General Report on Lands of the Tipperary Area, Northern Territory, 1961

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Land Research Series No. 13

View complete series online

Commonwealth Scientific and Industrial
Research Organization, Australia

Melbourne 1965

Printed by CSIRO, Melbourne

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PART I. INTRODUCTION

By N. H. SPECK*

I. INTRODUCTION

The survey area covers approximately 7500 sq miles and lies between lat. 13°30′S. and 15°S. and long. 131°E. and 133°E. It is a structural entity termed the Daly River basin, the boundaries of which are mainly drawn on the limits of an associated geological unit, the Daly River group, and was mapped as the Tipperary land system by Christian and Stewart (1953).

(a) *Origin of Survey*

The survey of the Katherine–Darwin area undertaken in 1946 was the first of a series of land resources surveys recommended by the newly formed Northern Australia Development Committee. These surveys, carried out by the Division of Land Research and Regional Survey, are of a broad reconnaissance nature. The objective has been to record the nature of the country, assess land use potential, make recommendations with respect to development and utilization, and suggest the nature of further research. The report of the Katherine–Darwin survey (Christian and Stewart 1953) described 18 land systems and recommended an investigation in three of them of the possibilities of economic crop production under natural rainfall conditions. Interest centred in the Tipperary land system and a research station was established at Katherine. Resulting from the work of this station and the recommendations of the Forster Committee (Commonwealth of Australia, Department of Territories 1960), the Administrator of the Northern Territory requested a more detailed survey of the Tipperary land system.

The field work for this survey was carried out in July–October 1961. Mapping was completed at a scale of 4 miles to 1 in., which satisfies the practical requirements of the identification of areas of 10,000 ac or more containing land suited to agriculture in conjunction with grazing land.

(b) *Survey Procedure*

It is reasonable that, following a resources survey conducted on broad reconnaissance lines, more detailed surveys of certain land systems will become necessary at some future time. The Tipperary survey is the first of such re-surveys.

The general procedure was similar to that of previous surveys carried out by the Division of Land Research and Regional Survey, but in greater detail.

Each survey is carried out by a small team of scientists working in collaboration with the object of scientifically mapping and describing large areas of country. The basic descriptive unit is the land system (Plate 1, Fig. 1), which has been defined as an area or group of areas with a recurring pattern of land forms, soils, and vegetation. The land system maps and descriptions provide a basis for an assessment of the potentiality of the area.

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The method of survey is based on the assumption that each type of country is expressed on the aerial photographs as a distinctive pattern (Plate 1, Fig. 2), hence the interpretation of aerial photographs is the basis of the approach. Prior to field work such interpretation guides the selection of sample areas, and after field work it enables the land systems of large areas to be mapped and described by the extrapolation of field data.

The initial photo interpretation was made in May–June 1961, and field work was done from July to October. Approximately 3000 traverse miles were covered linking about 300 areas of detailed observations (Fig. 1). In the field traverse routes,

