation and the Land Systems*

One vegetation type predominates in each of the land systems recognized and the map of land systems also serves as a map of the vegetation of the region. The second half of the land system titles is an abbreviation of the common name for the dominant vegetation (Table 2). Minor vegetation types in each land system can be derived from the descriptions of land systems and land units.

Grassland of *Astrebla* spp. predominates in SuD land system which forms a discontinuous area in the central part of the area; it is also a major component of AC land system, especially in the south, and occurs in AX and ABb in the north-west as well. Open-grassland is nowhere extensive and often appears to be the result of degradation of tree communities following clearing.

Open-woodland of *Eucalyptus microtheca*, confined to alluvial fine-textured soils, makes up much of land systems AC and Af. In the latter, shrubs of *Muehlenbeckia cunninghamii* and *Acacia stenophylla* are common. Open-woodlands of *E.*

orgadophila and *E. melanophloia* often occur together. *E. orgadophila* is more common in SuMc and BhMc land systems and as a minor component of SuD land system, whereas *E. melanophloia* is common in BuI land system. *Angophora costata* and *A. melanoxylon* both occur in open-woodland communities, the former predominantly in QuA land system in the hilly northern part of the area and also in (S)uBu land system south of the Moonie River. Open-woodland of *A. melanoxylon* is characteristic of a distinctive unit of CpCp land system between Bollon and St. George. *Angophora* communities often contain considerable quantities of *Callitris columellaris* and grade into open-forest of this species.

The most extensive community is woodland of *E. populnea*, usually with a shrub or lower tree layer. Open-woodland of *E. populnea* also occurs but is of minor importance. It is a unit of SuD land system, often with considerable *E. melanophloia*, and of the AC land system near Bollon. Woodland with a shrub layer of *Eremophila mitchellii* is common in (S)uX, SrX, and AX land systems and is less important in others. Several species form definite lower tree layers in *Eucalyptus populnea* woodland. These usually also form dense communities (open-forest) with only scattered eucalypts. On plains in the central part of the region west of the Maranoa River, *Acacia aneura* is a significant element of the vegetation and woodland of *E. populnea* and *A. aneura* occupies large parts of (S)uXM, AXM, and (S)rXM land systems. The density of *A. aneura* varies considerably, probably due to human interference, direct and indirect. In CpBXM land system in the extreme south-west, *A. aneura* and *A. harpophylla* occur together in *E. populnea* woodland. Open-forest of *A. aneura*, as well as occurring in small stands in *E. populnea–A. aneura* woodland, dominates (S)uM land system north-east of St. George and near the western edge of the area. Apart from *A. aneura* the species most commonly associated with *E. populnea* is *Callitris columellaris*. They form layered open-forests chiefly in QrCp land system but occupy smaller areas of other land systems. Open-forest of *C. columellaris*, usually with scattered eucalypts, predominates in QrCp and ACp land systems. *Casuarina luehmannii* is often found with *Callitris columellaris* in the eastern part of the area and *E. populnea–Casuarina luehmannii* layered woodland is widespread in (S)uBu land system. Woodlands of *E. populnea* with lower layers of *C. cristata* and *A. harpophylla* are widely spread in (S)uXB land system and to a lesser extent in (S)uBl land system. They grade into open-forests of either *C. cristata* or *A. harpophylla*.

The ironbarks, *E. drepanophylla* and *E. melanophloia*, also predominate in some woodland communities. *E. melanophloia* with *A. aneura*, *Callitris columellaris*, or *Casuarina luehmannii* are usually closely associated with similar communities containing *E. populnea*. In the north-east *E. melanophloia* tends to be replaced by *E. drepanophylla* which, however, forms a distinctive community with a lower layer of shrubs, mainly *Acacia* spp. in (S)rNi land system. *E. drepanophylla–Casuarina luehmannii* woodland is widespread in (S)uBu land system. In QhMe land system there is a floristically and structurally complex mixed eucalypt woodland similar to communities developed on sandstone to the north and north-east. Woodland of *E. largiflorens* which is extensive in New South Wales is found only in ABb land system in the south-west.

Except for locally dense patches of *E. drepanophylla* and *E. maculata* in (S)rNi land system in the extreme north-east, eucalypts do not form open-forests. As well

Table 24

NUMBER OF OCCURRENCES OF VEGETATION COMMUNITIES IN RELATION TO SOIL TYPE

(Based on 915 sites)

Vegetation	Soils																																					
	Aa	Ab	Ac	Ba	Bb	Bc	Bd	Be	Bf	Ca	Cb	Cc	Cd	Ce	Cf	Da	Db	Dc	Dd	De	Df	Dg	Dh	Di	Dj	Ea	Eb	Ec	Ed	Ee	Ef	Eg	Fa	Fb	Fc	Fd	Fe	Ga	Gb
Grassland																																							
Astrebla								1				16	2	12	1																								
Open			1					2						1									3	3															
Low open-woodland																																							
Atalaya hemiglauca and *Flindersia maculosa*								1															2	1															
Acacia harpophylla						1	1			1	2			1	1		1																						
Open-woodland																																							
Eucalyptus microtheca			1					9		1				36										1										2					
E. orgadophila									3			3			3																								
E. melanophloia							1		1			1			2																								
E. populnea						1	2				2	2				2							3														1		
Angophora melanoxylon																																	5	4			1		
Angophora costata																						1				1			1							2	3		
E. tessellaris								1																1	4						1		6						
Woodland																																							
E. largiflorens								1		1				2			1	1						1															
E. populnea, Callitris columellaris		1		2		1										6		2	7	5	7	12	1	1	2	4		4	1	1	2		3	1	1				
E. populnea, Casuarina luehmannii																			4	1																	1		
E. populnea, Acacia aneura										1						3		1			3				1	23	20	10	2	2	1	6							2
E. populnea, A. harpophylla				2	5	7				2	1					11	5	5	2	1				1	1	2		1			.								1
E. populnea, Eremophila mitchellii				1	1	3	2	1	2							25	9	9	6		1	3	7	4	2	25	2	9		2		2	1				1		1
E. populnea grassy woodland		2		1		1		3						3		1	3	1				1	3	6	1	3				3	3							1	
E. melanophloia, C. columellaris					1		1									1	1	1		1	2	5			1	5	4		3	3	1	2	11	1	1	3	2		2
E. melanophloia, A. aneura																	1									13	5		2	2		4	1						
E. melanophloia, C. luehmannii																		1				1							1										
E. melanophloia grassy woodland	1	1			1		1	2	1						1			2				1		1		9	3	2	7	3		1	1			1	1		2

E. drepanophylla, C. columellaris																	1				3				2						3			2	1			
E. drepanophylla, C. luehmannii																	1		3																			
E. drepanophylla grassy woodland																	4		1						1				2		2							1
Casuarina cristata							1				2																											
E. thozetiana and *E. microcarpa*				1	2	2					1							5		1						1													2
E. saligna									1																														
Mixed eucalypt woodland																														2					2		1	2	
Open-forest																																							
C. columellaris																				1	1	7												2	2	4	5		
A. aneura	1																1									13	2		1				2						1
A. harpophylla				3	2	4	1		2	16	10					10	3		1							1		1											
C. cristata				1	6	8		2		12	8			5		22	4	3	4									2			1								2
A. cambagei					1			3						2		1										1		4											
A. catenulata, A. shirleyi, and *A. microsperma*				1					1																	2						10	1						12
Scrub																																							
Semi-evergreen vine thicket									3																														1

as the open-forests of *Callitris columellaris* and *A. aneura* already mentioned the most important are those of *A. harpophylla* and *Casuarina cristata*. Open-forest of *A. harpophylla* is the dominant community in (S)uXB land system. Many stands show evidence of disturbance by fire and *C. cristata* may once have been a more important component than at present. *C. cristata* open-forests predominate in (S)uBl land system in the south-eastern and southern parts of the area. The replacement of open-forest dominated by *A. harpophylla* by those dominated by *C. cristata* seems to occur a little east of the Balonne River. *C. cristata* is in turn replaced by *A. cambagei* of CpG land system in the south-west.

Scarps formed on weathered rock in the central part of the area support distinctive communities often in complex mosaics. Open-forest of *A. catenulata* ((S)rBe land system) is the most widespread. This is replaced in the north-east by open-forest of *A. shirleyi*. Near Glenmorgan and Yuleba such sites are occupied by *A. aprepta* and near "Bonus Downs" by *A. microsperma*, all in (S)rBe land system. Often in close proximity, or a part in (S)hY land system, are woodlands of *E. thozetiana* or *E. microcarpa*.

Tall open-forest and closed-scrub (softwood scrub) are important in BtS and ShSw land systems respectively but occupy only a relatively small proportion of the whole area.

Plants recognized in the survey area, with their common names, are listed in Appendix I. Most common names have been taken mainly from Everist (1949, 1969). The nomenclature of Johnson and Marryat (1965) has been followed for the eucalypts.

II. Description of Vegetation

The relationship of vegetation communities to soil type is portrayed in Table 24.

(*a*) *Grassland*

(i) Astrebla *Grassland*.—This is tussock grassland, occasionally with scattered *Eucalyptus microtheca*, *E. populnea*, *E. melanophloia*, *E. orgadophila*, and low *Acacia farnesiana* and *A. victoriae*, with basal cover of about 3%, but it is extremely variable. *Astrebla* spp. occur in all stands except those that have been severely grazed. *A. lappacea* is the commonest species with *A. elymoides* and *A. squarrosa* only occasional. *Aristida leptopoda* occurs in most stands and predominates in some. Other species of note are *Thellungia advena*, *Malvastrum spicatum*, *Panicum decompositum* (especially in areas subject to flooding), *Iseilema* spp., *Bassia tetracuspis*, and (in the south) *Sporobolus mitchellii*. *Dichanthium* spp. occur in moister situations, especially near Roma, but are not common.

Under heavy grazing the proportion of *Aristida leptopoda* increases while that of *Astrebla* spp. declines. Higher grazing pressure particularly in areas of low rainfall may give rise to a preponderance of *Bassia tetracuspis*, and if continued a community consisting mostly of short-lived forbs (mainly *Bassia* spp.) develops. This is similar to the open-grassland described below.

Astrebla grassland is often interspersed with open-woodland of *Eucalyptus populnea* or *E. microtheca*.

(ii) *Open-grassland*.—The basal cover is extremely low. *Tripogon loliiformis* is constant. The only other species at all constant are *Sporobolus actinocladus*, *Bassia* *diacantha*, and *B. quinquecuspis*. In favourable seasons annuals are probably common. The community occurs on alluvial duplex soil in the south-west of the area. In some places it may have been derived from communities containing *Eucalyptus populnea*, *Flindersia maculosa*, or *Acacia cambagei*, but wind and sheet erosion are so severe that reversion to the original vegetation type is most unlikely under present conditions.

(*b*) *Low Open-woodland*

(i) Flindersia maculosa *Community*.—This occurs on alluvial soils mainly in the south-west of the region. The upper stratum 7–9 m tall consists of *Flindersia maculosa* and less common *Atalaya hemiglauca*. Scattered shrubs, commonly *Eremophila mitchellii* 2–3 m tall, are sometimes present. The ground cover is sparse, in composition resembling forbfield. *Tripogon loliiformis* and *Bassia diacantha* are the commonest species.

The community is subject to intense wind and sheet erosion and when disturbed may be degraded to forbfield.

(ii) Atalaya hemiglauca *Community*.—The community occurs on fine-textured soils adjacent to grassland mainly near Surat and Roma. There is a single layer of trees 7–9 m tall of *Atalaya hemiglauca*. *Bauhinia carronii* is an important constituent near Surat and there may be some *Acacia harpophylla*. The ground cover is similar to that of *Astrebla* grassland but where it is heavily grazed *Atriplex semibaccatum*, *A. muelleri*, and *Bassia tetracuspis* usually replace grasses.

(iii) Acacia harpophylla *Community*.—It is a minor community confined to clay soils in the extreme south-west of the area. The single tree layer is up to about 9 m tall and consists of *A. harpophylla* with occasional *Eucalyptus populnea*. There are no shrubs. The ground cover is sparse and consists of *Astrebla* spp. and forbs, mainly *Atriplex muelleri*, *Bassia diacantha*, *Sida trichopoda*, *Solanum esuriale*, and *Enchylaena tomentosa*.

(*c*) *Open-woodland*

(i) Eucalyptus microtheca *Community*.—This is widespread in the southern part of the area on deep cracking clay soils or alluvium. Occasionally it is woodland rather than open-woodland. The trees are 9–15 m, occasionally to 18 m, and are predominantly *E. microtheca* with occasionally scattered *E. populnea*, *E. largiflorens*, *Casuarina cristata*, or *Acacia pendula*. Shrubs do not usually occur but on the areas waterlogged for long periods there may be a moderately dense to dense shrub layer of *A. stenophylla* with occasional *Eremophila bignoniiflora*. In ecotones with communities containing *Eucalyptus populnea* or *Casuarina cristata* a shrub layer of *Eremophila mitchellii* is usually developed.

The ground cover is usually moderately dense and similar to that of *Astrebla* grassland with *Astrebla lappacea* predominant and less frequent *Paspalidium jubiflorum* and *Thellungia advena*. *Dichanthium* spp. and *Cyperus bifax* may occur in wetter areas. Near the Balonne downstream from St. George in areas subject to flooding, *Panicum decompositum* is common. In the south of the area *Eragrostis setifolia* and *Sporobolus mitchellii* predominate. *Bassia tetracuspis* often occurs.

When heavily grazed, perennial grasses disappear and species of *Bassia* become more conspicuous, especially *B. tetracuspis* and in the south *B. paradoxa* and *B. calcarata*. Occasionally only annuals such as *Atriplex muelleri, Malvastrum spicatum,* and *Calotis scabiosifolia* are found.

(ii) Eucalyptus orgadophila *Community*.—This community occurs sporadically in the east and north central parts of the region on cracking clay soils derived from fresh labile sediments or basalt. It is usually associated with grassland but in the Inglestone–"Coomrith" area there is a fairly large area without grassland.

The trees are usually 12–20 m tall, consisting of *Eucalyptus orgadophila* with occasional *E. populnea*, with a moderately dense ground cover of *Astrebla* spp., *Dichanthium* spp., *Aristida leptopoda*, and *Panicum decompositum*. In the "Coomrith" area the community is usually denser, sometimes almost woodland, with a lower layer of *Casuarina cristata* and *Acacia harpophylla* and a patchy shrub layer of *Geijera parviflora*. Here the species characteristic of *E. populnea* and *E. melanophloia* woodlands such as *Aristida ramosa, Chloris acicularis,* and *Ancistrachne uncinulatum* predominate in the ground layer though *Dichanthium* spp. and *Astrebla* spp. do occur.

(iii) Eucalyptus melanophloia *Community*.—It occurs on cracking clay soils derived from labile sediments or basalt in the north of the region, but is not extensive. The trees are 10–15 m tall. *E. melanophloia* and occasional *E. orgadophila* are the constituents of the upper stratum; shrubs and lower trees are not common. The ground cover is usually moderately dense. On basalt *Dichanthium* spp. and *Thellungia advena* predominate and on shales *Aristida latifolia* is usually most common.

(iv) Eucalyptus populnea *Community*.—There are two facets to this community, one on duplex and cracking clay soils derived from slightly weathered sediments (Roma–Wallumbilla area) and the other on alluvial duplex and cracking clay soils of the Balonne near St. George and near Bollon. The first facet consists of a tree layer of *E. populnea* often with a high proportion of *E. melanophloia*, or *E. melanophloia* alone. The trees are usually 10–16 m tall, with lower trees and shrubs absent or with scattered *Eremophila mitchellii*. *Acacia pendula* sometimes forms a rather dense layer of low trees. The ground cover is moderately dense and consists mostly of plants characteristic of *Astrebla* grasslands, namely *Astrebla* spp., *Thellungia advena*, *Sporobolus actinocladus*, *Aristida leptopoda*, *A. platychaeta*, and less commonly *Dichanthium* spp. and *Malvastrum spicatum*.

The second facet usually has an open tree layer *c.* 10 m tall beneath the box layer which is 12–14 m tall. A patchy shrub layer up to 2 m tall of *Scaevola spinescens, Rhagodia parabolica,* and *Eremophila mitchellii* usually occurs. Ground cover is sparse, consisting of *Bassia* spp. (*B. tricuspis*, *B. diacantha*, and *B. calcarata*), *Eragrostis setifolia*, and *Tripogon loliiformis*. Severe sheet and wind erosion often occur and then the ground cover often consists solely of *Tripogon loliiformis*.

(v) Angophora melanoxylon *Community*.—This is a distinctive community restricted to uniform sandy soils in small areas between St. George and Bollon. There are scattered trees, up to 25 per hectare, 12–15 m tall, of *Angophora melanoxylon*, and less common *Eucalyptus melanophloia* and *E. dealbata*. More scattered trees of *E. polycarpa* and *E. intertexta* sometimes occur. *Callitris columellaris* sometimes forms rather dense stands.

Shrub layers are usually well developed. *Acacia* sp. aff. *lineata* and *Grevillea parallela* commonly form a rather dense shrub layer *c*. 3 m tall and *Calytrix tetragona*, *Leucopogon mitchellii*, and *Dodonaea* spp. a lower shrub layer *c*. 1 m tall.

Ground cover is extremely open. *Triodia mitchellii*, *Aristida browniana*, *A. echinata*, *Amphipogon caricinus*, *Eragrostis lacunaria*, and *Digitaria ammophila* are most common.

The community is being continually modified by fire. In frequently burnt areas trees are more scattered, only 8 m tall with several stems, while the shrub layers are dense. The community might then be classified as heath with scattered emergents, but if not burnt the shrubs become more open and the emergent trees denser. If protected from fire for a long period *Callitris columellaris* reaches significant proportions.

(vi) Angophora costata *Community*.—Extensive areas of this community occur in the north of the area and south of the Moonie River west of Westmar. It is restricted to uniform sandy soils. Fire has greatly affected its structure and composition. The community has two facies depending on whether or not it has been protected from fire.

In both facies there is a tree layer 18–22 m tall of *Angophora costata* with occasional *Eucalyptus melanophloia* and *E. dealbata*. In the north *E. phaeotricha* and *E. bloxsomei* occur but both are restricted in their ranges. In one facies the lower tree layer is moderately dense but patchy, 9–15 m tall, of *Callitris columellaris* often with some *Casuarina luehmannii* and, in the north of the area, *Lysicarpus angustifolius*. Sometimes there is a moderately dense varied shrub layer including *Dodonaea* spp., *Leucopogon* spp., *Jacksonia scoparia*, and *Xylomelum pyriforme*. The incidence of shrubs depends on the thinning of the tree layer by fire.

The lower tree layer of the other facies is open and only 4–8 m tall. *Lysicarpus angustifolius* is common in the north and *Casuarina inophloia* in the south. The shrub layer is quite often dense. It is rich in species, some of which predominate over quite small areas. *Xanthorrhoea* spp. are widespread and *Acacia gnidium* is conspicuous in the south. Periodic burning influences the composition of the shrub layer and may sometimes remove it completely at least for a time.

The ground cover of the community (both facies) is sparse. *Triodia mitchellii* is often dominant. It is often reduced by fire and *Aristida muricata*, *A. ingrata*, *A. browniana*, *Panicum effusum*, and *Eremochloa bimaculata* are then conspicuous.

(vii) Eucalyptus tessellaris *Community*.—The community is found on rather loose uniform sandy soils on river levees and on reworked material from levees in the drier parts of the region.

The trees range from 18 to 30 m tall with less than 25 trees per hectare. *E. tessellaris* is usually the sole member of this layer though *E. polycarpa* occurs occasionally. Usually there is a rather dense lower tree layer, 12–15 m tall, of *Callitris columellaris* and occasional *E. dealbata*, *E. melanophloia*, and *Angophora melanoxylon*. Rarely are there no lower trees. Shrubs are sporadic, *Alstonia constricta*, *Canthium oleifolium*, and *Acacia murrayana* being most common. Ground cover is low, *Aristida echinata* is most common and is occasionally moderately dense. Other species are *Paspalidium constrictum*, *Chrysopogon fallax*, and *Bothriochloa decipiens*.

The community is often much disturbed by the removal (sometimes complete) of *Callitris columellaris* by fire. Grasses are then thicker, *A. echinata* becoming dense. Periodic burning of this ground layer prevents any establishment of *Callitris columellaris*.

(*d*) *Woodland*

There is considerable intergrading among the woodland communities recognized, both among themselves and with other formations. Small areas of open-woodland or open-forest occur, but if large areas are floristically uniform and predominantly of one structural type these minor areas have been disregarded.

(i) Eucalyptus largiflorens *Community*.—This is a widely spread community in New South Wales (Beadle 1948) but in the area surveyed it is restricted to cracking clay and brown and grey-brown soils in the south-western part.

The upper layer is 10–13 m tall with 75–125 trees per hectare. *E. largiflorens* is commonest but *E. microtheca*, *E. populnea*, *Acacia harpophylla*, or *A. cambagei* occur occasionally. There is sometimes a low shrub layer of *Muehlenbeckia cunninghamii* or *Rhagodia parabolica*. Taller shrubs are usually absent, except in communities somewhat transitional to woodland of *E. populnea* when *Eremophila mitchellii* occurs. The ground cover is sparse. *Eragrostis setifolia* is common and constant. Other species are sporadic in their occurrence, the only ones of note are *Bassia diacantha*, *B. tricuspis*, and *Sporobolus caroli*.

(ii) Eucalyptus populnea *Communities*.—Woodland in which *E. populnea* predominates is the most widespread formation in the area. Often it is distinctly layered and may be subdivided according to the commonest species in the lower tree layer. In some cases these lower-storey communities (synusia) intergrade with each other and with similar synusia of other woodland communities. *E. intertexta* occurs with, or slightly upslope of, *E. populnea*. The two species could not be distinguished on the aerial photographs used and consequently they could not be mapped separately. *E. intertexta* has therefore been included in the *E. populnea* communities.

(1) Woodland of *E. populnea* with understorey of *Callitris columellaris*.—This is widespread on duplex and brown and grey-brown soils usually on lower slopes. It is absent from the alluvium in the southern part of the area and from the western part of the country in which *Acacia aneura* is common.

The canopy is 13–18 m high with up to 250 trees per hectare and a lower tree layer 10–13 m tall, usually about three-quarters as tall as the canopy. The lower tree layer may be patchy and is much affected by fire. Shrub layers are sometimes well developed.

Besides *Eucalyptus populnea* (or *E. intertexta*), *E. melanophloia* occurs in about one-quarter of the stands and *E. dealbata* occurs occasionally. *Casuarina luehmannii* may be prominent in the *Callitris* layer. Other trees of lesser importance in this layer are *Heterodendrum oleifolium* and *Acacia excelsa*. A shrub layer, in some cases dense and up to 9 m tall, is developed in about half of the stands examined. *Eremophila mitchellii* and *Geijera parviflora* are common and constant. *Carissa ovata* and *Capparis lasiantha* sometimes form a low shrub layer, dense in patches. Other shrubs occur sporadically, *Dodonaea attenuata* being most important.

Ground cover is usually sparse. *Bothriochloa decipiens* and *Aristida ramosa* are common in most stands except where the surface soil is loose when *A. echinata* is most common. *A. ramosa* tends to be replaced by *A. jerichoensis* in drier areas. Other species frequently found but usually of less importance are *Chloris ventricosa, C. acicularis, Eragrostis lacunaria, Aristida caput-medusae*, and *Paspalidium constrictum*, the last being susceptible to heavy grazing. In areas subjected to sheet erosion *Tripogon loliiformis* colonizes bare areas and *Bassia birchii* may be conspicuous.

(2) Woodland of *Eucalyptus populnea* with understorey of *Casuarina luehmannii*.—Though commonest in the east of the region the community also occurs sporadically, mainly in the north. It usually occurs on duplex soils with columnar-structured B horizons.

The canopy of *E. populnea* (rarely *E. intertexta*), occasionally with some *E. drepanophylla*, is 10–15 m high with an open to dense lower layer of *Casuarina luehmannii* 4–12 m tall. Often *Callitris columellaris* is also common in this layer. A shrub layer which is sometimes dense occurs occasionally, *Eremophila mitchellii* being the most common and constant species. No species of the sparse ground cover is common throughout but *Aristida ramosa, A. caput-medusae, Bothriochloa decipiens*, and *Eragrostis lacunaria* occur at most sites.

(3) Woodland of *Eucalyptus populnea* with understorey of *Acacia aneura*.—Large areas occur in the south-western part of the region. On its eastern margin it is confined to upper slopes but elsewhere it and open-forest of *A. aneura* occupy all parts of the landscape. Its distribution possibly depends on the amount of winter rain. On its eastern margin *A. aneura* is replaced by *Eremophila mitchellii* and competition between these two is probably important throughout the range of mulga, especially where the original vegetation has been disturbed.

The upper tree layer of *Eucalyptus populnea* usually has 50–75 trees per hectare, averaging 15 m tall but often no more than 12 m in the west on shallow massive earths on slopes of stony hills and sometimes attaining 19 m in the east. *E. melanophloia* and, within the range of that species, *E. intertexta* are occasionally components of the upper stratum. The lower tree layer is rather open to moderately dense, averaging 12 m tall, sometimes only slightly lower than the upper stratum. This layer rarely contains any species other than *Acacia aneura*.

A shrub layer is sometimes present, though not when the mulga is uniform and at least moderately dense. In open and disturbed communities, however, the shrub layer may be dense, consisting of *Eremophila mitchellii* with occasional *Geijera parviflora* throughout the community in the eastern half of the area and on lower slopes in the west. On upper slopes scattered *Cassia nemophila* sometimes forms dense stands. *Eremophila glabra* occurs sporadically in the west.

Where the tree layers are dense the ground cover is open but it is denser in disturbed areas. *Neurachne mitchelliana* is widespread and common. *Aristida jerichoensis* is also widely distributed and becomes denser on heavily grazed areas. Other grasses, either widespread or common in places, are *A. leichhardtiana, Bothriochloa decipiens, Chloris acicularis, Danthonia bipartita, Digitaria brownii, Eragrostis lacunaria, Enneapogon gracilis, Paspalidium constrictum, Themeda australis*, and in the south-west *Eragrostis eriopoda*. Forbs are more prominent in the ground flora than in most other communities. The important are *Bassia diacantha*, *B. convexula*, *Hibiscus sturtii*, and *Sida brachypoda*. *Cheilanthes sieberi* is also common. In many places heavy grazing followed by sheet erosion has produced a hard-setting soil surface bare of grasses and forbs except for *Tripogon loliiformis* and in places *Phyllanthus* sp.

(4) Woodland of *Eucalyptus populnea* with lower storey of *Acacia harpophylla* and/or *Casuarina cristata*.—This is a widespread community though absent from the western part of the area of *Acacia aneura* and from the quartzose sandstone area in the north. It occurs on brown and grey-brown soils and on mosaics of duplex soils or massive earths and gilgaied cracking clay soils. Structurally and floristically it is intermediate between *E. populnea–Eremophila mitchellii* woodland and *Acacia harpophylla–Casuarina cristata* open-forests, but it occurs apart from these and warrants separate discussion.

The tallest stratum is 15–18 m tall and consists of *E. populnea* (25–75 trees per hectare) either alone or with *A. harpophylla* and/or *Casuarina cristata*. The lower tree layer ranges from 8 to 14 m tall and consists of *A. harpophylla* or *C. cristata* or both. When *C. cristata* and *A. harpophylla* occur together one may form the tallest stratum with *E. populnea* or both may constitute the lower tree stratum. A moderately dense shrub layer 3–8 m tall is usually present. *Eremophila mitchellii* is the most constant and common species, usually with *Geijera parviflora*. Another lower shrub layer, up to 2 m tall, may be present and is sometimes dense. Commonest components are *Carissa ovata* and *Capparis lasiantha*. Other species either somewhat constant or common in some stands are *Myoporum deserti* and *Cassia nemophila*.

The ground cover is usually sparse and in composition is related to the ground cover of *Eucalyptus populnea–Eremophila mitchellii* woodland and *Acacia harpophylla–Casuarina cristata* open-forest. *Aristida ramosa*, *Chloris acicularis*, *Paspalidium gracile*, and *P. radiatum* are the commonest and most constant species. Other plants of significance are the grasses *Bothriochloa decipiens* and *Chloris ventricosa* and the forbs *Bassia birchii*, *Kochia tomentosa* var. *tenuifolia*, and *Rhagodia nutans*.

(5) Woodland of *Eucalyptus populnea* with shrub layer of *Eremophila mitchellii*. —Its distribution is similar to that of the previous community and it is especially common in the Talwood–Nindigully area. It occurs mainly on duplex soils and massive earths.

The upper layer is predominantly *Eucalyptus populnea*, 50–200 trees per hectare, 10–20 m tall. The only other species of note in this stratum is *E. melanophloia*. Lower trees are not common, *Acacia excelsa* and *Heterodendrum oleifolium* being noteworthy. There is an open to dense (up to 1200 plants per hectare), often patchy shrub layer. *Eremophila mitchellii* is almost invariably present and is usually common. *Geijera parviflora* is less constant and common and *Canthium oleifolium* occurs only occasionally. Where the shrub layer is more than about 6 m tall there may be a layer of lower shrubs, patchy and varying in density. *Carissa ovata*, *Cassia nemophila*, and *Dodonaea attenuata* are the commonest of these.

The density of the ground cover depends on the density of the higher strata, dense in open communities but often sparse to only moderately dense. *Bothriochloa decipiens* is the commonest species though it is absent from some areas. *Chloris acicularis*, *Aristida ramosa*, and in drier parts *A. jerichoensis* are also common and fairly constant. Other widespread (locally common) species *Chloris ventricosa*, *Paspalidium constrictum*, *Eragrostis lacunaria*, *Aristida echinata*, *Chrysopogon fallax*, *Enneapogon gracilis*, and *Neurachne mitchelliana* are of less importance; the latter occurs mainly where the community adjoins woodland containing *Acacia aneura*.

In shaded situations *Ancistrachne uncinulatum*, *Paspalidium gracile*, and *P. radiatum* sometimes predominate.

On sheet-eroded areas or in places bared by heavy grazing, *Tripogon loliiformis* forms an extremely open ground cover.

Forbs are not major constituents of the stratum but in places *Brononiella australis* and *Bassia* spp. are common. In heavily grazed areas on roadsides and near watering points, particularly in periods of low summer rainfall, *Bassia birchii* is common and sometimes forms dense stands. *Kochia tomentosa* var. *tenuifolia* occurs in similar situations.

(6) Grassy woodland of *Eucalyptus populnea*.—Nowhere is the community extensive. It occurs on duplex soils throughout the area but is of limited extent in the north where the coarser alluvium carries *Callitris columellaris*, *Eucalyptus melanophloia*, and *Angophora floribunda* rather than *E. populnea*. Areas without shrubs occur in the other woodlands of *E. populnea*, but these are believed to be the result of some disturbance of the original community.

The trees are mainly *E. populnea* 15–18 m tall, sometimes in the Roma–Dulacca area up to 21 m and west of "Homeboin" as low as 12 m. *E. melanophloia* is sometimes an important constituent and on the headwaters of the Maranoa *Angophora floribunda* is conspicuous. *Acacia pendula* up to 12 m high sometimes forms groves.

The ground cover is well developed. *Bothriochloa decipiens* is usually common and is most constant. *Themeda australis*, *Aristida ramosa*, and *Chloris acicularis* are also common and fairly constant. Within the range of *Acacia aneura*, *Aristida jerichoensis* tends to replace *A. ramosa* and in the north *A. muricata* is conspicuous. On severely grazed areas *Bassia birchii* may form dense stands and on stripped eroded areas *Tripogon loliiformis* often occurs.

(iii) Eucalyptus melanophloia *Communities*.—These are closely related in structure and composition to communities containing *E. populnea*, and grade into them. They do occur separately, however, and are sufficiently widespread to warrant separate treatment.

(1) Woodland of *Eucalyptus melanophloia* with lower storey of *Callitris columellaris*.—This is a widespread community usually on upper slopes, particularly common in the north of the region but more or less absent from the north-east where it is replaced by a similar community with *Eucalyptus drepanophylla* in the upper storey.

The upper stratum is 12–18 m tall with trees up to 125, occasionally 175, per hectare. The lower tree layer ranges from open to dense, often patchy due to disturbance, and ranges from 9 to 12 m tall and may equal the upper storey. A tall shrub layer (to 8 m) is sometimes developed.

Besides *E. melanophloia*, *E. populnea* often occurs in the upper storey, *E. polycarpa* sometimes, and less commonly *E. tessellaris* and *E. dealbata*. In the lower tree layer *Callitris columellaris* predominates, the only other species at all frequent are *Acacia excelsa* and *A. aneura* or, where disturbed by fire, *A. burrowii*. *Geijera* *parviflora* is the commonest tall shrub, though *Eremophila mitchellii*, *Notelaea microcarpa*, and *Canthium oleifolium* also occur. Shrubs such as *Hovea longipes*, *Dodonaea attenuata*, and *Acacia cunninghamii* may be conspicuous where the community has been recently disturbed.

The ground cover is usually sparse. *Aristida jerichoensis* is the commonest and most constant grass. *A. echinata*, *A. arenaria*, *Chrysopogon fallax*, *Paspalidium constrictum*, and, in the north, *A. muricata* are important constituents. On hard-setting duplex or gravelly massive earths (possibly eroded) *Eriachne mucronata* is often common. Where the community grades into communities in which *Acacia aneura* is conspicuous *Neurachne mitchelliana* often predominates.

(2) Woodland of *Eucalyptus melanophloia* with lower storey of *Acacia aneura*.—The community occurs throughout the range of *A. aneura*, usually on upper slopes where it sometimes grades into open-forest of *A. catenulata*. The community tends to be replaced in the St. George–Bollon area by a similar *E. intertexta–A. aneura* woodland which has been considered with *E. populnea*.

The upper stratum averages about 15 m but ranges from 12 m near "Marlee Downs" to 22 m, with up to 125 trees per hectare. *E. populnea* often occurs with *E. melanophloia* in the upper stratum. The lower tree layer is open to moderately dense and ranges from 9 to 13 m tall. Shrubs occur but only rarely form a moderately dense layer. *Cassia nemophila* is most common. The ground cover is similar to that of the *E. populnea–A. aneura* woodland except that *Eriachne mucronata* is common in some stands.

(3) Woodland of *Eucalyptus melanophloia* with lower storey of *Casuarina luehmannii*.—This community is of only minor importance. It occurs with *C. luehmannii–E. populnea* woodland which it resembles in structure and range.

The predominant tree is *E. melanophloia* with occasional *E. populnea*. The lower tree layer is open to dense, 7–10 m tall, and consists of *Casuarina columellaris*. Shrubs are usually absent but *Eremophila mitchellii* sometimes occurs in clumps. The ground cover is sparse. *Aristida ramosa*, *A. jerichoensis*, *Bothriochloa decipiens*, and *Eragrostis lacunaria* are most common.

(4) Grassy woodland of *Eucalyptus melanophloia*.—The community is widespread, though absent or rare on alluvium and within the range of *Acacia aneura*. It is most extensive near "Noondoo". It occurs mainly on loamy or sandy massive earths and rarely on brown and grey-brown soils derived from sedimentary rocks. Where it abuts on communities containing *A. aneura* or *Callitris columellaris* it is difficult to determine whether these ever occurred in the community.

The upper stratum is 12–18 m tall with 25–200 trees per hectare. *E. melanophloia* is usually the only species in the upper stratum but *E. populnea* and *Brachychiton populneum* may be constituents. *Acacia excelsa*, *Canthium oleifolium*, and *Geijera parviflora* sometimes form a very open lower tree layer 6–10 m tall, and *A. burrowii* occasionally forms dense stands possibly only in communities that have been severely burnt. There is sometimes a moderately dense shrub layer of *Eremophila mitchellii* or less frequently *Cassia nemophila*.

On the fine-textured soils derived from sedimentary rocks there are usually no subordinate strata.

The ground cover is usually sparse to moderately dense. *Bothriochloa decipiens*, *Aristida jerichoensis*, *A. echinata*, and *Neurachne mitchelliana* are the commonest and most widespread species. Other fairly constant but less common species are *Panicum effusum*, *Chrysopogon fallax*, *Eragrostis lacunaria*, *Themeda australis*, *Enneapogon gracile*, *E. pallidus*, and *Digitaria brownii*. Along drainage lines (south of "Carnarvon") on coarse-textured soils *Eremochloa bimaculata* and *Sorghum leiocladum* are common.

(iv) Eucalyptus drepanophylla *Communities*.—*E. drepanophylla* replaces *E. melanophloia* in the north-east of the area and these communities are more or less equivalent to those in which *E. melanophloia* predominates.