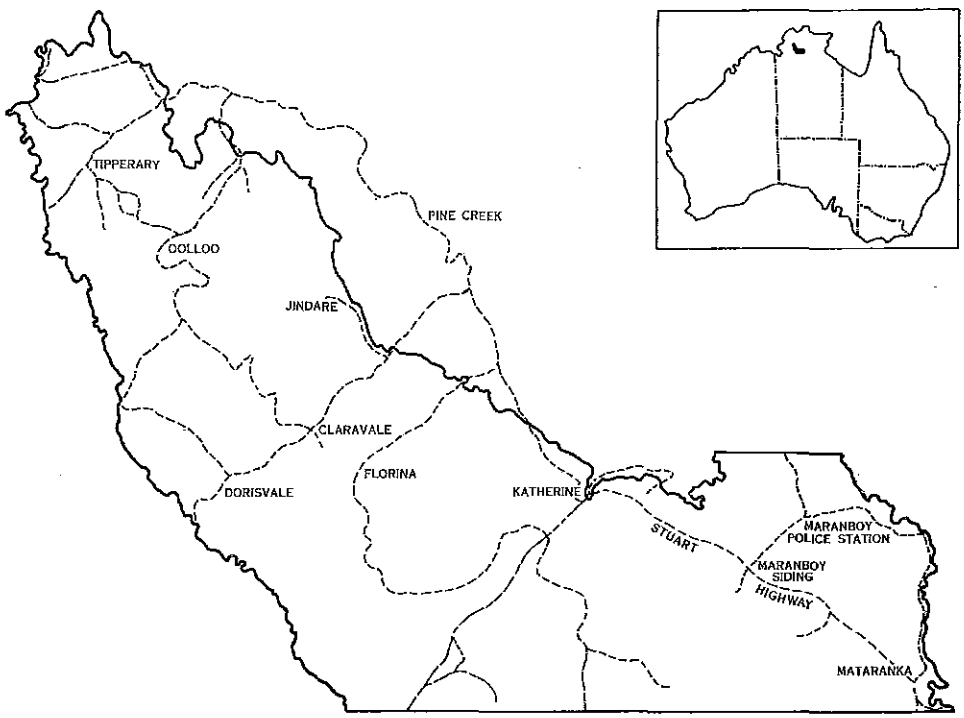

Fig. 1.—Traverse map.

speedometer milages and descriptive notes were marked on the aerial photographs. At sample areas, the scientists worked in close collaboration and the relationships between landscape components were established. Final photo interpretation and mapping were completed in the laboratory by April 1962.

II. History of Research in the Area

Post-war agricultural investigations in the Katherine region began with a land resources survey and the establishment of the Katherine Research Station by CSIRO in 1946. The survey indicated that parts of the region, hitherto utilized only for extensive beef-cattle raising on native pastures, might be suitable for arable agriculture and more intensive land use. Therefore, the twofold function of the Katherine Research Station was, first, to examine the possibility of establishing dry-land agriculture in the Tipperary land system and, second, to serve as a type location for the study of dry-land agriculture in the monsoonal zone of northern Australia, a zone in which, in the past, arable agriculture had been only of a very minor and spasmodic nature.

Research began after taking over a 100-ac river levee farm at Katherine which had been used by the army for vegetable production. The farm was used as headquarters and for the first year the 30 ac of cleared land were used for plant introduction investigation. In 1948 the investigation was extended to Tippera clay loam when an area of 1100 ac of red limestone country about 3 miles behind the levee was acquired. It is on this dry-land farm that the main investigations of the research station have been concentrated. Work on the levee soils was mainly restricted to special crops and seed production.

In a new area such as this there are no established agricultural procedures and the research approach must take into account a large number of variables and their interactions. One of the first objectives of research, therefore, is to define the true nature of the problems so that solutions may be sought in the right fields. Further, in a region with a single growing season each year, the need to sample a range of seasons means that conclusive results cannot be obtained quickly.

In 1951 the research programme entered the second phase. Investigation was restricted to Tippera clay loam and Elliott sandy clay loam (agriculturally similar), to the three crops, peanuts, sorghum, cotton, and to sown pastures and fodder crops. By 1957 the research programme had reached the stage where the likely pattern of agriculture and the broad nature of its problems were more clearly seen. It had been shown that the climate of the growing season, from the point of view of both growing conditions and reliability, permits some types of summer crops to be grown successfully (CSIRO Division of Land Research and Regional Survey 1959).

Peanuts and grain sorghum proved to be the most reliable crops and with improved cultural methods their yields were comparable with those of other areas. Further research was still necessary before either cotton or tobacco growing could be recommended extensively.

Only field investigations were possible until 1956, when a small laboratory was established at the headquarters farm, but this made possible the beginning of laboratory studies mainly concerned with the relationships between atmospheric, plant, and soil nitrogen.

In 1952, the Northern Territory Administration established the Katherine Demonstration Farm to apply and test under farm-scale conditions the findings of the research programme.

In the period 1957–61, two other soil types were included for investigations. Blain sands have shown some promise. They are physically easy to manage, and moisture is available for a longer period giving a longer growing season. However, they are prone to erosion and to leaching of nutrients under cultivation.

Investigation of Florina soils indicated their usefulness was limited to pastures.

Also during this period, considerable work has been done on both fodder crops and natural pastures. The results of recent experiments suggest that up to the time of the early storm rains, prior to the wet season proper, the dry standing native pasture is an adequate source of energy, which can be effectively utilized if cattle are given a small quantity of high-protein supplement. During the period of early rains, the pasture is not an adequate source of energy, and high-protein supplements do not prevent liveweight loss. High spring temperatures before the early rains did not appear to affect adversely the performance of supplemented cattle.

III. Acknowledgments

It is desired to acknowledge the assistance of many individuals and organizations, both during the survey and in the preparation of the report.

The Agricultural Branch, Northern Territory Administration, made available J. Muspratt, pedologist, for the major part of the field season and for a period of photo interpretation later in Canberra. The Bureau of Mineral Resources, Geology and Geophysics made available maps and current geological information on the area. The National Mapping Division, Department of National Development, compiled the base map of the area. Meteorological information was supplied by the Commonwealth Bureau of Meteorology. The Commonwealth Census Office supplied population figures for the area.