(1) Woodland of *Eucalyptus drepanophylla* with lower storey of *Callitris columellaris*.—This minor community occurs on massive earths in the north-east. There is an upper storey 15–18 m tall of *E. drepanophylla* with occasional *E. populnea*, *E. melanophloia*, and *E. polycarpa*, usually fewer than 125 trees per hectare. The lower tree layer of *Callitris columellaris* is 8–12 m tall. It may be moderately dense or is usually patchy due to disturbance. *Casuarina luehmannii* may be prominent. A moderately dense shrub layer is developed in the north where the community grades into mixed layered eucalypt woodland and near Westmar where it adjoins open-woodland of *Angophora costata*. *Lysicarpus angustifolius*, *Petalostigma pubescens*, *Acacia longispicata*, and *A. cunninghamii* are conspicuous in the north and *Casuarina inophloia*, *Alphitonia excelsa*, and *Petalostigma pubescens* in the south.

The ground cover is sparse. *Aristida caput-medusae* and *Eriachne mucronata* are most common and constant. *Panicum effusum* and *Eragrostis lacunaria* are fairly constant though not common. *Triodia mitchellii* alternates with *Aristida* spp. in the Westmar area.

Near Yuleba *Eucalyptus drepanophylla* is sometimes replaced by *E. fibrosa* subsp. *nubila*.

(2) Woodland of *Eucalyptus drepanophylla* with lower storey of *Casuarina luehmannii*.—The community has a similar range to the last community with which it often forms mosaics. It is best developed north and east of Yuleba.

The upper storey of 60–100 trees per hectare consists mainly of *E. drepanophylla* with occasional *E. populnea* and less commonly *E. polycarpa*, *E. melanophloia*, or *E. microcarpa*, 15–18 m high. The lower tree stratum, *c*. 8 m tall, consists of *Casuarina luehmannii* often with considerable *Callitris columellaris*. Shrubs are scattered. The commonest are *Petalostigma pubescens*, *Lysicarpus angustifolius*, *Acacia longispicata*, and *A. cunninghamii*. The commonest and most constant of the open ground layer are *Aristida caput-medusae*, *Eriachne mucronata*, and *Panicum effusum*.

(3) Grassy woodland of *Eucalyptus drepanophylla*.—The community is best developed in the extreme north-east and in the Thomby Range area. It occurs on upper slopes on shallow skeletal soils and massive earths. The upper stratum, consisting of *E. drepanophylla* with occasional *Brachychiton populneum*, rarely with *E. melanophloia*, *E. fibrosa* subsp. *nubila*, or *Angophora costata*, is 13–20 m tall. In the Dulacca North area pure stands of *E. maculata* occur. There are usually scattered lower trees 5–10 m tall. *A. cunninghamii* is most common near Dulacca North and *A. burrowii* and *E. exserta* in Thomby Range, elsewhere *Bursaria incana* is most common. There is

occasionally a dense shrub layer, usually of *Carissa ovata*, but *Eremophila mitchellii* and *Cassia nemophila* occur.

The ground cover is sparse to occasionally moderately dense. The composition is similar to that of grassy woodland of *E. melanophloia* but it varies greatly from site to site. *Aristida caput-medusae* is probably constant and usually common. *Cymbopogon refractus*, *Neurachne mitchelliana*, and *Lomandra leucocephala* are the only other species at all constant.

In the Thomby Range area where woodland of *E. drepanophylla* occurs with open forest of *Acacia catenulata*, fire has greatly modified the woodland community resulting in dense stands of *A. burrowii* and occasional *E. exserta* *c.* 8 m tall with an extremely dense impenetrable shrub layer *c.* 2 m tall of *Ricinocarpos bowmanii* and *Phebalium glandulosum*.

(v) Casuarina cristata *Community*.—The community is associated with grassland and occurs on cracking clay and brown and grey-brown soils derived from unresistant deeply weathered sediments mainly near Surat and Roma.

There are up to 200 trees per hectare, 10–15 m tall. *Casuarina cristata* is most common. *Acacia harpophylla* occurs occasionally and *Bauhinia carronii* is common near Surat. *Eremophila mitchellii* and *Geijera parviflora*, about 6 m tall, are the usual components of the sparse shrub layer. The ground cover is either moderately dense or consists of *Astrebla* spp. and *Thellungia advena*, or more frequently it is sparse and consists of chenopods—*Bassia calcarata*, *Rhagodia parabolica*, *Atriplex semibaccatum*, and *A. muelleri*.

(vi) Eucalyptus thozetiana *Community*. —This occurs throughout the area except in the area of sandstone in the extreme north and in the south-west. It occurs on shallow skeletal loams and duplex soils as well as brown and grey-brown soils, all on weathered parent rocks.

E. thozetiana, sometimes with *E. microcarpa*, with up to 150 trees per hectare forms a tree layer 15–21 m tall. On shallow soils there is often no lower tree layer; on deeper soils there is usually a moderately dense stratum of *Casuarina cristata* and/or *Acacia harpophylla*. Two moderately dense shrub layers are usually developed: the taller, up to 3 m tall, of *Geijera parviflora* and less commonly *Eremophila mitchellii*, and the lower, about 1 m, of *Carissa ovata*. The sparse ground cover resembles that of open-forests of *Acacia harpophylla* and *Casuarina cristata*. The commonest species are *Ancistrachne uncinulatum*, *Bassia quinquecuspis*, *Enchylaena tomentosa*, *Paspalidium gracile*, and *Rhagodia nutans*.

In the Morven–Mitchell area *Cadellia pentastylis* occurs either with *Eucalyptus thozetiana* or alone. Plants associated with it are similar to those of the community described.

(vii) Eucalyptus microcarpa *Community*.— This occurs in similar situations to those of *E. thozetiana* woodland but is less common and is restricted to the north-east, about as far west as Mungallala.

There are up to 220 trees per hectare, usually 15–18 m tall. Sometimes the community is lower and more open and approaches open-woodland. *E. microcarpa* is usually alone in the upper layer. There is usually an open to moderately dense lower layer, 5–12 m tall, consisting of *Casuarina luehmannii* and occasional *Callitris col-*

umellaris in the north-east and of *Acacia harpophylla* elsewhere. The shrub layer is also open to moderately dense, 3–4 m tall. It consists usually of *Eremophila mitchellii* and *Geijera parviflora*, though *Acacia semilunata* is common south of Dulacca. The ground cover is sparse. *Aristida caput-medusae*, *Chloris ventricosa*, *Paspalidium gracile*, and *Eragrostis* are the most widespread common species.

(viii) Eucalyptus saligna *Community*.—Though widespread in the upper part of the catchment of the Comet River, this community occupies only a small proportion of the Balonne–Maranoa area, mainly on shallow brown and grey-brown soils on stripped margins of basalt tablelands.

The commonest trees, which are about 12 m tall and about 60 per hectare, are *E. saligna* with sometimes *E. punctata* and *E. orgadophila* common. *E. melliodora* is a minor constituent. *Macrozamia moorei* forms a patchy lower storey about 6 m tall and *Themeda australis* is often the sole constituent of the ground layer.

(ix) *Mixed Layered Eucalypt Community*.—The community is extremely rich and variable in composition. It has different aspects depending on what eucalypts are prominent, whether ironbarks, stringybarks, or bloodwoods. It is expected that further study would result in the segregation of more homogeneous smaller communities. It is restricted to shallow uniform sandy soils on quartzose sandstones in the north of the area.

The upper stratum varies from 12 to 22 m tall. There are usually scattered trees and well-developed shrub layer. The ground cover is invariably extremely sparse.

Prominent trees in the community are *Angophora costata*, *Eucalyptus bloxsomei*, *E. trachyphloia*, *E. umbra*, *E. major*, *E. punctata*, *E. drepanophylla*, *E. fibrosa* subsp. *nubila*, *Acacia longispicata*, *Lysicarpus angustifolius*, *Callitris columellaris*, *Casuarina inophloia*, and *Petalostigma pubescens*. Common shrubs are *Acacia bancroftii*, *A. neriifolia*, *A. cunninghamii*, *Cassinia laevis*, *Leptospermum sericatum*, and *Leucopogon* spp. *Entolasia stricta*, *Cleistochloa subjuncea*, *Eragrostis lacunaria*, *Amphipogon caricinus*, *Dianella* sp., and *Aristida* spp. are some constituents of the ground layer.

(*e*) *Open-forests*

(i) Callitris columellaris *Community*.—The community occurs on uniform sandy and duplex soils on upper slopes and crests chiefly in the north of the area but in small areas elsewhere.

There is a more or less continuous canopy of *Callitris columellaris*, 12–15 m tall. Other species which occur in the canopy or as emergents up to 22 m tall are *Angophora costata*, *Eucalyptus melanophloia*, *E. dealbata*, and occasionally *E. polycarpa*. Shrubs and low trees occur sporadically. *A. longispicata* and *Lysicarpus angustifolius* are conspicuous small trees (in the north) and *A. cunninghamii* and *Monotoca scoparia* are shrubs. The ground cover is open. The most common and widespread species are *Aristida caput-medusae*, *A. ingrata*, *A. muricata*, *A. browniana*, and *A. jerichoensis*. *Eragrostis lacunaria*, *Panicum effusum*, and *Lomandra leucocephala* are widespread but not common in any stand. *Triodia mitchellii* sometimes occurs.

(ii) Acacia aneura *Community*.—This is best developed on sandy or loamy red earths mainly in the west-central part of the area and north-east of St. George. It grades into eucalypt woodland with a lower layer of *A. aneura* and if partly cleared often cannot be distinguished from these communities.

A. aneura is 10–14 m tall and there are up to 1200 trees per hectare. Eucalypts, mainly *E. melanophloia* and *E. populnea*, are often present in the canopy or occasionally as emergents up to 18 m tall. *E. exserta* may occur on shallow soils and *E. terminalis* is a component in the west. Lower trees and shrubs are not common, *Eremophila mitchellii* being the only one at all constant.

The ground cover is usually very sparse. *Neurachne mitchelliana* is probably most common and constant. *Aristida jerichoensis*, *A. leichhardtiana*, *Eragrostis lacunaria*, *Paspalidium constrictum*, *Danthonia bipartita*, and *Cheilanthes sieberi* are also widespread, the last occasionally the only species where the canopy is dense. Forbs such as *Sida brachypoda* and *Hibiscus sturtii* are sometimes conspicuous.

(iii) Acacia harpophylla *Community*.—The community is found on cracking clay and brown and grey-brown soils, though not usually alluvial soils, mainly in the east and north of the area and near the confluence of the Balonne and Maranoa Rivers.

It is a layered open-forest consisting of a rather dense layer of *A. harpophylla* 10–15 m tall, sometimes with substantial *Casuarina cristata* of the same height or forming a taller layer up to 18 m tall. Eucalypts, mainly *Eucalyptus populnea* and *E. thozetiana*, less commonly *E. microcarpa*, *E. orgadophila*, and *E. microtheca*, occur within either the *E. harpophylla* or *C. cristata* layers or as emergents up to 22 m tall. Other trees are not common. The only ones of note are *Brachychiton rupestre* and, south of Morven, *Cadellia pentastylis*.

There is a moderately dense or in places dense shrub layer 2·5–6 m tall. *Eremophila mitchellii* and *Geijera parviflora* are the most common and constant species. When the shrubs are tall there is sometimes a second shrub layer about 1 m tall. *Carissa ovata* is the commonest species and *Myoporum deserti* often occurs if there is *Casuarina cristata* in the upper layers.

The ground cover is open. *Chloris acicularis*, *Paspalidium gracile*, *P. radiatum*, *Sporobolus caroli*, and *Ancistrachne uncinulatum* are the commonest grasses. Forbs are conspicuous. *Abutilon oxycarpum*, *Enchylaena tomentosa*, *Brunoniella australis*, *Rhagodia nutans*, and *Bassia quinquecuspis* are most common. *Zygophyllum apiculatum* is common in disturbed communities.

In the vicinity of "Bonus Downs" the dominant *Acacia harpophylla* community has probably been greatly disturbed and is rather low and open. It might well be classified as low open-woodland but is floristically related to the open-forest of *A. harpophylla* described rather than to the low open-woodland of the south-eastern part of the area.

Near "Womblebank" there is a brigalow community *c.* 15 m tall with occasional *Casuarina cristata* and *Brachychiton rupestre*. The dense shrub layer is about 6 m tall with composition similar to semi-evergreen vine thicket, mainly *Geijera parviflora* and occasional *Ehretia membranifolia* and *Atalaya hemiglauca*, and a lower less dense one about 2 m tall of *Myoporum deserti*, *Elaeodendron australe*, *Heterodendrum diversifolium*, and *Citriobatus spinescens*.

Communities with no *Casuarina cristata* occur, but most of these seem to be regeneration following fire or other disturbance, possibly as long as 50 years ago.

There is a gradation of open-forests consisting of *Acacia harpophylla* alone to those consisting of *C. cristata* alone but, because the latter occurs on rather different soils, has a different though overlapping range, and is usually less difficult to clear and maintain free of woody regrowth, two communities have been recognized, though the placing of some stands containing considerable quantities of both species has been arbitrary.

(iv) Casuarina cristata *Community*.—The range of this community overlaps that of the previous one, especially in the north-east, but it extends into drier areas, for example in the Dirranbandi–Bollon area. It also occurs on duplex and cracking clay soils but often occurs on alluvium.

C. cristata forms an upper layer 12–20 m high with up to 1000 trees per hectare. There is occasional *Acacia hypophylla* either in the canopy or forming a lower stratum 8–15 m tall. Eucalypts also occur occasionally in the canopy. *E. populnea, E. thozetiana,* and *E. microtheca* are the most common, but *E. orgadophila* and *E. largiflorens* occur occasionally. There is usually a moderately dense shrub layer 2–7 m tall consisting of *Eremophila mitchellii* and *Geijera parviflora* and occasionally a second lower layer about 1 m tall of *Carissa ovata* or *Myoporum deserti.*

The ground cover is usually open. *Paspalidium radiatum, P. gracile, Chloris acicularis,* and *Sporobolus caroli* are common and constant grasses. *Ancistrachne* and *Aristida ramosa* occur frequently and *Rhagodia nutans, Bassia quinquecuspis, Enchylaena tomentosa,* and *Brunoniella australis* are common forbs.

(v) Acacia cambagei *Community*.—Structurally and floristically this community is simpler than other open-forest communities on cracking clay and duplex soils. It is confined to the south-west.

There is a tree layer 10–14 m tall consisting of *A. cambagei* (up to 500 trees per hectare), with occasional *Casuarina cristata, Eucalyptus microtheca,* or *E. largiflorens* where these trees occur in adjoining communities. The community may be more open on strongly gilgaied soils because usually trees do not grow in the gilgais. There is usually an open shrub layer of *Eremophila mitchellii* and, less frequently, *Geijera parviflora.* Scattered low shrubs of *Myoporum deserti* and *Rhagodia parabolica* sometimes occur. The ground is open and is composed mostly of forbs, *Bassia* spp. (*B. diacantha, B. convexula, B. tricuspis*), and *Enchylaena tomentosa.* The commonest grasses are *Tripogon loliiformis, Paspalidium gracile,* and *Chloris acicularis.*

(vi) Acacia catenulata *Community*.—This is the most widespread of three open-forest communities dominated by *Acacia* that occur on shallow soils usually on scarps. Together with woodland of *Eucalyptus thozetiana* and *E. microtheca* they indicate that the landscapes have been subjected to deep weathering.

The community consists of a dense tree layer, 500–1200 trees per hectare, 10–12 m tall, sometimes with emergents up to 20 m tall. *A. catenulata* is usually the only constituent of the tree layer, though *A. aneura* and rarely *A. aprepta* may also occur. *Eucalyptus populnea, E. melanophloia,* and *E. drepanophylla* are the commonest emergents but *E. microcarpa, E. thozetiana, E. trachyphloia, E. exserta,* and *Cadellia pentastylis* are also found. There may be a shrub layer up to 5 m tall. *Geijera parvi-*

flora and *Eremophila mitchellii* are commonly found but in the Thomby Range area *Phebalium glandulosum* and *Eriostemon difformis* are common.

The ground cover is extremely open. Commonest species are *Neurachne mitchellii, N. xerophila, Paspalidium caespitosum, Ancistrachne uncinulatum,* and *Cheilanthes sieberi.* The last often occurs alone in dense stands of *A. catenulata.* Near Yuleba and Glenmorgan, *Acacia aprepta* forms similar communities without *A. catenulata.*

(vii) Acacia shirleyi *Community.*—This occurs in similar situations to the previous community but is confined to the north-east and is also found occasionally in the north.

There is a dense tree stratum with more than 500 trees per hectare, 10–12 m, rarely to 18 m, tall, consisting solely of *A. shirleyi.* There are often emergent eucalypts up to 25 m tall, *E. drepanophylla* and occasionally *E. fibrosa* subsp. *nubila* in the south and *E. decorticans* in the north. There is usually no shrub layer and the ground cover is sparse. *Cleistochloa subjuncea* and *Aristida caput-medusae* are most common.

(viii) Acacia microsperma *Community.*—The range of the community is disjunct. It occurs near "Bonus Downs" and east of "Weengallon" on shallow skeletal soils associated with scarps.

There is a dense layer, 10–13 m tall, of *A. microsperma* usually with (occasionally) *Eucalyptus populnea, E. melanophloia,* or (rarely) *E. exserta.* There is usually a moderately dense shrub layer 3–7 m tall consisting usually of *Geijera parviflora.* Ground cover is sparse. *Ancistrachne uncinulatum, Paspalidium gracile,* and *Enchylaena tomentosa* are most common and constant.

(*f*) *Tall Open-forest*

(i) Eucalyptus eugenioides *Community.*—This is probably of greater biogeographical than ecological interest. It is restricted to a small area of highlands in the north where it occurs on humic red earths developed from leached basalt. The rainfall is probably higher than in other parts of the region and the evaporation less.

E. eugenioides is the only tall tree species. It is about 45 m tall with a patchy understorey 6 m tall of *Macrozamia moorei* and occasional *Acacia implexa.* The ground cover is rather dense and consists of *Themeda australis* and *Imperata cylindrica.*

(*g*) *Closed-scrub*

(i) *Semi-evergreen Vine Thicket.*—The community is rather varied in structure. It occurs mainly in the north-east on shallow brown and grey-brown soils.

There is usually a dense shrub layer *c.* 5 m tall with one or two dense lower shrub layers. Emergent trees usually *c.* 9 m tall occur. *Eucalyptus orgadophila* and *Casuarina cristata* are common emergents as is *Cadellia pentastylis* (up to 18 m tall) near Amby. The shrub layers are rich in species. *Geijera parviflora, Eremophila mitchellii,* and *Planchonella cotonifolia* are common taller shrubs and *Heterodendrum diversifolium, Carissa ovata, Croton phebalioides, Critriobatus spinescens,* and *Heterocalymnantha minutifolia* lower ones. Ground cover is very sparse. *Eragrostis megalosperma* and *Ancistrachne uncinulatum* are probably the commonest components.

(*h*) *Fringing Communities*

Three communities have been recognized, depending on the texture and possibly fertility of the alluvium. They may be formally classed as woodland or open-forest, but as they are often only one or two trees wide it seems more appropriate to discuss them as fringing communities.

(i) Eucalyptus microtheca *Community*.—This is widely distributed throughout the southern part of the region on cracking clay soils. *E. microtheca* is usually rather sparse but in periodically flooded sites there is usually a dense shrub layer of *Muehlenbeckia cunninghamii* and/or *Acacia stenophylla*.

(ii) Eucalyptus camaldulensis *Community*.—This is also widespread along channels, even quite small ones, throughout the area. It occurs usually on less clayey alluvial soils than the previous community. Besides *E. camaldulensis* there are often (on larger streams) lower trees of *Melaleuca linariifolia* and on the upper part of the Balonne *Casuarina cunninghamiana* also occurs.

(iii) Eucalyptus tereticornis *Community*.—On alluvium derived from basalt on Dooloogerah Creek (headwaters of Warrego River), there is a fringe of *E. tereticornis* and *Angophora floribunda* with lower *Callistemon viminalis*. *A. floribunda* often extends well away from the channel into the open-woodland of *Eucalyptus melanophloia* characteristic of the area.

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PART IX. PASTURE LANDS OF THE BALONNE–MARANOA AREA

By L. Pedley*

I. Introduction

The pasture plants are predominantly perennial grasses that respond to summer rain, with some perennial forbs. The perennials are supplemented by annuals, mainly forbs, some of them winter-growing. Such annuals are commoner in the south because of the higher and more reliable winter rain there. Edible trees and shrubs, discussed by Everist (1969), provide additional fodder but except in times of drought these merely supplement the diet of grazing animals.

The effects of grazing and burning on the ground vegetation are evident throughout the whole area and management of the pasture has obvious and often long-term effects on the vegetation. Prior to settlement by Europeans a little more than a century ago, the country was subject to rather low grazing pressure mainly by kangaroos. The number of kangaroos might have been high in a series of years of high rainfall but would have been rather low in normal years. The lack of surface water would then severely limit kangaroo populations. The amount of surface water available throughout the year has increased greatly since settlement, mainly from artesian bores, and the country may even support more kangaroos now than formerly despite widespread shooting. The number of rabbits in the area has declined remarkably in recent years and they are no longer of significance except perhaps on sandy river levees in the south. All except the most rugged parts of the area is now grazed by sheep or cattle. More palatable species are removed by selective grazing. Kangaroo grass (*Themeda australis*) which is now uncommon was probably widely spread before settlement. Removal of perennial grasses by grazing, which is especially likely with sheep, often leaves topsoil open to erosion by wind and water, leaving areas of hard-setting soil which are recolonized slowly or occupied by short-lived plants such as five-minute grass (*Tripogon loliiformis*). Run-off from these areas provides additional water for plants on lower slopes but the result is often an increase in unpalatable shrubs rather than herbage. Areas near watering points and stock yards may be so trampled that they support only such fibrous and unpalatable species as cotton-bush (*Kochia tomentosa* var. *tenuifolia*) or galvanized burr (*Bassia birchii*).

Fire has probably been a significant environmental factor over most of Australia since the beginning of aboriginal occupation. Merrilees (1968) considered that aborigines used fire freely and repeated burnings probably had a marked effect on plant ecosystems. The distribution of fire-susceptible species such as belah (*Casuarina cristata*) and cypress pine (*Callitris columellaris*) may have been profoundly altered by such fires, but it is impossible to even guess at what the effect on ground vegetation has been. Since white settlement burning has been used deliberately to destroy excess dry herbage at the end of the dry season and to try to control regrowth of eucalypts and unwanted shrubs. Much of the eastern part of the area was burnt in the 1930s to

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remove large quantities of dead prickly pear (*Opuntia stricta*), a plant which had been a major pest. The effects of these fires are still discernible in communities of some woody species, notably in open-forest of brigalow (*Acacia harpophylla*) and belah. If grazing pressure is high there may be such a reduction in the ground cover that it will not support a fire. There may then be an increase in shrubs with a further decline in ground cover. The interaction between grazing and burning is most important in the regeneration of mulga (*Acacia aneura*). Mulga seeds germinate in large quantities following a fire (Everist 1969) but the young plants may be eaten off before they become established. On the other hand, if the plants are not grazed until they are a metre or more tall they often form thickets almost impenetrable to stock which prevent the formation of ground vegetation. Adjacent paddocks may vary widely in the amount of young mulga carried, not because of the difference in average stocking rates but because of the difference in timing of grazing in relation to fires.

II. Pasture Lands

An attempt has been made to divide the Balonne–Maranoa area into a number of pasture lands according to the composition and density of the major community in each land system. Table 25 shows the grouping of land systems into pasture lands.

Table 25

LAND SYSTEMS INCLUDED IN PASTURE LANDS

Pasture land	Land systems
Basalt	BtS,* BhMc, BuI
Downs	SuMc,† SuD, AC, Af
Brigalow–belah	ShSw, (S)hY, (S)uXB, (S)uBl, CpG
Box	SuMc,‡ (S)uX, (S)uIX, AX§
Wire grass	QhMe, QuA, QrCp, (S)rNi, (S)uBu, CpCp, ACp
Mulga	(S)rBe, (S)rXM, (S)uM, (S)uXM, CpXM, CpBXM, AXM, AX,‖ CpG, ABb

* Rather exceptional, see text.

† Excluding areas SW. of Meandarra.

‡ Including areas SW. of Meandarra.

§ Excluding areas on flood-plain of Balonne R. downstream from St. George.

‖ Including areas on flood-plain of Balonne R. downstream from St. George.

The distribution of the pasture lands can be deduced from the land system map by using this table. In the pasture lands described the major factors affecting their utilization have been mentioned.

(*a*) *Basalt Pasture Land*

This is moderately dense mid-height grass with species of blue grass (*Dichanthium* spp.), mainly *D. affine*, common though Mitchell grasses (*Astrebla* spp.) occur towards the west. When heavily grazed, white spear grass (*Aristida leptopoda*) and feather-top wire grass (*A. latifolia*) usually become conspicuous. Other species of some importance are coolibah grass (*Thellungia advena*) and native millet (*Panicum decompositum*).

The grasses usually occur in rather open communities of mountain coolibah (*Eucalyptus orgadophila*) and silver-leaved ironbark (*E. melanophloia*) usually with few shrubs and regrowth of shrubby species is not a problem as it is in some of the other pasture lands. Carrying capacity is rather high but much of the pasture land cannot be utilized because of the hilly and locally mountainous nature of the terrain and the lack of permanent surface water.

BtS land system which is quite small is included here mainly for convenience. The major pasture type which occurs in tall open-forest of *E. eugenioides* and woodland of Sydney blue gum (*E. saligna*) and other eucalypts consists of a dense stand of kangaroo grass and some blady grass (*Imperata cylindrica*). The composition of the pasture suggests that it is burnt frequently but the great quantity of kangaroo grass indicates that the grazing is light. The land system is inaccessible and is not used for grazing.

(*b*) *Downs Pasture Land*

This is tussock grassland dominated by Mitchell grasses, the commonest being curly Mitchell grass (*Astrebla lappacea*) with minor hoop and bull Mitchell grasses (*A. elymoides* and *A. squarrosa*). Other grasses commonly associated are coolibah grass, blue grass, and white spear grass, the last being commonest on heavily grazed areas. Everist (1964) in an account of the Mitchell grass country in Queensland stated that the spaces between grass tussocks might be occupied temporarily by a great variety of other species. Though the seasonal conditions at the time of the survey did not favour the growth of these plants, malvastrum (*Malvastrum spicatum*), Flinders grasses (*Iseilema* spp.), *Rhynchosia minima*, and pigweed (*Portulaca* sp. aff. *oleracea*) were noted. In depressions, particularly on alluvium in AC land system, downs nut-grass (*Cyperus bifax*) is common and in flooded areas along river frontages in the same land system native millet is often very common. Composition of the pasture often varies from the puffs to the hollows of linear gilgai.

Heavy grazing seems to lead to an increase of white feather grass and in alluvial situations in the south it is probable that further degeneration to open-grassland of five-minute grass and annual forbs or to bare ground may follow.

The pasture land is either treeless or has only open stands of trees, usually coolibah (*Eucalyptus microtheca*) or mountain coolibah, and shrubs are uncommon. Carrying capacity is about one sheep to one hectare (Everist 1964). The fertility of the soil and the ease of any necessary clearing have led to the cultivation of much of this pasture land in the Roma–Mitchell area. Outside this area rainfall is too low and unreliable for large-scale cropping.

(*c*) *Brigalow–Belah Pasture Land*

Open-forest of brigalow and belah and woodlands with understoreys of these species have a distinct ground flora consisting of short perennial grasses and forbs. The major grasses are *Paspalidium* spp. (mainly *P. gracile* and *P. radiatum*), spider grass (*Chloris acicularis*), fairy grass (*Sporobolus caroli*), and in more open communities hooky grass (*Ancistrachne uncinulatum*) and *Aristida ramosa*. The commonest forbs are berry cotton-bush (*Enchylaena tomentosa*), a flannel weed (*Abutilon oxycarpum*), berry saltbush (*Rhagodia nutans*), and brigalow burr (*Bassia quinquecuspis*). Where the upper strata of trees are dense the ground cover is low. This is particularly noticeable in many dense stands of belah where there may be only about two plants per 100 m^2.

The pasture species are palatable and nutritious but because of their low density the carrying capacity of the pasture land is low. Clearing, even without grazing, results in the rapid disappearance of the commonest grasses and forbs probably because of the increase in light intensity. They are replaced by blue grass in wetter areas and by Mitchell grasses elsewhere. Utilization of the pasture land by clearing is made difficult by problems presented by regrowth of woody plants (Johnson 1964), especially in areas where brigalow predominates. The usual method of clearing is to fell trees with the aid of large tractors and then to burn the fallen trees some time after the initial felling. The control of belah which is quite sensitive to fire is usually not a problem but, depending somewhat on the soil moisture present and climatic conditions at the time of felling (and other factors), brigalow usually suckers profusely from the roots and without some further treatment following the burn an area of brigalow will soon become a dense stand of suckers that excludes other plants. One method of controlling brigalow regrowth, not often practised with complete success, is to graze sheep on the suckers as they emerge. The regrowth may be controlled but there is considerable loss of production from both the sheep used and the cleared area which remains virtually bare for some time after control measures have stopped. Cultivation in several successive years eliminates most regrowth and in the better-watered areas much of this pasture land has been cleared and cultivated. One serious limitation to cultivation is the occurrence of deep gilgais which are often severe obstacles to farm machinery.

(*d*) *Box Pasture Land*

This is one of the most extensive and intensively used pasture lands. It is associated with woodland of poplar box (*Eucalyptus populnea*) and silver-leaved ironbark. The major components of the pasture are mid-height grasses, pitted blue grass (*Bothriochloa decipiens*), wire grasses (*Aristida ramosa* and *A. jerichoensis*), spider grass, tall chloris (*Chloris ventricosa*), *Enneapogon* spp., and purple love grass (*Eragrostis lacunaria*). In sheltered situations beneath trees and fallen branches there are usually a few plants of species characteristic of the brigalow–belah pasture land, e.g. hooky grass and *Paspalidium* spp. Mulga grass (*Neurachne mitchelliana*) is also common where poplar box and mulga communities adjoin. Kangaroo grass is now uncommon but has probably decreased since the pasture land has been subjected to regular grazing.

Under prolonged heavy grazing wire grasses tend to replace more palatable species, and near watering points and around yards where both trampling and grazing are severe, galvanized burr or cotton-bush often form dense stands. On eroded gravelly soils usually in silver-leaved ironbark woodland *Eriàchne mucronata is* often conspicuous. Shrubs are a conspicuous feature of this pasture land. A small proportion is edible and useful but the commonest, sandalwood (*Eremophila mitchellii*), is harsh and unpalatable. It is common and in many places so seriously affects carrying capacity that it is regarded as a major weed. In recent years the problem of regrowth of eucalypts and the incidence of inedible shrubs in this pasture land has become acute and is the subject of considerable research. The germination and growth of sandalwood and other shrubs were favoured by a number of years of high rainfall in the 1950s. There has been a resultant decrease in ground cover, possibly made worse by heavy grazing in recent dry years. Clearing of woody vegetation is desirable as shown by Moore and Walker's (quoted by Moore 1970) finding that a several-fold increase of dry matter production of herbage occurs following removal of trees and shrubs without disturbance of the soil. Clearing, however, is usually followed by vigorous regrowth particularly of poplar box and sandalwood and until there is some economical method of controlling this regrowth the pasture land cannot reach maximum productivity.

(*e*) *Wire-grass Pasture Land*

This pasture land is closely related to the previous one. It usually has sparser and less palatable grasses and its carrying capacity is lower, especially in areas of lower rainfall. The predominant grasses are species of wire grass (*Aristida jerichoensis*, *A. echinata*, *A. browniana*, *A. caput-medusae*, and *A. ingrata*), purple love grass, a mulga grass (*Amphipogon caricinus*), and hairy panic with a smaller quantity of pitted blue grass and *Aristida ramosa*. Spinifex (*Triodia mitchellii*) is often dominant in QuA land system but it seems to have been reduced by fire. In the QhMe land system where the ground cover is extremely low, *Entolasia stricta* and *Eremochloa subjuncea* are as common as wire grasses.

In its undisturbed state the pasture is unproductive because the rather dense tree layers of usually cypress pine or bull oak (*Casuarina luehmannii*) allow only a few scattered plants to survive. Handling of stock in such heavily timbered country is also difficult. Clearing increases the ground cover but the grasses are fibrous and unattractive to stock. The effect of clearing is marked on sandy levees of the Maranoa River where, after clearing, dense stands of cypress pine and occasional carbeen (*Eucalyptus tessellaris*) are succeeded by almost pure dense stands of a wire grass (*Aristida echinata*) of little value to stock except when very young.

On harder-setting soils, mainly in poplar box–cypress pine woodland, heavy grazing can result in severe infestations of galvanized burr or in the production of open stands of such small plants as five-minute grass.

The portion of the pasture land that occurs in QhMe land system is rugged and without water and is not used for pastoral or agricultural pursuits.

(*f*) *Mulga Pasture Land*

This has many pasture species in common with box pasture land but their proportions differ, ground cover is on the whole lower, and the carrying capacity is also lower. The commonest species are mulga grass (*Neurachne mitchelliana*), *Aristida jerichoensis*, *A. leichhardtiana*, mulga oats (*Danthonia bipartita*), silver spike grass (*Digitaria brownii*), and woollybutt grass (*Eragrostis eriopoda*). Forbs are more conspicuous than in most other pasture lands and contribute much of the available forage; *Sida* spp. and *Hibiscus sturtii* are commonest. In dense stands of mulga or bendee (*Acacia catenulata*) light intensity is low and the ground cover consists of only scattered plants of *Neurachne* spp., hooky grass, and mulga fern (*Cheilanthes sieberi*). In CpBXM land system there is a mixture of brigalow and mulga and also a mixture of grasses, but because of the aridity of the land system it is managed like other country and is therefore included in the mulga pasture land.

Mulga is a valuable fodder tree forming a useful reserve in times of drought when the ground vegetation is eaten off. Mulga grows at such densities that even in undisturbed communities the ground cover is low, and management of this pasture land consists to a large extent in clearing enough mulga to increase ground cover for grazing in years of normal rainfall while keeping enough mulga in reserve for use during drought. Regeneration of mulga is not a problem in this part of its range. Regulation of grazing following germination is, however, important to prevent the formation of dense unproductive stands and to ensure that reserves of mulga are maintained.

The ground cover of the pasture land has already been modified by grazing. Palatable species such as mulga oats have been replaced by wire grasses and on the stony soils common in (S)rXM land system the pasture often consists solely of scattered woollybutt grass and five-minute grass.

Unwanted shrubs are not as troublesome as in other pasture lands though sandalwood and butter bush (*Cassia nemophila*) form dense stands in some places.

(g) *Short-grass Pasture Land*

This pasture land is confined to the south-west, the most arid part of the region. Ground cover is extremely low and there is much bare ground. Annual forbs are common with no species being particularly conspicuous. In gidgee (*Acacia cambagei*) and poplar box communities five-minute grass, fairy grass, and *Bassia* spp. (mainly *B. diacantha* and *B. tricuspis*) are common, while in the woodland of black box (*Eucalyptus largiflorens*) neverfail grass (*Eragrostis setifolia*) is also a major component.

Stocking rates are low and because the common plants are short-lived it is doubtful whether the pasture land can be used for any length of time without stock having access to other pasture lands, either mulga or downs pasture lands being the most likely. Despite the low stocking rates over-grazing is evident. The result is often baring the ground followed by wind and water erosion and the production of clay pans devoid of vegetation.

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PART X. CURRENT LAND USE IN THE BALONNE–MARANOA AREA

By K. D. Cocks*

I. Introduction

The paramount natural feature of Balonne–Maranoa is a moderate to low rainfall of high variability. Prior to settlement, the ecosystems which had evolved there were characterized by both drought-avoiding (ephemeral and quickly responsive) and drought-resisting (deep-rooted) plants. Herbivore populations were low and through migration, death, and delayed breeding exerted low grazing pressure on vegetation in times of stress (Main 1969).

The history of subsequent development can be summarized as the attempt by man to

(1) replace (crops and improved pasture species) or encourage the successional replacement (clearing, grazing resistant species) of the original vegetation with less developed ecosystems having higher primary production;

(2) divert a larger proportion of primary production through consumers (stock) which are eventually removed from the ecosystem;

(3) introduce species (crops) whose production is removed from the ecosystem without passage through consumers;

(4) stabilize, without reducing, net production of the ecosystem.