The work of Mrs. C. Muntz in editing the report and the guidance of Mr. G. A. Stewart, Chief of the Division, are gratefully acknowledged. Maps, diagrams, and illustrations were prepared by the staff of the Division.

The members of the survey team are indebted to various station owners and managers and to the staff of the Katherine Research Station for assistance and hospitality during the field season.

IV. References

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PART II. SUMMARY DESCRIPTION OF THE TIPPERARY AREA

By N. H. Speck*

I. Population and Communications

The area is connected with the port of Darwin, 100 miles to the north, by the all-weather Stuart Highway and an associated railroad which cross the south-eastern parts of the area and run parallel with, but slightly beyond, its northern boundary. Although several gravel roads cross the area, bridges are rare and much of the country is isolated for periods during the rainy season.

Katherine, in the south-east, with a white population of 770 (1961 census), is the main town in the area. Mataranka, a small settlement also in the south, has a white population of 70. Another 150 whites are associated with the cattle stations and other small settlements. In all, the total population is less than 1000 whites and mixed races together with less than 600 full-blood aborigines, more than half of whom are associated with the Government welfare station at Beswick Creek. The others are mostly associated with cattle stations and small settlements.

II. Climate

The climate of the area is tropical savannah, with two seasons — a warm dry winter period from May to September and a hot summer period from October to April. Virtually all the rain falls in summer, mostly during December to March (Slatyer 1960). Rainfall is the most important climatic factor affecting plant growth in this area.

Average rainfall decreases from 45 in. in the north-west to about 30 in. in the south-east with little variation in seasonal distribution. Annual rainfall variability is relatively low and uniform over the north-western parts but is higher in the south-east. Rainfall intensity is high.

A study of the estimated agricultural growing period indicates that the dates of "ploughing rains" and "sowing rains" differ by about one month over the area, being earliest in the north-west and latest in the extreme south. The estimated mean length of the agricultural growing period ranges from about 23 wk at Daly River to 15 wk at Willeroo (both outside the actual area). A 12-wk agricultural growing period can be relied upon except in the extreme southern part of the area. Furthermore, growing periods longer than 16 wk can be expected in about 75% of all seasons. In the north-western parts, rainfall excesses during the early wet season may be troublesome from an agronomic point of view, especially on heavy soils.

The estimated pastoral growing period follows a similar pattern. The mean estimated date of commencement of the dominant period of pasture growth occurs in late November over the entire area except in the extreme south. Most of the area has at least a 16-wk period of useful pasture growth with a 24-wk period in the north-west.

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Irrigation may increase crop yields by eliminating periods of water stress during the wet season and by extending crop growth into the dry season. Water requirements for these purposes are described in Part IV.

III. Geology

The area is a structural entity, the Daly River basin, in which gently dipping Middle Cambrian limestone, sandstone, and siltstone overlie Lower Cambrian extrusive basalt and Upper Proterozoic sandstone, siltstone, and greywacke, which crop out on the margins of the basin. Remnants of a thin subhorizontal cover of Cretaceous sandstone and siltstone unconformably overlying the Cambrian and Proterozoic rocks survive as plateaux in many areas, particularly in the south and south-east. Geologic control of land systems by the Middle Cambrian rocks is mainly restricted to the youngest lowlands flanking the main rivers and in the northern plains region. Elsewhere, the effect of original lithology has been considerably reduced, firstly by extensive ferruginous duricrusts and silicification resulting from deep weathering, and secondly by extensive superficial deposits.

IV. Geomorphic Regions

The area has been divided into the Daly plateaux province and the Daly plains province, with major relief due to the survival of the Cretaceous cover in the former and to the removal of this cover exposing the underlying Cambrian rocks in the latter. These provinces have been subdivided into regions which, although embracing a diversity of rock types, have a unity of relief that is expressive of a unity of geomorphic history.

The margins of the Daly plateaux province consist of high plateaux, mainly between 800 and 1000 ft above sea level, and its central parts comprise mainly low plateaux and undulating terrain which decline along the Daly River from 700 ft in the south-east to about 250 ft above sea level in the north-west.

The Daly plains province mainly comprises extensive plains and undulating terrain, both drained by the Daly River and its main tributaries, and which decline from about 650 ft in tributary headwater areas to less than 100 ft above sea level downvalley.