As in other semi-arid environments, this approach has resulted in semi-intensive land use, still variable production, and a decrease in the level of production consequent on the elimination of more palatable species (Newman and Condon 1969).

Without judging this strategy in terms of long-term stability or efficiency, its short-term relative success is crudely indicated by the percentage increases in output of different products between the decades 1946/47 to 1955/56 and 1956/57 to 1965/66 for Roma and two adjacent statistical divisions.

	Roma	South-west	Downs
Cattle	78	72	20
Sheep	75	79	351
Wool	28	16	55
All grain	97	—	42

The point of comparing successive decades is to overcome the year-to-year variability of the raw data. It would, of course, be more instructive to consider changes in the net value of production, although even here there are index number problems and also it would be difficult to adequately cost permanent environmental

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change. Whilst net value of regional production cannot be specified, aggregated financial details are available for some 35 farms in the 10 shires wholly or partly included in the survey area and surveyed by the Bureau of Agricultural Economics (B.A.E.) between 1962/63 and 1966/67 in their beef and sheep industry surveys. For 105 farm years of production over the period the average annual profit per farm was $5313 representing an average rate of return of 1·6% on capital or a rate of return of 3·1% on average capital of $170,500. The tremendous range of financial performance concealed here is indicated by the performance of uppermost and lowest deciles in the sample. The uppermost decile earned a rate of return of 14·7% (a profit of $47,993) and the lowest decile earned −11·9% (a loss of $21,398).

The major enterprises realizing the productive capacity of the region are sheep, beef, and grain production. There is some forestry and a small irrigation scheme at St. George. In 1965/66 there were 3143 holdings in the 10 shires associated with the survey area. Average size was 6342 ha and the percentage of holdings in different size classes was:

<810 ha	17·3%	4050–8099 ha	16·0%
810–2024 ha	23·8%	8100–20,249 ha	16·7%
2025–4049 ha	19·5%	>20,250 ha	6·7%

The percentages of farms carrying on different major enterprises were as follows: sheep 59%; beef 17%; sheep and cereal grain 7%; cereal grain 5%; other 12%. The following sections describe these enterprises in turn at broad regional level.

II. Sheep

Apart from small numbers of British breed fat lamb mothers, almost all sheep are Peppin medium-wool Merinos run in flocks of up to 6000. Most of the region is regarded as "breeding country" and ewe numbers are controlled to provide flock replacements and to expedite flock build-up as required. Maiden ewes are generally mated at 18 months and lambing spreads from August to December. Mean lambing percentage varies from 50 to 59% across the district. Ewes are kept till about 7 years old and wethers sold as weaners or at 4–6 years if required for flock build-up. In general terms, stocking policy is to limit flock size to a number that can be supported by the native vegetation, a number determined by the feed available over winter. Nearly every year there are periods when sheep have to graze dry perennial grasses and, in a drought, when these reserves are exhausted the farmer has to choose a stocking–feeding policy based on some combination of agistment, sale (initially wethers and older ewes), deferred mating, lopping edible shrubs, buying in feed, and allowing sheep to die. Feed produced during periods of maximum growth is not conserved, firstly because it is relatively sparse and secondly because it dries off to form poor-quality "standing hay". Wadham *et al.* (1957) point out that although the storage of larger reserves would ease the situation during dry spells it would do little to mitigate the effects of a protracted drought. Dillon and Lloyd (1962), using a binomial probability model from Verhagen and Hirst (1961), calculate that there is a negligibly low probability of going more than 15–17 months without effective rain in the survey area and, using assumptions which probably understate standing fodder reserves, calculate drought fodder reserves of 2–5 months as being optimal to maximize net revenue over this period.

There is little improved pasture despite reported successes with buffel grass (Wilson 1961) and because they are unreliable, winter fodder crops are not used to enable higher stocking rates. It is commonly believed that the best way to improve feed supplies, perhaps double forage production, is by ringing or clearing timber, although in areas with edible shrubs and trees this raises the problem of balancing extra non-drought production against reduced drought reserves and increased erosion hazards. Extensive clearing became much more common after World War II with the advent of heavy machinery capable of clearing large areas at low cost.

Generally, sheep health is good. Riches (1958) described disease incidence in the area relative to other Merino sheep areas in eastern Australia as moderate to high for blowfly, moderate for lice, worms, and scabby mouth, and low for gangrenous mastitis, swelled head, arthritis, hypocalcaemia, pregnancy toxaemia, photosensitization, balanitis, and copper deficiency. Mulesing, despite excellent trial results (Beasley and Mullens 1969), is not practised very widely as a blowfly control. The only predator of any established importance is the dingo whose presence precludes sheep-raising north of the main east–west dog fence (Fig. 21). Although not necessarily influencing sheep health directly, five main plants were recorded by Riches (1958) as being regarded as objectionable by graziers: Bathurst burr, Noogoora burr, galvanized burr, mintweed, and white spear grass.

For a number of reasons it is not possible to accurately compare the inherent productivity (output/input) of the survey region with adjacent regions, i.e. the Downs division to the east and the South-western division to the west. Nevertheless, some idea of these relationships is gained by comparing these divisions for production per sheep and per sheep hectare (total area corrected for crop area and cattle numbers (10 sheep = 1 beast)) over 1946/47 to 1967/68.

	Roma	South-west	Downs
Total sheep per sheep ha	0·84	0·30	1·48
Wool per sheep ha (kg)	3·27	1·13	5·79
Wool production per sheep (kg)	3·99	3·98	3·95
Net sales per sheep carried	0·10	0·086	0·057

The best available indications of the profitability of wool-growing are the aggregated profit and loss accounts for 26 farms in the B.A.E. sheep survey over the three years 1964/65 to 1966/67. In summary these are as follows:

	1964/65	1965/66	1966/67
Total returns ($)	29,275	14,686	35,239
Total costs ($)	26,881	24,475	22,774
Return to capital and management ($)	2,394	−9,789	12,465
Total capital including land ($)	155,373	149,694	143,291

III. Beef

In 1965/66 87% of 1508 rural holdings in Roma division ran cattle although only 24% of holdings earned more than half gross income from beef. The herd size distribution was as follows:

Herd size (head)	Percentage of herds
<10	46·6
100–499	42·6
500–999	7·6
1000–9999	3·2

Most beef cattle are Herefords although Shorthorns become more important in the drier areas (Beattie 1956) and there is an increasing use of Brahman blood. In general cattle are run as an extensive breeding enterprise with widely varying turn-off age and condition. Crop fattening of purchased stores has been a growing but as yet not widely established enterprise. Cattle graze either with the sheep flocks or in separate paddocks. It is commonly held that where cattle are grazed alone standing reserves of native grass are more easily achieved but, by the same token, sheep appear to be more effective in controlling seedling regrowth. There has been no local research on the degree to which cattle and sheep complement each other.

Generally there is insufficient winter herbage to give cattle a positive plane of nutrition over the period April–August (Sutherland 1959) and the use of urea–molasses licks to supplement dry feed is increasing. High compensatory weight gains are achieved in summer and bodyweight increases with age in a seasonally cyclical but rising pattern.

Husbandry standards are not high. Many farmers do not attempt to restrict calving to the August–November period or to wean by May–June. As a consequence large numbers of breeders are mated in backward store condition with subsequent low calving rates or long calving intervals (nutritional infertility).

It is difficult to generalize about the importance of disease in the region. Ticks are not a problem; the "tick-line" runs along the north-eastern boundary of the region. Lice infestation appears to have increased in the last few years but is cheaply controlled by autumn–winter sprays. Localized occurrence of St. George disease has to be controlled by periodically moving cattle to healthy areas. The recent discovery of *Pimelea polystachya* as a cause may lead to control measures. Dingoes are blamed for up to 10% reduction in marking percentages in the northern part of the region.

The productivity of beef enterprises in Roma and adjacent divisions compares roughly as follows over the period 1946/47 to 1967/68:

	Roma	South-west	Downs
Total beasts carried per 100 beef ha	3·7	1·3	6·5
Net beasts sold per 100 beef ha	0·66	0·13	1·10
Net beasts sold per beast carried	0·17	0·10	0·17

The only financial data available for beef production in the area are the aggregated B.A.E. results from nine beef properties over the period 1962/63 to 1964/65. In summary these are:

Annual returns ($)	36,974
Annual costs ($)	19,820
Return to capital and management ($)	17,154
Average capital including land ($)	238,688

IV. Crops

Despite expansion in recent years, cropping is still a relatively unimportant land use in the region. Over two recent decades (1946/47 to 1955/56 and 1956/57 to 1965/66) crop areas as a percentage of the area of all holdings have increased from 0·13 to 0·42% in Roma and from 7·4 to 11·0% in Downs. Thus, while cropping has been pushed out into drier country since the early 1950s, an even greater intensification has taken place in recognized cropping areas.

Table 26

Breakdown of total crop area in Roma division in 1955/56, 1965/66, and 1967/68*

Crop	1955/56		1965/66		1967/68	
	(ha)	(% total)	(ha)	(% total)	(ha)	(% total)
Oats for fodder	3040	22·6	22,627	42·3	27,892	30·7
Wheat for grain	534	41·2	15,759	29·5	42,409	46·7
Sorghum for fodder	426	3·2	2609	4·9	2906	3·2
Wheat for fodder	1172	8·7	2367	4·4	6128	6·8
Oats for grain	374	2·8	1262	2·4	1496	1·6
Sorghum for grain	969	7·2	1106	2·1	1539	1·7
Hay (all kinds)	429	3·2	1597	3·0	1731	1·9
Other fodder (non-cereal)	1008	7·5	4834	9·0	4403	4·9
All other crops	475	3·6	1322	2·4	2305	2·6
Total	13,427	100	53,483	100	90,758	100

*Source: Commonwealth Bureau of Census and Statistics.

The composition of total crop area has also changed dramatically. Table 26 compares the absolute and percentage breakdown into crop types of the total Roma crop area in 1955/56, 1965/66, and 1967/68. In a first general expansion of cropping, grazing oats displaced wheat as the major cropping enterprise because: (*a*) it was recognized to be a profitable land use in areas considered too dry for wheat and (*b*) the use of oats for crop fattening of turn-off and purchased beef was recognized to be as profitable as wheat in the wetter areas. Since 1965/66 wheat has moved ahead again, probably in part due to difficulties in obtaining enough suitable beasts for fattening. About 80% of wheat is classified as prime hard and draws a quality premium payment of 8–27 cents per hectolitre.

The declining relative importance of grain sorghum is probably due to the fact that although sorghum yields are as high and as reliable as wheat yields, wheat prices have been about 80% higher than sorghum prices. A second reason is that summer crops are felt to be less effective than winter crops in controlling the timber regrowth which is a problem on much newly cleared land. Forage sorghum, on the other hand, has held its importance relative to oats because it is seen as a useful bridge between the summer growing season and the time when oats are ready for grazing.

Considerable dual-purpose wheat is still being grown because in a good winter it is not needed for grazing and can be carried on for a moderate grain yield. Similarly, oat grain has been less profitable than wheat but has held its relative importance for many years because of grazing possibilities, as a source of weed-free seed, and the regard with which it is held as stock feed. When recent acreage figures become available they will reflect wheat quotas via a lower rate of cropping expansion and a lower proportion of wheat. At a purely physical level it is clear that the region is not particularly favoured for cropping. Table 27 shows yields to be 36–53% lower and

TABLE 27

GRAIN YIELDS IN ROMA AND DOWNS STATISTICAL DIVISIONS, 1951/52 TO 1967/68*

	Wheat		Oats		Sorghum	
	Roma	Downs	Roma	Downs	Roma	Downs
Mean yield (hl/ha)	12·3	19·3	10·9	17·1	12·0	25·4
Median yield (hl/ha)	13·1	18·5	12·5	17·4	12·7	24·1
Standard deviation of yield (hl/ha)	5·3	4·0	5·5	3·1	5·0	4·3

* Source: Commonwealth Bureau of Census and Statistics.

yield variability (standard deviation) to be 16–74% higher than in the Downs division, admittedly one of the highest-yielding divisions in the wheat belt. There are no clear-cut yield trends in these series and the Wallis–Moore run test for phase lengths (Wallis and Moore 1941) does not detect "bunchiness" in wheat yields. As might be expected, the two winter grains, wheat and oats, have highly correlated yields ($r = 0 \cdot 9$) but correlations between winter grain and sorghum yields are much weaker at around $r = 0 \cdot 6$. Negative skewness in yield distributions is demonstrated by medians being greater than means for the three Roma series and this in turn suggests the existence of some strongly limiting factor—almost certainly rainfall.

The influence of rainfall on the intensity of cash cropping is illustrated by the fact that 92% of the 1969 wheat crop area was grown in the 66% of the survey region having an estimated mean annual rainfall greater than 470 mm. Practically all the remaining crop is grown just outside this 470-mm boundary in the far south of the region where the proportion of annual rainfall coming in winter is relatively high. The interesting feature of the comparable grazing oats figures is that 8% is grown below 444 mm, i.e. in areas considered too dry for wheat. The reason is that grazing oats do not need soil water sufficient to carry through to maturity.

As a general practice, crops get little or no fertilizer. In 1965/66 in the Roma division, 34 out of 477 holdings having some crop used 208 tonnes of fertilizer on 1053 ha, much of it probably irrigated. This is despite the fact that widely dispersed trials by the Queensland Wheat Research Institute (1970) indicate major phosphate responses and localized responses to copper, zinc, sulphur, and molybdenum.

Rainfall–fertilizer interactions have not been studied in trials designed to identify economic optima.

Insects, weeds, and diseases cause relatively little yield reduction in most years, partly due to the availability of chemical controls. Severe stem rust has been observed on irrigated wheat at St. George. In a survey of wheat properties in Roma and Downs divisions, Hamilton (1966*a*, *b*) found that 57% of growers considered they had "an insect problem" and 67% had a "major weed problem". In his sample the percentages of farms recording different insect pests were: corn ear worm 36%; army worm 25%; sorghum midge 5%; cutworm 5%; other insects 5%.

For weeds the figures were: wild turnip 39%; buckwheat 33%; mintweed 9%; Noogoora burr 7%; black oats 7%; saffron thistle 9%; wild radish 5%; other weeds 25%.

Winter crop area is at least ten times summer crop area and it is clear that double cropping (two crops a year from one area) is unimportant in the region. It has a small place in the most favoured areas as a technique for rotating from summer to winter crops (considered necessary for weed control) without a 12-month fallow and its associated erosion hazards. Wheat is normally sown (23–28 kg/ha) on the land fallowed since the previous crop, following the first substantial falls of rain (25–40 mm) after June 1 (Hamilton 1966*b*), and harvesting normally starts in early November. Forage oats are sown (23–28 kg/ha) from February onwards and grazing starts within two months of germination. Oats for grain are sown about June (34 kg/ha) and harvested October–November. Sorghum for grain is sown in late December–early January often on land that has had little or no fallow. Low seeding rates (2–3 kg/ha) are used to forestall water stress near maturity.

With predominantly winter cropping, land is fallowed during the summer period of highest and most intensive rainfall and on many soils in the region there is considerable erosion hazard (Shaw 1971). Hamilton (1966*b*) found 28% of his sample farmers had some contour banks, diversion banks, etc., and a further few regularly cultivated across the slope to reduce run-off. No data are available relating erosion to crop yields although this may already be a serious problem.

Some indication of the profitability of cropping is given in the survey results of Hamilton (1966*a*). For a two-year period (1962/63 to 1963/64) having better than average yields, 74 cropping farms from Roma and Downs having enterprises typical of Roma division had the following summary financial results.

	Grain–sheep farms (24)	Grain–cattle farms (34)	Grain–sheep–cattle farms (16)
Total returns ($)	19,796	13,895	17,704
Total costs ($)	12,924	9318	13,062
Return to capital and management ($)	6872	4577	4642
Total farm capital ($)	140,004	97,551	158,231

On the humid side of the 470-mm isohyet, approximately 80% of the wheat area is on the 40% of that area which lies within 65 km of one of the three railway lines penetrating the region. Given that cropping intensity in areas wetter than 470 mm is not strongly correlated with rainfall, this suggests that transport costs may be an important determinant of where wheat is grown. In principle the boundary between crop and livestock areas will be where it is equally profitable to grow crop or raise animals. Even if cropping is more profitable at the railhead, moving 65 km out incurs transport costs of about 9% gross railhead returns for wheat and only 2% for beef. This is partly recognized in regional land prices which drop by about 5% as one moves 50–65 km from a railhead.

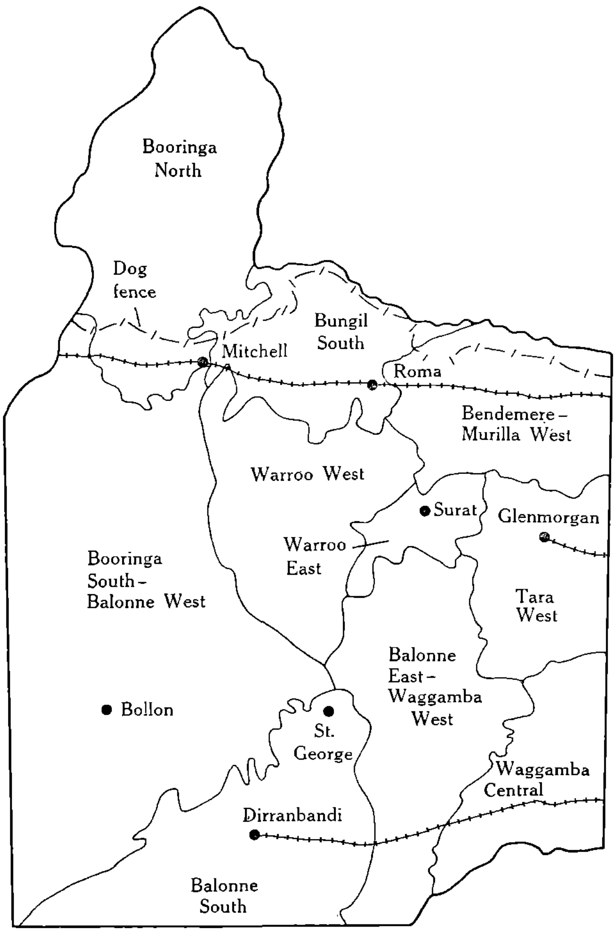

Fig. 21.—Agro-ecological districts of the Balonne–Maranoa area.