V. History of the Physical Landscape

A large part of the area consists of inherited land forms such as staged, old erosion surfaces with relict soils and fossil deep weathering profiles. Furthermore, the achievements of each older stage have influenced subsequent achievements of landscape formation. Therefore, the present landscape can only be fully understood in terms of its geomorphic history (Plate 2, Fig. 1).

The oldest landscape element is termed the Bradshaw surface and it survives as plateau summits underlain by Cretaceous rocks, forming main divides. Deep lateritic weathering, typically to a depth of 150 ft and with strong silicification in the lower parts of the pallid zone, has extended through the Cretaceous rocks into the underlying strata.

During a subsequent stage of erosion, probably caused by uplift, the Bradshaw surface was stripped of the upper, less silicified parts of the pallid zone and a lower surface, termed the Maranboy surface, was produced. This surface now survives as either broad, gently undulating secondary divides, or low plateaux and interfluve crests. It carries an ironstone which is commonly underlain by Bradshaw pallid zone rock that has undergone reweathering and desilicification to a depth of between 30 and 60 ft.

The Maranboy surface was, in turn, dissected during a third stage of erosion and an extensive younger erosion surface, the Tipperary surface, was produced (Plate 2, Fig. 2). This latter surface consists of broad plains, gently undulating terrain, and headwater valley floors. Such weathering profiles as occur are shallow or negligible in comparison with the depths of Bradshaw and Maranboy weathering.

Subsequent phases of hill slope instability and river rejuvenation and deposition may have resulted from climatic fluctuations similar to those dated as Pleistocene and later in other parts of Australia.

VI. Soils

The soils show clear-cut, but not always exclusive, relationships with the various erosional and depositional surfaces recognized geomorphologically.

Deep mature soils do not occur on slopes greater than 5%, probably because of relatively high rainfall intensity and inadequate vegetative cover.

Most of the soils of the area are "earth-type" profiles in which the horizons merge into one another gradually; the clay content normally increases gradually with depth, and the structure is massive with many fine pores. They are moderately acid to neutral in reaction, and the clays are mainly kaolinite. Soil colours range according to drainage status from red to yellow-red, yellow-brown, brown, and light greyish brown; the last three normally have marked reddish mottling. Varying amounts of ferruginous concretions are common. In field experiments, responses have been obtained only to phosphorus in legumes and phosphorus and nitrogen in non-legumes.

There are also small areas of less leached and less weathered soils. Red earths on alluvium are similar to the above but are dominantly fine sandy and have a wider range of available moisture. They occur only on levees along major streams. Grey-brown cracking clays occur mainly on alluvial plains. Prairie–rendzina complex soils occur on alluvial floors where apparently calcareous ground waters have affected soil genesis. Minor areas of alluvial regosols occur along the major streams.

VII. Vegetation

The vegetation of the area is characteristic of the higher-rainfall parts of northern Australia. Although rain forest elements, deciduous trees, and a number of other tropical elements (including cycads and palms) occur, *Eucalyptus* spp. characterize all the major communities.

Rainfall is the most important climatic factor affecting plant growth in this area. The range of rainfall (45 in. to 30 in.) from the north-west to the south-east produces a gradual change in the height and density of the vegetation without any major floristic changes. Although climate is the main influence in the selection of species and life form and is the major factor in controlling structure and density, soil characteristics determine the distribution of communities.

The communities have been classified as forests, open forests, woodlands, shrublands, and grasslands. Open forests and woodlands are the most extensive.

VIII. Native Pastures

Native pastures comprise only the ground storeys of the communities and are mainly gramineous. Four kinds of pasture are recognized.

(a) *Spinifex–Tall Grass*

This mainly consists of drought-resistant perennial spinifex (*Plectrachne pungens*) with variable amounts of other perennial and annual grasses. It occurs mainly as a ground storey of tall and low open forests. Stock-carrying capacity is low.

(b) *Tropical Tall Grass*

This is the most important and extensive pasture in the area. In the undisturbed state it comprises a vigorous perennial community strongly resistant to invasion by other species, little affected by fire (probably conditioned by it), markedly modified but not destroyed by extreme drought, and capable of rapid recovery after droughts. Although adapted to low soil nutrient levels it shows a remarkable response to nitrogen and phosphate when applied together. It occurs mainly as a ground storey of the savannah woodlands on red and yellow clayey soils, and comprises various combinations of *Sorghum plumosum*, *Themeda australis*, *Chrysopogon* spp., and *Sehima nervosum*. The pasture is palatable and nutritious during the wet season but becomes increasingly poor during the dry season.