V. Forestry

Currently the only species with significant potential for commercial timber is cypress pine. There are approximately 200,000 ha of state forests and timber reserves carrying cypress pine and in the survey area these are slowly being enlarged by incorporation of suitable adjacent expiring leases. The estimated merchantable volume of mill timber is 10,000 m^3, representing approximately one-third of Queensland's cypress pine resources (Department of Forestry, personal communication). It is anticipated that a sustained annual cut of about 76,000 m^3 will be achieved by 2000 A.D. A typical yield for managed forest is 3·0 m^3 per hectare per 20-yr cycle and a high yield is around 18 m^3. Stumpage revenue (there are 24 sawmills in the area) is about $4.00/$m^3$ and management costs per hectare are $17–20 per cycle.

VI. Agro–Ecological Districts

This section is designed to study the way in which internal physical variations in the area differentially control possibilities and limitations within the region. The method adopted is to divide the survey region subjectively into "agro–ecological districts" (Fig. 21) named according to their major shire portions. These ten districts plus the St. George irrigation area represent the smallest areas about which even approximate land use data are available and the largest areas about which it is thought possible to generalize with any confidence. The extreme north-west of the area and the south-eastern corner in New South Wales were not included in this study.

(a) *Booringa North*

This is the country drained by the upper Maranoa above about 300 m and lying between the Chesterton and Great Dividing Ranges. It includes the highest, remotest, and most northerly part of the survey area. In the extreme north abutting the Carnarvon Range there is an area of steep mountain ridges. Dropping away to the south are low dissected plateaux and hills. Major soils are deep sands and sandy duplexes to the north and lithosols and solodics to the south. There is an area of brigalow scrub at the eastern edge of the district but most of the region carries poplar box woodland with large occurrences of cypress pine on the sandier soils. Mean annual rainfall is 500–625 mm with approximately two-thirds falling in November–April and a relatively more variable one-third falling in winter.

Most of the area is north of the main east–west dog fence and here sheep are not run. The main enterprise is cattle breeding turning off 12–18-month-old stores. Frequent nutritional stress in winter makes fattening to three years difficult and the use of urea–molasses licks at this season (particularly for breeders) is increasing. A little oats for winter fodder is the only cropping. A winter rainfall little greater and less reliable than in the driest part of the survey area plus light soils (erodible and with low water-holding capacity) and considerable relief suggest that cropping is never likely to be important. The high summer rainfall suggests the possibility of more buffel grass being sown. Cattle properties range from about 6000 ha in the south to 20,000–25,000 ha in the north with 8000–10,000 ha as a modal range. In the virgin state carrying capacity is in the range of a beast to 12–20 ha. Ringing, a common practice on box flats, raises this to a beast per 8–12 ha. There is some suggestion that on buffel pasture it might be possible to carry a beast per 3–4 ha. Clearing is not practised to any extent except as an aid to access. There is practically no artesian water but surface supplies are generally adequate. A property is commonly divided into 5–7 paddocks to keep different classes of stock separate. Herd size ranges from 250 to 2000 breeders. In general stocking is conservative, especially on the larger properties, and this is reflected in the comparative stability of stock numbers in the district. Despite poor winter nutrition, calving figures of 60–70% are typical and, it is claimed, might be 70–80% without depredation by dingoes. Other common problems are sawfly and cypress seedling regrowth. Isolation makes the attraction and retention of labour difficult in the north of the district.

Moving south of the dog fence, properties are smaller (1600–4000 ha), often freeholded under past attempts at closer settlement. Some sheep, often wethers, are run and a little cash cropping is practised close to the railway line. Clearing is more common, including some patches of bendee-carrying lithosols, and control of timber regrowth is a problem. Native carrying capacity at a beast to 10–12 ha is higher than in the north of the district.

(b) Booringa South–Balonne West

This is the dry country (380–480 mm mean annual rainfall) west of the lower Maranoa and the flood-plains of the lower Balonne–Culgoa. Drainage to the west of the district is via Mungallala and Wallam Creeks. It is an area of undulating to irregular plains carrying box–mulga to the east and mulga–box to the west on red earths. There are patches of cracking clay with coolibah to the south-west.

The major enterprise is sheep-breeding with some cattle, whilst about 10% of properties mainly to the north carry cattle only. Property size ranges from 2000 to 30,000 ha, common figures being 4000 ha in the east and 16,000 ha in the west. The larger properties are generally held under 30-yr pastoral lease and the smaller properties as various types of grazing selections. On the larger properties it is common to subdivide into 800–1200-ha paddocks and run sheep in mobs of 700–800. Subdivision is generally governed by the run of bore drains following the south-westerly dip of the country. The district is strongly dependent on a dense network of artesian bores for water. As a rough guide, a flow increment of 30–40 m^3/day will service 1 km of drain and hence a maximum of 6–7 km^2 of sheep country. In the northern higher parts, large numbers of bores have stopped flowing since peak discharges were achieved about 1930. Further south there has been a substantial diminution of flow at a rate of perhaps 3% per annum, until recently when the rate of diminution has dropped to 1% per annum. It would appear that a steady state is being approached.

District carrying capacity ranges over one sheep to 2 to 5 ha on uncleared country, i.e. more than 90% of the district. There would appear to be considerable potential for ringing and sucker-bashing box country. Mulga, however, although deficient in phosphate and energy (Everist 1969) constitutes a valuable drought reserve and, where mulga is at all dense, the implied management problem is to balance the reserve of top feed for pushing down in drought, plus leaf-fall, against the more regular extra ground feed that follows clearing. The two policies followed are to push (in long cross-wise strips) approximately one-third of the area and to leave 200–250 mulga trees per hectare as a drought reserve when clearing. Sheep readily eat mulga seedlings and, given that this is not a long-lived tree (perhaps 60 years, Condon 1949), mulga is disappearing in some parts. On the other hand, mulga regrowth can be a problem where cattle are run alone.

Two possibilities for further improvement of feed supplies are improved sown pastures and fodder cropping. Neither is common and their future use is difficult to predict. Buffel grass, from limited experience and testing (Ebersohn 1970), might persist successfully on eastern poplar box country to produce perhaps twice the summer feed of a native pasture and persist with difficulty on more arid, low phosphate, higher run-off mulga country. Some grazing oats are grown just west of the Maranoa and typically produce 1200–1500 sheep days of grazing per hectare in autumn–winter. There is no cash cropping in the area apart from some negligible plots of wheat just west of the Maranoa, not enough to derive yield estimates.

From police portion data average flock size in the district appears to be about 7400 sheep equivalents.

(*c*) *Balonne South*

This district encompasses the triangle of cracking clay flood-plains and levee-type plains and rises of brown duplex soils below St. George and lying between the Culgoa and lower Moonie. Rainfall is low (380–480 mm annual mean) with about 60% falling in November–April. Reliability as measured by coefficient of variation is the same (about 50%) for both seasons, implying a much lower standard deviation for total winter rainfall. The levee soils, in the eastern part of the district, carry box–wilga–sandalwood and the "black" country carries coolibah–Mitchell grass.

As a result of past attempts at closer settlement, well documented by Heathcote (1965), property size ranges from 4000 ha in the east to about 8000 ha in the west. Bores are much less important than surface storage in the stock water supply. A large proportion of the coolibah country has been ringed for many years but the levee country has not been cleared to any extent and on what has been cleared the regrowth of box suckers and sandalwood is severe. Whilst this is still a predominantly sheep-breeding district, both cropping (less than 1% total farm area) and to a lesser extent cattle have become a little more important in recent years. Cattle numbers are relatively more variable than sheep numbers, which suggests that the impact of seasonal variation is absorbed more in cattle herds than in sheep flocks. Wheat yields are low (around 8 hl/ha) and cropping is partly seen as an aid to regrowth control and occasionally as a precursor to buffel pasture. A little oats is sown as winter fodder for cattle to yield 120–200 beast days of grazing per hectare. Whilst the levee soils have the advantages of cultivatability and responsiveness to moderate winter rains, the cracking clays are much higher in phosphorus (50–80 p.p.m. *v.* 8–25 p.p.m.) and have much higher water-holding capacity. Crops on cracking clay are sometimes flooded out.

Sheep do well on pastures having significant winter herbage production and cut 3·7–4·3 kg per head overall at high stocking rates. Coolibah country is rated at one sheep per hectare and uncleared levee country at one sheep to 1·5 ha.

(*d*) *Balonne East–Waggamba West*

This district is the long tongue of red earths and red-brown earths extending from the Thomby Range in the north to the border at Mungindi and carrying box, belah, and ironbark. Also there are significant areas of cracking clays carrying belah–brigalow. Starting at the Thomby Range (hills with lithosols), the district drops in undulating and irregular plain lands from 420 m (Mt. Weribone) to 150 m in the extreme south. Drainage is via the Balonne (in the north-west) and Moonie Rivers. Despite the latitudinal spread of the district, annual mean rainfall ranges only over 480–560 mm with approximately 60% falling in November–April.

The district is devoted mainly to sheep-breeding with about one-quarter of its carrying capacity used for cattle, a fraction which is increasing in the north and remaining relatively constant in the south. An occasional property runs cattle only and some northern properties can run only wethers because of the presence of the poisonous weir vine. Carrying capacity ranges over one sheep to 1–1·5 ha, the red earths having the lowest capacity. Property size ranges from about 6000 ha in the north to about 3000 ha in the south, smaller properties often being freehold. Flocks lie in the range of 3000–4000 head and are often associated with a herd of about 100 cattle. The main methods of property development are ringing of poplar box and bulldozing belah; there is little reliance on artesian water. A little buffel grass has been sown.

Cropping has increased at a spectacular rate in recent years but still uses less than 2% of district area. Mean wheat yields increase from about 8 hl/ha on red-brown earths in the extreme south to 12–14 hl on duplexes and cracking clays east of St. George around the Moonie River. Substantial areas of oats for winter grazing are also grown. There is some evidence that deterioration of soil structure occurs with regular cropping on red-brown earths.

(*e*) *Warroo West*

This district is the tongue of red-brown and red earths lying between the Balonne and Maranoa Rivers and below the Roma–Mitchell downs. It is an area of flat to undulating plains bisected by the Cogoon River. There is a substantial area of bendee-carrying lithosols to the north-west and a north-east to south-west strip of red earths through the district. Vegetation is basically poplar box–sandalwood open forest. Mean annual rainfall is 420–530 mm, about 65% of it falling in November–April and a relatively unreliable 35% in winter.

Property size ranges from 4000 to 8000 ha with larger properties tending to be in the west and smaller properties on frontage country. A few properties run cattle only but most can be classified as sheep–cattle with typical stock complements of 3000–4000 sheep plus 130–180 cattle. A large area to the west of the district is infested with weir vine and only wethers can be run. Also, St. George disease of cattle has been recorded on a number of occasions.

Average carrying capacity on red-brown earths ranges from 1 sheep to 1–1·5 ha uncleared, 1 sheep to 0·8–1 ha on ringed box, and, it is claimed, 1 sheep to 0·4–0·8 ha on buffel sown into a seed bed. Lithosols and red earths have much lower capacities. Uncleared bendee country might carry 1 sheep to 8 ha and, after pulling, 1 sheep to 1·5 ha for perhaps 10 yr until substantial regrowth occurs (Tiller 1971). Red earths with box–ironbark might carry 1 sheep to 3–4 ha. Ringing has been done on substantial areas but figures are not available; timber regrowth is a common problem. Artesian bores are common along the western edge of the district but there are few elsewhere.

Current cropping intensity ranges from less than 0·1% of area in the west to about 2% in the north and east. The small wheat areas in the west might average 8–9 hl/ha yield and the range elsewhere is 10–13 hl. Grazing oats are the other form of cultivation and yields of 180–200 beast days are expected. The red-brown earths develop poor structure after a few years' cropping and phosphate is deficient from the start of cropping, although not used as a fertilizer.

(*f*) *Warroo East*

This small district delineates the Mitchell grass open downs around Surat together with some flanking strips of loamy duplexes with brown subsoils which carry belah and brigalow. Drainage is via the Balonne River. Mean annual rainfall is 560–590 mm with about 65% falling in November–April and a relatively more variable 35% in winter.

Apart from a few properties running cattle only, this has been dominantly sheep-breeding country. In recent years cattle numbers have been allowed to build up at the expense of sheep numbers. Property size ranges from 3000 to 6000 ha often subdivided into paddocks of 400–1200 ha which are watered from surface sources. Property size reflects high carrying capacities of 1 sheep to 0·7–1·2 ha. Flock sizes of 4000–5000 sheep or sheep equivalents are common.

Cropping to wheat or forage oats is practised on a majority of properties, typically within the range of 100–200 ha, occasionally 400 ha. To some extent cropping has become necessary as a control for white spear grass (*Aristida leptopoda*). Average wheat yields range over 13–16 hl on the self-mulching heavy clay soils of the open down. As the soils are heavy and have slopes of 1–3%, there is some danger of gully erosion; contour cultivation and the use of grass strips are recommended by the Department of Primary Industries. Also, a lucerne phase every 8–10 yr is recommended to rejuvenate soil structure but this is uncommon. Buffel grass, which has a very small seed, is difficult to establish and maintain on these soils.

(*g*) *Bungil South*

This district is the sweep of country rising gently north from the Roma–Mitchell downs to the crest of the Great Dividing Range. A broad band of undulating solodic soils carrying box–callitris–ironbark occupies the north of the district. Between this and the heavy-textured Mitchell grass downs there is a substantial area of brigalow–belah–box on undulating brown duplex soils. There is an area of sedentary clays carrying brigalow–belah to the east of the open downs. Drainage is via Muckadilla and Bungil Creeks. Mean annual rainfall is 530–600 mm, approximately 65% falling in November–April.

South of the solodic belt, which is devoted to cattle with some sheep on 2000–4000 ha properties, grain, sheep-breeding, and cattle are all important enterprises. Downs properties are typically 1000–3000 ha with 200–400 ha of crop. Cropping, along with cattle, plays a secondary management role in controlling hard-seeded grasses such as white spear grass which affect sheep productivity. On the larger downs properties cattle tend to be more important than sheep, a reflection of relative labour requirements. The red-brown earths are less extensively cropped but it is an important enterprise because many of the properties on these soils are very small (400–1000 ha). Dingoes are also something of a problem on this brigalow–belah country. Clearing has been extensive off the downs and sandalwood regrowth is a particular problem on the red-brown earths.

Average carrying capacity ranges from 1 sheep to 0·6–0·8 ha on downs country to 1 sheep per 0·8–1 ha on solodic country. Pulled brigalow will carry 1 beast per 5 ha and 1 beast to 2–3 ha when sown to buffel pasture. Buffel grass can be established on solodics and red-brown earths but lucerne and *Sorghum almum* are the main contenders as pasture species, albeit short-lived, on heavy country. Clay pans, high in chlorides, are common along drainage lines in downs country. On solodics, with shallow A horizons and 3% slopes, permanent buffel grass is sown after only one or two years' cropping.

Self-mulching downs soils with good fertility (no fertilizer needed) and (say) 2% slopes are quite suitable for cultivation although low infiltration rates make them susceptible to gully erosion. Red-brown earths with 1–3% slopes are highly susceptible to erosion and lose structure with regular cropping. Average wheat yields for the district are around 13 hl and grazing oats are expected to yield about 2200 sheep days of grazing per hectare.

(*h*) *Bendemere–Murilla West*

This district is the compact undulating area of brigalow–belah–box on red-brown earths and cracking clays north of the Condamine–Balonne River. There is a large irregular area of cypress pine on solodic soils in the middle of the district, most of it state forest. The area is drained by creeks running from the Great Dividing Range to the Condamine. Mean annual rainfall is 580–630 mm, about 64% falling in November–April.

Typical property sizes in the distict are 800–2500 ha grading to 2500–5000 ha in the south. Additionally, there are numerous small freehold blocks, up to 800 ha in the former dairying areas along the railway line. Fat lambs are an important enterprise here. Forest leases on solodic country range over 3000–10,000 ha.

Both north and south of the main east–west dog fence cattle are run exclusively, mainly in breeding units with 10–18-month turn-off. Crop fattening has been declining in importance in recent years due to lack of suitably priced stores. Sheep-breeding is common only in the south of the district. Virgin brigalow–belah carries 1 beast to 14–16 ha, 1 beast to 6 ha when ringed, and 1 beast to 2–3 ha on the good buffel pasture which is possible in the district. Green panic, Rhodes grass, and *Sorghum almum* will establish but not persist like buffel. Virgin cypress–ironbark–bull oak on solodic soils carries 1 beast to 16 ha and 1 beast to 8–10 ha when ringed.

Cattle on this country often suffer nutritional stress in late winter–early spring. Sandalwood regrowth has proved a problem following recent extensive clearing on red-brown earths and is fully controllable only by cropping. Apart from a number of deep bores in older established areas, stock are watered from surface sources. North of the railway line, up to 30% of farmers make some cereal or buffel hay (yields of about 0·7 tonne/ha) as a drought or production reserve.

Current cropping intensity increases from 3 to 15% of total farm area moving eastwards across the district, except in the south where less than 1% is cropped and on solodic soils which are rarely cropped except as a precursor to sowing pasture. Crop area in the district increased by approximately 400% between 1959 and 1969. Winter crops, wheat and grazing oats, have been of major importance but with the advent of wheat quotas and a decline in crop fattening, diversification can be expected.

Summer sorghum areas have not been more than 2–3% of total crop area in recent years. Average wheat yields on better soils increase from 13 to 19 hl/ha moving eastwards across the district. In the south, the average of 9–11 hl is from small areas and is reduced by low yields from solodic areas. Oats are expected to yield about 250 beast days of grazing per ha.

Red-brown earths, the main cropping soils, have slopes which are long and up to about 3% and they are liable to both water and wind erosion. This threat is accentuated by the structure deterioration and reduced permeability which follow regular cropping. Fertility is moderate with some superphosphate starting to be used. Weeds (black oats and buckwheat) and insects are considered a problem but chemical controls are not widely used.

(*i*) *Tara West*

This district is the area of gilgaied cracking clays and undulating red-brown earths east of the main Thomby Range and between the Condamine and Moonie Rivers. Red-brown earths (mixed with patches of lithosols and red-subsoiled duplexes) occupy the west and south of the district and carry mainly belah–brigalow. The cracking clays elsewhere carry heavy brigalow although a large part of the district has now been cleared. Drainage is via intermittent creeks flowing north to the Condamine and south to the Moonie from an east–west spur of the Thomby Range. Mean annual rainfall is 530–580 mm with approximately 61% falling in November–April.

Average property size in the district is 3000 ha with a general range of 1000-8000 ha. The average property runs about 3000 sheep, mostly in a breeding flock, and 120 cattle. From 200 to 400 ha of crops are grown. Virgin brigalow–belah carries one beast to 15–18 ha rising to one beast per 6 ha when cleared and better than two sheep per 1 ha when sown to improved pasture (buffel, Rhodes, green panic, lucerne, and barrel medic). Brigalow on gilgai country carries one beast to 20–25 ha uncleared, one beast to 6 ha cleared, and, if sown pastures (lucerne, *Sorghum almum*) can be established and held, about one sheep per 0·4 ha. The most common brigalow development technique is to pull, burn, spray, and then clean up the remaining suckers with wethers kept for this developmental function. Scrub regrowth is a major problem in the district and a period of cropping seems to be the only really effective method of control.

Cropping intensity in recent years has been at about 8% of total district area, representing a ten-fold increase since 1959.

Wheat with 80% and grazing oats with 17% of total area are the main crops. Average wheat yield for the district is 16 hl and oats are expected to yield about 250 beast days of grazing per hectare. There are no erosion hazards on gilgai country in so far as overall slopes are low (0·5%) and drainage is largely internal. Yields are low and operations are difficult for some years after first cultivation until gilgais are levelled somewhat. Red-brown earths, as in the district to the north, are liable to erosion and loss of structure.

(*j*) *Waggamba Central*

This district is the triangle of brigalow, belah, and coolibah in the south-east corner of the survey area. The cracking clay flood-plains of the Weir and McIntyre

Rivers in the south of the district carry coolibah and there is brigalow scrub on gilgaied cracking clay in the north. Between these two areas there is a peninsula of red-brown earths carrying mainly belah. Mean annual rainfall is 480–530 mm with approximately 63% falling in November–April.

Average property size in the district is about 5000 ha with a range of perhaps 2000–7000 ha. The average property would have a stock complement of 4500 sheep and 80 cattle, both breeding enterprises. The carrying capacity of coolibah country, much of it ringed, is 1 sheep to 1–1·3 ha. Brigalow and belah country carries 1 sheep to less than 1 ha when cleared. There is little improved pasture in the district. Overall district stocking rates average 1 sheep equivalent per 0·8 ha. Apart from a few artesian bores on brigalow country, often yielding brackish water, stock are watered from surface sources.

Cropping intensity in the district has increased from practically nothing in 1959 to 5–8% of total farm area in recent years. There are considerable areas subject to flooding along the lower Weir River where there is no cropping and cropping intensity is highest on the northerly belah and brigalow country. Until recently, 90% of crop area has been in wheat and most of the remainder in grazing oats. Average wheat yields range from about 12 hl/ha on coolibah country to about 14 hl in the north.

(*k*) *St. George Irrigation Area*

The present St. George Irrigation Scheme, opened up in 1957, comprises 20 farms of about 240 ha situated on (mainly) cracking clays a few miles south-west of St. George. In 1965/66, 2700 ha were watered with an average of 580 mm (Anon. 1967). Initially cotton and fat lambs were the major enterprises but in 1965/66 land use statistics as recorded by van Haeringen and Wegener (1968) showed the following areas (ha): cotton 91; winter grain, mainly wheat 537; maize 30; sorghum 110; lucerne 590; summer grazing crops 243; winter grazing crops 556; annual clover pastures 68; perennial clover pastures 224; other 229.*

Cotton acreage has increased again since 1965/66, although insect control is still a problem and the soils are not regarded as particularly suitable (Basinski 1963). Pasture and grazing crops are used for the production of fat lambs (a thousand ewes is typical), fat cattle, and hay. A survey of five remaining original settlers (van Haeringen and Wegener 1968) showed the following annual average percentage returns on capital:

1958/59	−5·4%	1962/63	−0·4%
1959/60	−5·5%	1963/64	8·0%
1960/61	−5·2%	1964/65	3·4%
1961/62	−3·2%		

*A personal communication in June 1973 from Mr. R. S. Epworth, Queensland Department of Primary Industries, brings the description of land use on the St. George Scheme up to date.

He states that lucerne, pasture, and stock activities have now disappeared from the area. The land is now used mainly for cotton with soybeans as a secondary crop. The average yield of seed cotton in 1971/72 was 3800 kg/ha. Crop average figures for the scheme in 1972/73 were as follows: cotton 2499 ha; sunflower 142 ha; wheat 73 ha; maize 81 ha; soybean 502 ha; popcorn 154 ha; navy beans 1 ha; potatoes 4 ha; total area 3456 ha.

The same survey showed that between 1959 and 1965 the average equity of these five farmers increased from $14,504 to $35,128, excluding appreciation in land value. Farm turnover has been high and the slow development of the area is attributed by van Haeringen and Wegener to inadequate technical knowledge, inadequate experience of irrigation farming, and, less importantly, inadequate capital.

Production possibilities on the scheme are illustrated by the following estimates used by Department of Primary Industries personnel in drawing up budgets:

Seed cotton	2520 kg/ha
Sorghum	71 hl/ha and 889 sheep grazing days per ha
June wheat	60 hl/ha and 296 sheep grazing days per ha
July wheat	45 hl/ha and 296 sheep grazing days per ha
Lucerne hay	14,000 kg/ha
Lucerne pasture	6311 sheep grazing days per ha
March grazing oats	2482 sheep grazing days per ha
June grazing oats	2112 sheep grazing days per ha
Permanent pasture	6444 sheep grazing days per ha
Annual pasture	4000 sheep grazing days per ha
Lambing	90% of ewes mated

When current extensions to the scheme (32 farms of 180 ha) are completed it will supply a planned 46,000,000 m^3 of water per annum for a capital cost of $10,600,000 or, approximately, a total cost of $0.23/$m^3$ per annum. The benefit–cost ratio claimed for the extensions is 1·79 with a calculated internal rate of return of 9·4% (Anon. 1967).

(1) Comparison of Agro-Ecological Districts

Variation in production and development possibilities between districts is mainly a function of the physical environment and the state of technology. The basic technologies of clearing, cropping, sowing pasture, and extensively running sheep and cattle used in the region are qualitatively very similar from district to district. Operational recipes use the same ingredients but in differing proportions. There are, however, restricted areas where certain activities are in some sense (probably implicitly economic) fundamentally inappropriate.

(1) Sheep are not run in dingo country—basically the northern portions of Booringa North, Bungil South, and Bendemere–Murilla West.

(2) Cattle are not run in weir vine country—basically the western portion of Warroo West.

(3) Crops are not grown on the flood-plains of the lower Balonne River in Balonne South and the Weir River in Waggamba Central.

(4) Crops and improved pastures are not grown in the drier parts of Booringa North and Booringa South–Balonne West.

Within these constraints the farmer's management decisions are grouped in the areas of stocking policy, cropping policy, and development policy. An attempt is made to summarize recent interdistrict expression of some of these decisions in Table 28. No data are available on development.

Whilst the reasons for adopting particular enterprise mixes are highly complex, a substantial part of the explanation can be found in variation in performance measures between districts. A number of these are summarized in Table 29.

It is not possible, due to data inadequacies and lack of process knowledge, to give a functional explanation of these performance variations. However, one environmental factor, rainfall, stands out. For example, a simple linear regression of typical district wheat yield on district average annual rainfall explains 82% of the variance in yields amongst districts. This regression indicates an increase in yield of 1·1 hl per 25 mm of rain in excess of 45 mm per annum. District sorghum yields tend to follow district wheat yields, but with the modification that sorghum yields are 1–3 hl/ha higher in districts with lighter soils and 1–3 hl/ha lower in districts with heavier soils.

Rainfall *per se* explains only 32% of variance in average district stocking rates but if annual rainfall is multiplied by a measure of available soil water (cm/cm) applicable to typical district soils R^2 rises to 0·66 ($P<0·01$). The regression suggests that, at any rainfall, carrying capacity increases with water-holding capacity and that carrying capacity increases at much the same rate with extra rainfall on a range of soil types.

TABLE 28

TYPE AND INTENSITY OF PRODUCTION ACTIVITIES IN AGRO-ECOLOGICAL DISTRICTS*

	Mean stocking rate (sheep equiv./ha)	Coeff. of var. of stocking rate (%)	Cattle fraction (% total sheep equiv.)	Ewes (% total flock)	Crop area (% total area)	Wheat area (% total crop area)
Bendemere–Murilla West	1·18	11	88	25	10	58
Bungil South	1·48	9	56	33	4	67
Booringa North	0·72	11	68	26	<0·2	97
Warroo East	0·91	7	28	34	2	45
Tara West	1·36	12	29	24	8	79
Balonne East–Waggamba West	0·82	13	24	40	2	72
Waggamba Central	1·18	14	25	39	6	83
Warroo West	0·67	11	34	30	<0·5	80
Balonne South	0·89	16	20	46	1	80
Booringa South–Balonne West	0·47	16	30	35	<0·1	25

* Source: Commonwealth Bureau of Census and Statistics.

VII. The Future of Balonne–Maranoa

The socio-economic environment within which short-term development of Balonne–Maranoa seems most likely to take place is one characterized by wool and beef prices around current levels, slightly relaxed wheat quotas (given the relative ease of selling hard wheat), slowly rising costs, and rather minor technological advances.

Given that the area is only marginally prosperous, with the available evidence suggesting rates of return on capital of no more than 2–4% it is difficult to see any substantial flow of investment capital into agriculture. For example, a farmer earning 2% on capital can only service a debt bearing 6% if his equity is greater than 75% of assets. Whilst equity ratios have not been measured in the survey area, Haug and Hoy

TABLE 29

PERFORMANCE MEASURES IN AGRO-ECOLOGICAL DISTRICTS*

District	Lambing (%)	Wool cut per head (kg)	Wool cut per acre (kg)	Sheep turn-off rate (%)	Sheep death rate (%)	Calving (%)	Beef turn-off rate (%)	Beef death rate (%)	Wheat yield (hl/ha)	Sorghum yield (hl/ha)
Bendemere–Murilla West	55	3·5	1·7	7	6·6	54	28	4·8	15	17
Bungil South	59	3·4	2·1	10	7·0	71	24	5·4	13	13
Booringa North	54	3·7	1·1	8	6·5	44	23	4·8	8	11
Warroo East	56	3·7	1·4	11	7·4	51	28	6·9	14	13
Tara West	52	3·7	2·0	3	7·2	47	22	4·9	16	13
Balonne East–Waggamba West	55	3·9	1·3	14	8·2	43	21	5·7	12	14
Waggamba Central	59	3·7	1·8	17	8·6	41	18	6·6	13	10
Warroo West	50	3·7	1·2	7	8·0	50	23	6·3	10	11
Balonne South	58	4·0	1·5	19	8·0	40	20	4·0	8	<8
Booringa South–Balonne West	52	3·9	0·8	7	9·2	40	18	3·1	<8	<8

* Source: Commonwealth Bureau of Census and Statistics.

(1970) found that a sample of sheep properties to the immediate west had an average equity ratio of 0·79 in 1967/68. More significantly, they found a steady decline in equity ratio over the previous six years.

In these circumstances it would appear that development, the profitable exploitation of technological possibilities, is likely to be extremely limited. Opportunities which would have been worth taking up even a few years ago have become economically doubtful. Alternatively, it is the socio-economic environment and not the physical environment that is currently constraining development opportunities.

The other major query overhanging future development is the threat of massive environmental deterioration. It is just not known whether regional stocking and clearing practices have led or are leading to a permanent decline in carrying capacity. The situation is obscured by high interseasonal variability and considerable past investment in facilities which might be expected to have enabled higher stocking rates.

It is not difficult in fact to envisage a gloomy future for Balonne–Maranoa with widespread bankruptcy caused basically by economic factors but hastened by a further run of bad seasons before complete recovery from the 1965/66 drought, decreasing carrying capacity, diminishing artesian flows, and continued attempts at closer settlement.

More realistically, the region will enter upon a period of adjustment rather than decline. The main adjustments one can foresee are a trend towards property aggregation, a swing from sheep to beef, and an increase in sorghum acreage.

(a) *Property Aggregation*

At current product prices profitable production of wool, beef, and crops is still possible in most districts provided that land prices adjust to realistic levels. Given that the probability of achieving some reference profit increases with property size (assuming no diseconomies), many farmers will still be seeking to expand operations provided that they do not have to borrow heavily to do so. There is some evidence that larger properties are as efficient as and possibly more efficient than smaller properties in their use of capital and it is these which are most likely to have acquired reserves. Consequently it can be expected that, as land prices fall (as they are doing), the larger properties will tend to acquire land coming onto the market. More specifically, in the drier areas it will be the larger cattle properties that will be in the best position to expand, not only because of their reserves but also because they will not be seeking large sums to change stock (and facilities) from sheep to cattle. Table 30 shows the areas required in different enterprises and districts to give $5000 return to capital.

(b) *Sheep to Beef*

In the wetter parts of the region, at current product prices both a higher rate on capital and a higher return to capital per hectare can be earned with cattle than with sheep. It can be expected then that there will be a movement into cattle where farmer funds permit. If the change is to be financed with borrowed funds, however, the rate of return on marginal capital is such that only in the most favoured districts will this be an acceptable proposition to institutional lenders—repayment periods are of the order of 5–8 years.

In the drier part of the region (Booringa South–Balonne West, Balonne South, Balonne East–Waggamba West, Waggamba Central), cattle give a higher absolute return on capital per hectare but a lower rate of return on capital. It might be expected, therefore, unless wool prices fall further, that it is only the smaller properties which will seek to change to cattle to get total profits up, albeit using capital less efficiently.

Neither borrowed nor farmer funds are likely to be available to smaller properties and expansion into cattle is likely to be limited to some proportion of natural increase of stock already on hand.

(c) *Increased Sorghum Acreage*

Provided that land is already cleared for cropping, calculations indicate that the rate of return on marginal capital (12–60%) is attractive enough for the farmer to use his own funds to move from sheep to sorghum in all parts of the region except Balonne South and Booringa South–Balonne West.

If new plant has to be purchased with borrowed funds the pay-back period in the additional districts Waggamba Central, Booringa North, and Warroo West would be too long (>11 yr) for most lenders.

TABLE 30

AREAS (HA) REQUIRED TO GIVE $5000 RETURN TO CAPITAL

District	Wheat	Sorghum	Beef	Sheep
Bendemere–Murilla West	179	206	2000	16,875
Tara West	165	322	2474	13,149
Balonne East–Waggamba West	355	355	4516	10,764
Warroo East	233	413	2638	15,698
Bungil South	233	494	2018	14,062
Warroo West	533	800	4845	23,437
Waggamba Central	266	844	4092	7,533
Booringa North	1446	964	4595	23,276
Balonne South	780	>2250	4612	7,399
Booringa South–Balonne West	>2900	—	10,871	24,223

If land clearing capital has to be borrowed as well, Bendemere–Murilla West becomes the only district with a pay-back period (6–7 yr) of less than 9 yr.

It is likely then that regional sorghum acreage will expand slowly as farmer funds become available and this expansion will tend to be on country already cleared and on the open downs.

These then are the general prospects that can be foreseen for the districts in the region. To go further and break down prospects within districts would require:

(1) Accurate knowledge of current land use, i.e. productivity, capitalization, and financial performance of farms in the district. It would be of considerable help here if standard statistical data could be made available for defined physical areas smaller than agro-ecological districts.

(2) Predictions of the results of applying *a priori* technology recipes of known feasibility to farms and land units in each district.

Even given these data, potential would be measured subject to an assumed socio-economic environment and the technologies subjectively chosen for evaluation.

Whilst not proposing an integrated research programme to realize these finer objectives, certain recurring questions will have to be tackled eventually if a stable and prosperous agriculture in a pleasant milieu with a range of land-use options is to be achieved.

(1) Is the region experiencing a continuing decline in native carrying capacity? What is the long-term carrying capacity of improved pastures across the region? Can better pasture species be developed, especially for areas with less than 450 mm annual rainfall? What is the effect of clearing and development on pest numbers and regional water balance?

(2) How rapidly is soil erosion proceeding and what effect will this have on long-term cropping prospects? Is it possible to develop and promote cheap and easy soil conservation techniques?

(3) What are optimal stocking–feeding policies in face of high interseasonal variability? Under what conditions is fodder conservation profitable? What are the prospects for reliable long-range weather forecasts?

(4) What areas should be reserved for uses other than agriculture? What is the true value of cypress pine reserves? How is diversion to alternative uses to be achieved administratively?

(5) What research avenues exist to raise production per head rather than carrying capacity? Why are stock management standards so low in the region? At what rates do beef cattle substitute for sheep?

(6) Should property aggregation be actively encouraged in the hope that the result will be a smaller number of viable economic units run less intensively but with more stable output?

(7) Should closer control be exerted over individual development activities with respect to such things as clearing, water conservation, and the cropping of erodible soils?

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APPENDIX I

Land Capability

I. Introduction

Interactions between landscape attributes, namely climate, topography, rock type, soil, and vegetation, give rise to a wide range of environmental conditions in the area and impose limitations in varying degree on the use of land for different purposes. The cultivation of cash and fodder crops, the grazing of native and improved pastures, and the exploitation of hardwood and softwood forests are at present and are likely to continue to be the most important forms of land use in the area. Nevertheless, other aspects such as the use of land for outdoor recreation, conservation of native animals and plants, and engineering will also need consideration in specific areas.

The 76 land units described in Part III and assemblages of them in the 33 land systems shown on the map accompanying this report provide some of the basic information required for evaluating landscapes in terms of these present or potential uses. The land capability classes given in the land unit descriptions are based on the interpretative system developed by the United States Department of Agriculture (1958)* and modified slightly to suit local conditions. The purpose of this Appendix is to define the land capability classes and subclasses which indicate the degree and kind of limitations respectively to land use in the area. The broad distribution of the various classes of land is shown in Figure 22.

More quantitative data on climate and land are required before accurate predictions can be made regarding the effects of various forms of land use on specific landscapes. It is suggested that some of the more important factors requiring research are:

(1) soil moisture characteristics (sorptivity, hydraulic conductivity, and water storage capacity);

(2) land clearing effects on soil mosture regimes, salting, and regeneration of woody plants leading to reduction in carrying capacity;

(3) soil erosion, particularly with regard to rainfall intensity and energy factors, wind characteristics, and the erodibility of various soil landscapes under different treatments;

(4) the effectiveness of various land treatments in terms of soil and water conservation (e.g. ripping, ridging, minimal tillage).