(c) *Mixed Tropical Grass*

This pasture is variable but is characterized by annuals (annual *Sorghum* spp., *Panicum* spp., *Eragrostis* spp.) and scattered perennial grasses. Carrying capacity is low to moderate.

(d) *Frontage Grass*

These pastures comprise the tall, coarse grasses associated with depressions, drainage floors, and stream fringes. The grasses are not readily eaten by stock.

IX. Pasture Lands

Beef-cattle raising on native pastures at a low rate of stocking has been practically the only form of land utilization over the last 80 years. Although parts are suitable for arable agriculture, the nature of the terrain over most of the area and the possible pattern of intensified land use indicates that the utilization of native pastures must be a part of any development scheme.

The growth cycle of the tropical tall grass pasture over a full year reflects the highly seasonal climatic regime. Dry matter increase occurs wholly within the wet season. Cattle on tropical tall grass pasture gain 100 to 300 lb per head from the beginning of the wet season until one or two months after the rains cease, but lose approximately

20% of their body weight between May and November. The dry standing pasture is an adequate source of energy, which can be effectively utilized during the dry season if cattle are fed small amounts of high-protein supplement; but during the period of early rains the pasture is not an adequate energy source and high-protein supplements do not prevent liveweight loss.

Burning (Plate 3, Fig. 1) is almost the only form of pasture management practised by cattlemen in the area. With tropical tall grass pastures burning decreases productivity but, as controlled burning is necessary to prevent destructive wild fires, it is recommended the pasture be burnt as late as possible in the dry season and at two-year intervals.

By grouping land systems with similar patterns of pastures six pasture lands have been recognized.

(*a*) *Plateaux Spinifex Country* (*850 sq miles*)

This is characterized by spinifex–tall grass pastures (Plate 3, Fig. 2). Steep escarpments and rocky terrain limit stocking rates, which are low.

Mullaman land system comprises extensive high plateaux (relief up to 400 ft) and Yujullowan land system broken low plateaux (relief mainly less than 100 ft).

(*b*) *Undulating Spinifex Country* (*1790 sq miles*)

This pasture land (Plate 4, Fig. 1) is characterized by spinifex–tall grass pastures but has also some better perennial grass. Stock-carrying capacity is low. It comprises undulating country, mainly on deeply weathered rocks, with extensive sandy and shallow gravelly soils.

Of the five land systems in the pasture land, Claravale is uniformly sandy undulating terrain, Yungman has extensive upper slopes underlain by ironstone, and the other three differ mainly according to the soils on lower slopes. In Woggaman land system the lower slopes are alluvial with loamy soils, in Beemla they are on limestone with reddish clay loams, and in Chinaman they are partly on siltstone with cracking clays.

(*c*) *Tropical Tall Grass–Spinifex Country* (*350 sq miles*)

This pasture land is characterized by tropical tall grass (greater than 50%) and spinifex–tall grass (up to 40%) pastures. It has a moderate stock-carrying capacity. It is flat or undulating country, on deeply weathered rocks, with brownish, sandy, gravelly soils with outcrop and brownish and reddish clay loams.

Maranboy land system comprises plains, with local rocky rises and stony crests; Wallingin land system comprises undulating terrain.

(*d*) *Tropical Tall Grass Country* (*2950 sq miles*)

This is the most extensive pasture land (Plate 4, Fig. 2) and is predominantly composed of tropical tall grass pastures. Carrying capacity is moderate.

It comprises plains and undulating country (mainly on relatively unweathered rock) either forming a part of or eroded below the Tipperary surface, and characterized by mainly reddish clay loam soils, locally shallow, with scattered outcrop.

Jindara land system comprises strongly undulating terrain in which slopes underlain by ironstone occur in the upper parts. Wriggley, Kimbyan, Tagoman, Budbudjong, and Douglas land systems are plains mainly underlain by unweathered rock and differing according to the extent of soil-covered surfaces and the nature and extent of rock outcrop. Karaman land system consists of sandy alluvial plains.

(e) *Mixed Tropical Grass Country (650 sq miles)*

Although mixed tropical grass pastures (consisting mainly of annuals) characterize this pasture land (Plate 5, Fig. 1) in the higher-rainfall parts, perennial grasses are more important in the drier parts. Blain, the only land system in the pasture land, comprises plains of alluvium–colluvium with reddish sandy or loamy soils.