II. Classes

The objective in assigning capability classes is to facilitate the grouping of lands having the same degree but not necessarily the same kind of limitation. It is a system of classifying land in terms of its capability for possible types of use. It does not rate

*United States Department of Agriculture (1958).—Land capability classification. Soils Memorandum SCS-22.

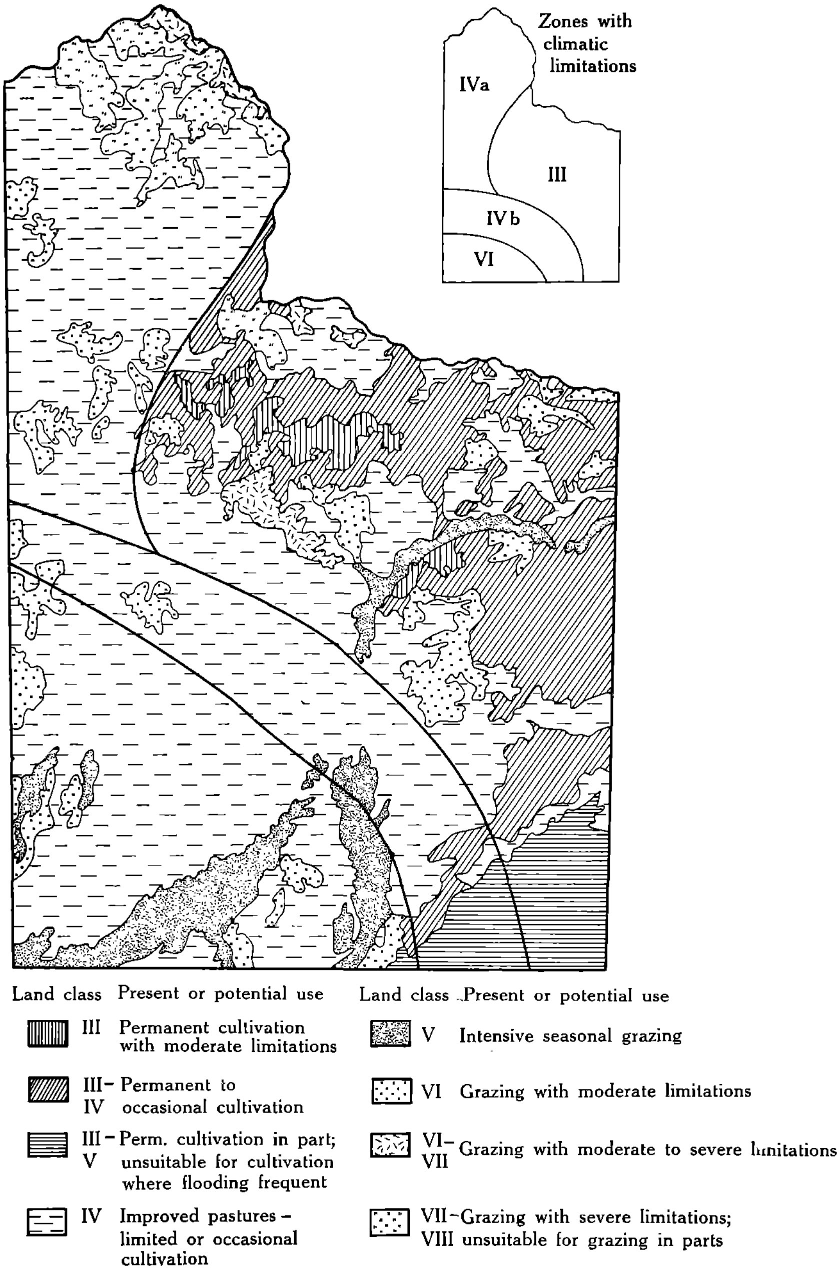

Fig. 22.—Land capability, showing land classes and their present or potential use.

the productivity of land which is dependent partly on management and economic factors and partly on the inherent characteristics of the land. The evaluations are largely subjective and may change with economic conditions or as new technologies or plant material become available.

Eight classes of land are defined below in terms of their suitability for cultivation or grazing. Lands in classes I–IV are suitable for cultivation but limitations become progressively more severe. Lands in classes V–VII are suitable only for grazing and class VIII land is unsuitable for cultivation or grazing.

(*a*) *Class I Land*

Land in this class has few limitations restricting its use for permanent cultivation or other purposes such as grazing or forestry. It is nearly level land with deep easily worked soil and erosion hazard is low. The soils are well drained but water-retentive and are either well supplied with plant nutrients or highly responsive to inputs of fertilizers. The climate is favourable for a wide range of crops.

No land in the Balonne–Maranoa area has been placed in this class owing to climatic and soil limitations.

(*b*) *Class II Land*

This land is suitable for permanent cultivation but it has slight limitations with regard to choice of crops and erosion hazards that require simple conservation practices. Limitations include gentle slopes, less than ideal soil depth and other physical properties, wetness correctable by drainage, and slightly unfavourable climate.

(*c*) *Class III Land*

Class III land is suitable for permanent cultivation but has moderate limitations that require careful soil management and erosion control. The limitations are moderately steep slopes, stones or gravel, slightly uneven microrelief, and soil physical and chemical properties which affect the choice of crops.

(*d*) *Class IV Land*

This class of land is suitable only for occasional or limited cultivation. It has one or more severe limitations such as marginal climate, steep slopes, strong microrelief, moderately high gravel or stone content, and soils with physical or chemical properties that limit or restrict the growth of crops. This land is best suited to the establishment of permanent pasture species that are adapted to soil and climatic conditions in the area.

(*e*) *Class V Land*

Land in this class is unsuitable for cultivation but is not susceptible to erosion. It consists mainly of land that is subject to frequent, deep, prolonged flooding by overflow from rivers or creeks. When not flooded it can be used for grazing without special restrictions.

TABLE 31

SUBCLASSES: KIND AND DEGREE OF LIMITATION

Limitation	Degree of limitation	Class	Subclass
Slope classes in which increasingly intensive erosion control practices are required	Slope <1% or up to 2%, on short slopes up to 300 m long	I	
	Slope 1–3%	II*	e_2
	Slope 3–6%	III*	e_3
	Slope 6–15%	IV*	e_4
Slopes limiting use of machinery and access to grazing	Slope 15–30% or moderate gullying	VI	t_6
	Slope 30–60% or severe gullying	VII	t_7
	Slope >60%	VIII	t_8
Microrelief (gilgai) limiting tillage or drainage	<30 cm	III	g_3
	30–150 cm	IV	g_4
Gravel, stones, or rock outcrop limiting tillage, grazing, and water storage capacity	<2% very slight restriction	II	r_2
	2–10% slight restriction	III	r_3
	10–25% moderate restriction	IV	r_4
	25–50% severe restriction	VI	r_6
	>50% very severe restriction	VII–VIII	r_{7-8}
Effective depth of soil limiting root development and water storage capacity	90–120 cm	II	d_2
	60–90 cm	III	d_3
	30–60 cm	IV	d_4
	<30 cm	VI–VII	d_{6-7}
Soil physical properties affecting emergence and/or root development of crops, e.g. hardpan, hard-setting surface horizons	Slight restriction } (solodized horizons absent)	II	p_2
	Moderate restriction } (solodized horizons absent)	III	p_3
	Severe restriction, e.g. columnar structure	IV	p_4
Soil physical properties affecting tillage, e.g. high clay content, compaction	Slight restriction	II	k_2
	Moderate restriction	III	k_3
	Severe restriction	IV	k_4
Salinity/alkalinity in root zone limiting growth or choice of crops	Crops slightly to moderately affected (pH <9·0, salt content <0·35%, exch. Na <10%)	III	s_3
	Crops seriously affected (pH 9·0 or more, salt content 0·35–0·5%, exch. Na >10%)	IV	s_4
Water storage capacity (cm of water in profile or root zone)	High >15 cm	II	m_2
	Medium 7·5–15 cm	III	m_3
	Low <7·5 cm	IV	m_4
Wetness—frequency, depth, and duration of flooding	Flooding 1 in 5 yr	III	w_3
	Flooding >1 in 5 yr	IV	w_4
	Deep, prolonged, frequent flooding	V	w_5

* Class may be downgraded according to susceptibility of a particular soil to erosion, e.g. duplex soils with dispersed clayey subsoils.

(*f*) *Class VI Land*

This class of land is suitable for grazing or forestry with moderate limitations such as steep slopes, stoniness or rockiness, shallow soils, or low rainfall. Grazing lands depleted by drought or mismanagement may require severe restrictions for a few years to permit recovery of pastures. Contour furrows, ridges, and water spreaders may be required for restoration.

(*g*) *Class VII Land*

Land in this class has severe limitations in its use for grazing or forestry owing to very steep slopes and liability to erosion, very shallow soils, extensive rock outcrop, or severe erosion. Careful regulation of grazing is necessary.

(*h*) *Class VIII Land*

This land is not suitable for grazing or forestry because it is too steep, rocky or barren. It may be permanent swamp land or excessively saline land that it is not feasible to reclaim. Land in this class should be reserved for watershedding, wildlife, or recreation.

TABLE 32

SUBCLASSES: DEGREE OF CLIMATIC LIMITATION

Limitation	Degree of limitation: Summation of monthly median rainfall (mm)		Potential evaporation (mm)		Class	Subclass
	Winter (Apr.–Sept.)	Summer (Oct.–Mar.)	Winter (Apr.–Sept.)	Summer (Oct.–Mar.)		
Climate—effective rainfall	110–140	250–>300	630	1320	III	C_3
limiting crop and pasture	>110	250–>300	n.a.	n.a.	IVa	C_4
growth	<110–140	225–250			IVb	C_4
	<100–130	<175–225	620	1427	VI	C_6

III. SUBCLASSES

The subclasses or kinds of limitations are given in Tables 31 and 32. Most of the limitations listed are those imposed by variations in topographic and/or soil conditions but an attempt has been made to include climate in the classification. The area has been subdivided into four broad zones based on summation of the median rainfall during the summer frost-free months (October–March) and the winter months (April–September) when frosts occur (Fig. 22).

APPENDIX II

Plant Names and their Common Equivalents

Abutilon oxycarpum	Flannel weed
Acacia aneura	Mulga
A. aprepta	Miles mulga
A. bancroftii	
A. burrowii	Currawong
A. cambagei	Gidgee
A. catenulata	Bendee
A. complanata	Flat-stem wattle
A. conferta	
A. cunninghamii	Black wattle
A. excelsa	Ironwood
A. farnesiana	Mimosa bush
A. gnidium	
A. harpophylla	Brigalow
A. implexa	Lightwood
A. ixiophylla	
A. jucunda	
A. leptostachya	
A. sp. aff. *lineata*	
A. longispicata	
A. macradenia	Zig-zag wattle
A. maitlandii	
A. microsperma	Bowyakka
A. murrayana	
A. neriifolia	
A. omalophylla	Yarran
A. pendula	Myall
A. pustula	
A. shirleyi	Lancewood
A. stenophylla	River myall or belalie
A. victoriae	Gundabluey
Alstonia constricta	Bitterbark
Amphipogon caricinus	Mulga grass
Ancistrachne uncinulatum	Hooky grass
Angophora costata	Rusty gum or cabbage gum
A. floribunda	Rough-barked apple
A. melanoxylon	
Aristida arenaria	Kerosene grass
A. browniana	
A. caput-medusae	Many-headed wire grass
A. echinata	No. 8 wire grass
A. ingrata	
A. jerichoensis	Wire grass
A. latifolia	Feathertop wire grass
A. leptopoda	White spear grass
A. leichhardtiana	
A. muricata	
A. platychaeta	

PLANT NAMES (*Continued*)

A. ramosa	
Arundinella nepalensis	Reed grass
Astrebla elymoides	Hoop Mitchell grass
A. lappacea	Curly Mitchell grass
A. squarrosa	Bull Mitchell grass
Atalaya hemiglauca	Whitewood
Atriplex lindleyi	
A. muelleri	Annual saltbush
A. semibaccatum	Creeping saltbush
Aotus subglabra	
Baeckea jucunda	
Bassia birchii	Galvanized burr
B. calcarata	Red burr
B. convexula	Copper burr
B. diacantha	
B. lanicuspis	Woolly-spined burr
B. quinquecuspis	Prickly roly-poly or black roly-poly
B. tetracuspis	Brigalow or dog-burr
B. tricuspis	Giant red burr
Bauhinia carronii	Bauhinia
Bothriochloa decipiens	Pitted blue grass
Brachychiton populneum	Kurrajong
B. rupestre	Narrow-leaved bottletree
Brunoniella australis	
Cadellia pentastylis	Ooline
Callistemon viminalis	Red bottle-brush
Callitris columellaris	Cypress pine
Calotis scabiosifolia	Creeping daisy-burr
Calytrix tetragona	
Canthium oleifolium	Myrtle tree
Capparis lasiantha	Nipan
Carissa ovata	Currant bush
Cassia artemisioides	Silver cassia
C. nemophila	Butter bush
Cassinia laevis	Wild rosemary or cough bush
Casuarina cristata	Belah
C. cunninghamiana	River oak
C. inophloia	Thready-bark oak
C. luehmannii	Bull oak
Cheilanthes sieberi	Mulga fern
Chionachne cyathopoda	
Chloris acicularis	Spider grass
C. ventricosa	Tall chloris
C. unispicea	
Chrysopogon fallax	Blue-leaf grass
Citriobatus spinescens	Wallaby apple
Croton phebalioides	
Cyperus bifax	Downs nut-grass
C. gracilis	Slender sedge
Danthonia bipartita	Mulga oats
D. linkii	Wallaby grass

PLANT NAMES (*Continued*)

Dianella spp.	Blue flax-lilies
Dichanthium spp.	Blue grasses
D. affine	Small blue grass
Digitaria ammophila	Silky umbrella grass
D. brownii	Silver spike grass
D. diminuta	
D. divaricatissima	Blow-away grass
Dodonaea attenuata	Hop-bush
Ehretia membranifolia	Peach bush
Elaeodendron australe	
Enchylaena tomentosa	Berry cotton-bush
Enneapogon gracilis	Bottle-washer grass
E. pallidus	Bottle-washer grass
Entolasia stricta	
Eragrostis eriopoda	Woollybutt grass
E. lacunaria	Purple love grass
E. megalosperma	
E. setifolia	Neverfail grass
Eremochloa bimaculata	Poverty grass
Eremophila bignoniiflora	Creek wilga or gooramurra
E. glabra	Black fuchsia
E. mitchellii	Sandalwood
Eriostemon difformis	
Eucalyptus bloxsomei	
E. camaldulensis	River red gum
E. crebra	Narrow-leaved ironbark
E. dealbata	Tumble-down gum
E. decorticans	Gum-topped ironbark
E. drepanophylla	Narrow-leaved ironbark
E. eugenioides	White stringybark
E. exserta	Mallee; Queensland peppermint
E. fibrosa subsp. *fibrosa*	Broad-leaf ironbark
E. fibrosa subsp. *nubila*	Dusky ironbark
E. intertexta	Forest gum
E. largiflorens	Black box
E. maculata	Spotted gum
E. major	Grey gum
E. melanophloia	Silver-leaved ironbark
E. melliodora	Yellow box
E. microcarpa	Green-leaved box
E. microtheca	Coolibah
E. orgadophila	Mountain coolibah
E. phaeotricha	White stringybark
E. polycarpa	Bloodwood
E. populnea	Poplar box
E. punctata	Grey gum
E. saligna	Sydney blue gum
E. tereticornis	Blue gum
E. tessellaris	Carbeen
E. thozetiana	Yapunyah
E. trachyphloia	Brown bloodwood
E. umbra	Yellow stringybark
Eulalia fulva	Brown-top grass

PLANT NAMES (*Continued*)

Flindersia maculosa	Leopardwood
Geijera parviflora	Wilga
Grevillea parallela	Silver oak
G. striata	Beefwood
Heterocalymnantha minutifolia	
Heterodendrum diversifolium	Scrub boonaree
H. oleifolium	Boonaree
Heteropogon contortus	Black spear grass
Hibiscus sturtii	
Hovea longifolia	Purple bush pea
H. longipes	Purple bush pea
Imperata cylindrica var. *major*	Blady grass
Iseilema spp.	Flinders grasses
Jacksonia scoparia	Dogwood
Kochia coronata	
K. tomentosa var. *tenuifolia*	Cottonbush
Leptospermum sericatum	
Leucopogon biflorus	
L. mitchellii	
Lomandra leucocephala	Iron grass
Lysicarpus angustifolius	Budgeroo
Macrozamia moorei	Zamia
Malvastrum spicatum	Malvastrum
Melaleuca linariifolia	River tea-tree or flax-leaved paper-bark
Monotoca scoparia	
Muehlenbeckia cunninghamii	Lignum
Myoporum deserti	Ellangowan poison bush
Neurachne mitchelliana	Mulga grass
N. xerophila	Mulga grass
Notelaea microcarpa	Native olive
Opuntia stricta	Prickly pear
Panicum decompositum	Native millet
P. effusum	Hairy panic
P. queenslandicum	Yabila grass
Paspalidium constrictum	Belah grass
P. criniforme	
P. gracile	
P. jubiflorum	Warrego summer grass
P. radiatum	
Petalostigma pubescens	Quinine bush
Phebalium glandulosum	
Phyllanthus sp.	
Planchonella cotinifolia	

Plant Names (*Continued*)

Pimelea pauciflora	Poison pimelea
Portulaca sp. aff. *oleracea*	Inland pigweed
Rhagodia nutans	Berry saltbush
R. parabolica	
R. spinescens	
Ricinocarpos bowmanii	Wedding bush
Scaevola spinescens	Spiny fan-flower
Sida brachypoda	
S. trichopoda	High sida
Solanum esuriale	Quena
Sorghum leiocladum	Native sorghum
Sporobolus actinocladus	Katoora or ray grass
S. caroli	Fairy grass
S. mitchellii	Creeping rat's-tail grass
Thellungia advena	Coolibah grass
Themeda australis	Kangaroo grass
Trianthema triquetra	Red spinach
Triodia mitchellii	Spinifex
Tripogon loliiformis	Five-minute grass
Triraphis mollis	Purple plume grass
Ventilago viminalis	Vine-tree or supplejack
Xanthorrhoea spp.	Grass-trees
Xylomelum pyriforme	Woody pear
Zygophyllum apiculatum	Twin leaf

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