(f) *Frontage Country (580 sq miles)*

This country is characterized by a complex of frontage grass pastures (stream fringes, drainage floors, and depressions) and tropical tall grass pastures (levees and back plains). It is restricted to the alluvial lands fronting the main stream-lines. Carrying capacity is moderate during the wet season but some areas are boggy during rainy periods.

The main flood-plains (Banyan land system) consist of back plains with dark cracking clay soils and levees with reddish sandy soils. Green Ant and Wongalla land systems are tributary alluvial plains, both consisting mainly of dark cracking clays, but Wongalla has sandy rises flanking narrow levee zones, and Green Ant contains moderately extensive sandy plains.

X. Agricultural Prospects

Agriculture is practised only on a few small farms along the levees of the Katherine and Daly Rivers. These farms were originally established for peanut growing, but now large parts of them are not regularly cropped and small areas are devoted to a range of other crops.

The average length of the agricultural growing season ranges from 15 weeks in the south to 23 weeks in the north, and is generally adequate for short-season summer crops.

A wide range of agricultural investigations has been carried out at the CSIRO Katherine Research Station, established in 1946, and at the nearby Experimental Farm of the Northern Territory Administration.

The most extensive potentially arable soils are the loamy red and yellow earths (estimated 900 sq miles arable) occurring mainly in erosional plains, underlain by relatively fresh rock, flanking the main rivers. Most of the experimental work has been done on these soils and it has been shown that the following crops are adapted to them: forage crops—bulrush millet, forage sorghums, sudan grass, cowpea, guar; pasture legumes—Townsville lucerne; and pasture grasses—buffel and birdwood grasses. Cotton has not given satisfactory results.

Slightly higher in the landscape approximately 800 sq miles of potentially arable sandy red and yellow earths occur in relatively stable plains and gently undulating terrain underlain by weathered rock. Less experimental work has been done on these soils but they appear to be best suited to the deep-rooted crops, cotton and bulrush millet. Townsville lucerne is less adapted to them.

There are approximately 100 sq miles of other potentially arable soils, including red earths on alluvium, some of which are being farmed at present.

A very small amount of irrigation by pumping from the Katherine River is practised at present. From information gained during this survey there do not appear to be any large areas of land near major stream channels suited to gravity irrigation development. The Water Resources Branch of the Northern Territory Administration has made an assessment of the possible irrigation development from underground water, and agronomic investigations of irrigated cotton are being initiated by both CSIRO and the Northern Territory Administration. Cotton has been selected because it has the potential to give a high return per unit area and a high value per pound of produce—essential characteristics for pump irrigation in this isolated area.

In 1960 the Forster Committee reported on all aspects of agriculture in the Northern Territory (Commonwealth of Australia, Department of Territories 1960). It evaluated the possibility of pilot farms based on peanuts for oil but found them uneconomic. It recommended pilot farms for cattle fattening on improved pastures grazed in the wet season but none has yet been established. Since then considerable progress has been made in dry-season cattle feeding. Good liveweight gains in the dry season have been achieved by grazing dry standing Townsville lucerne and bulrush millet, both of which maintain reasonable protein contents. An interdepartmental committee is now making an assessment of the economics of cattle fattening based on these crops, with a view to the establishment of pilot farms.

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PART III. LAND SYSTEMS OF THE TIPPERARY AREA

By N. H. SPECK,* R. L. WRIGHT,* and R. H. M. VAN DE GRAAFF†

The lands of the area have been mapped and described in 20 land systems which are composite mapping units defined by Christian and Stewart (1953)‡ as an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation.

The land systems, classified according to their geomorphological relationships, are described in tabular form and illustrated with block diagrams sketched to represent the land system in somewhat idealized form. The text above the diagram relates to the land system as a whole, that below the diagram deals with characters peculiar to each unit.

The areas of the land systems were determined with a dot grid (25 dots per sq in) from the map at a scale of 4 in. to 1 mile, and were then rounded to the nearest 50 sq miles in the larger land systems and to the nearest 10 sq miles in the smaller ones. The relative areas of units in each land system were estimated from field experience and photo patterns.

More detailed information concerning the land systems is contained in Parts V–VIII. One small area of Volcanics land system, described in the report of the Katherine–Darwin area (Christian and Stewart 1953), is mapped in the south-east of the area but is not described in this report.

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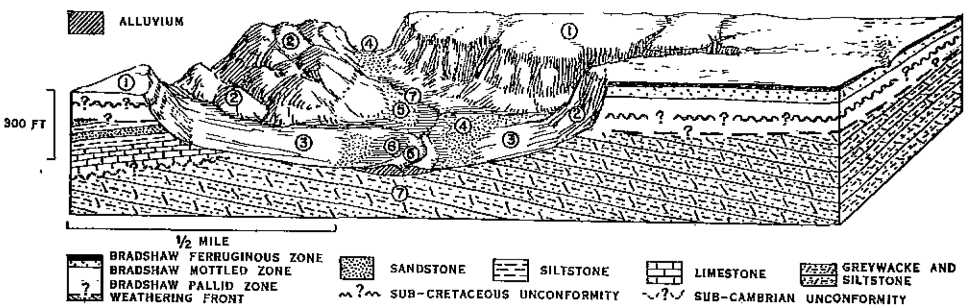
‡CHRISTIAN, C. S., and STEWART, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. CSIRO Aust. Land Res. Ser. No. 1.

(1) Mullaman Land System (450 sq miles)

High plateaux with extensive sandy surfaces and tall open forest. Plateau spinifex country. Grazing access difficult; unsuitable for agriculture because of shallow soils and steep escarpments.

Geology.—Deeply weathered, subhorizontal or gently dipping Cretaceous sandstone and siltstone unconformably overlying deeply weathered and relatively unweathered Cambrian limestone, sandstone, and siltstone, or siltstone and greywacke of Lower Proterozoic age.

Geomorphology.—Plateaux formed by dissection of the Bradshaw surface: intact and stripped plateau surfaces forming major divides up to 10 miles wide, with rocky hill slopes and stony or sandy lower slopes in deeply entrenched valleys; dense branching drainage pattern with alluvial floors comprising sandy slopes which form levees and interchannel rises up to 5 ft high, and flats of finer-textured alluvium; relief up to 400 ft.



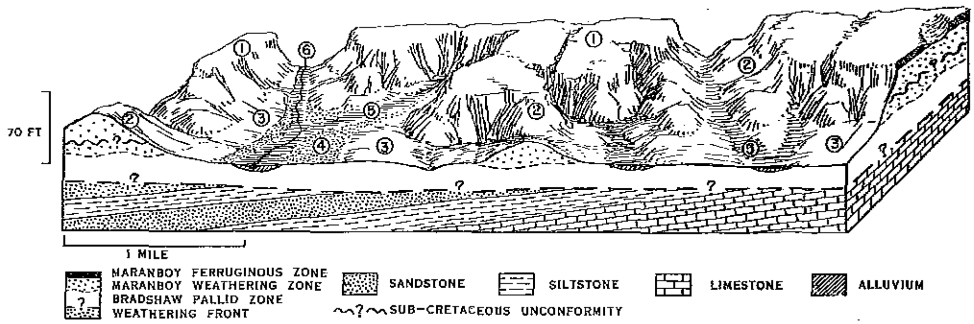
Unit	Area	Land Forms	Soils	Vegetation
1	Very large	**Plateau surfaces:** sandy slopes less than 0·5%, sparsely strewn with ironstone gravel; marginal boulder-strewn slopes up to 7% and ½ mile long, with frequent exposures of ironstone or mottled and pallid-zone rock	Mainly brownish sand over mottled brownish subsoil with concretions (Florina); locally reddish soils with concretions (Xanthippe, Vivienne); skeletal soils and outcrop on marginal slopes	Tall open forest 50–70 ft (*E. tetrodonta*, *E. miniata*, and scattered *E. bleeseri*, *E. dichromophloia*, *Callitris columellaris*), with moderate shrub layer (*Livistona* palms in high-rainfall parts) and spinifex–tall grass (*Plectrachne pungens*, annual sorghum with *Heteropogon triticeus* in high-rainfall parts)
2	Medium	**Rocky hill slopes:** benched, boulder-strewn outcrop slopes up to 60%, commonly with sheer upper escarpments of ironstone or silicified pallid-zone rock, and with basal screes up to 40%	Much outcrop and minor pockets of reddish brown sandy or loamy skeleta soils	As unit 1 but *E. bleeseri*, *E. dichromophloia*, and *E. alba* more prominent. Lower-rainfall parts include *E. umbrawarrensis*, *E. phoenicea*, and patches of lancewood forest
3	Small	**Stony lower slopes:** concave, cobble-strewn slopes up to 10% and ½ mile long; outcrops of pallid-zone rock locally	Reddish brown sandy or loamy skeletal soils	Savannah woodland 25–35 ft (*E. tectifica*, *E. foelscheana*), with shrubs sparse or absent, and open tropical tall grass (*Heteropogon triticeus*, *Sorghum plumosum*, *Themeda australis*)
4	Very small	**Sandy lower slopes:** concave sandy slopes, up to 7% and 200 yd long, with grit patches	Deep red sand (Cockatoo), commonly stony; brownish loam over mottled yellow clay commonly with concretions (Elliott) in the lower parts	Tall open forest 40–70 ft (*E. tetrodonta*, *E. miniata*, sparse *E. ptychocarpa*, and *E. alba*), with shrubs sparse, and tropical tall grass (*Heteropogon triticeus*, *Chrysopogon* spp.)
5	Very small	**Sandy alluvial slopes:** sandy slopes up to 2% and 400 yd long, with grit patches	Deep light grey sand	Low open forest 20–30 ft (*E. ferruginea*, *Erythrophleum chlorostachys*, *Callitris columellaris*), with spinifex–tall grass
6	Very small	**Flats of finer-textured alluvium:** lightly sealed surfaces up to 250 yd wide, gradients less than 1 in 100	Mottled dark grey loam over mottled clay subsoil (Marrakai)	Very open savannah woodland (*E. latifolia*), sparse, patchy shrub layer (*Melaleuca* sp.), and mixed tropical grass (*Aristida hygrometrica*, annual sorghum, *Chrysopogon* spp.)
7	Very small	**Channels:** up to 100 ft wide and 20 ft deep; incised in alluvium	Deep sand bed-loads	Fringing forests 40–80 ft (*E. camaldulensis*, *Tristania suaveolens*, *Melaleuca* spp.)

(2) Yujullowan Land System (400 sq miles)

Low broken plateaux with extensive stony surfaces and tall or low open forest. Plateau spinifex country. Grazing access difficult, unsuitable for agriculture because of steep escarpments and shallow soils.

Geology.—Deeply weathered, subhorizontal or gently dipping Cretaceous sandstone and siltstone unconformably overlying deeply weathered and relatively unweathered Cambrian limestone, sandstone, and siltstone, or basalt.

Geomorphology.—Formed by dissection of the Maranboy surface—plateaux and undulating terrain: stony plateau surfaces forming low secondary divides, with rocky hill slopes and restricted lower slopes which are stony in the upper sectors and sandy in the lower parts; sparse pattern of narrow, unchannelled alluvial floors locally with through-going entrenched channels; relief mainly less than 100 ft, but locally attaining 200 ft in deeply dissected headwater areas.



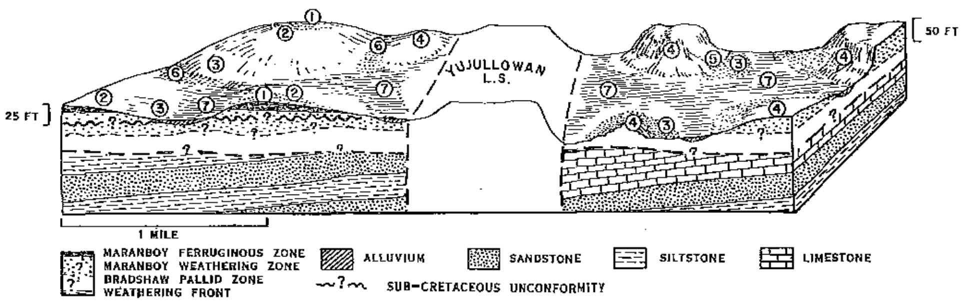
Unit	Area	Land Forms	Soils	Vegetation
1	Large	**Stony plateau surfaces:** up to 1½ miles wide; cobble-mantled slopes up to 1% with short, rocky marginal slopes up to 7%; frequent exposures of ironstone and weathered rock	Shallow skeletal soils with outcrop, and brownish sand over mottled brownish subsoil with concretions (Florina)	Tall open forest 40–70 ft (*E. bleeseri, E. tetrodonta, E. miniata, E. dichromophloia;* lower rainfall, *E. umbrawarrensis*); patches of lancewood forest, with moderate shrub layer, and spinifex–tall grass (*Plectrachne pungens*, annual sorghum, *Heteropogon triticeus*)
2	Medium	**Rocky hill slopes:** benched, boulder-strewn outcrop slopes up to 55%, with basal screes up to 25%	Much outcrop and minor pockets of sandy skeletal soil	Similar to unit 1 but *E. umbrawarrensis* and lancewood forest more extensive
3	Small	**Stony lower slopes:** concave, cobble-strewn slopes up to 15% and 200 yd long, locally dissected up to 10 ft; bouldery outcrop locally	Shallow or skeletal soils with some outcrop, interspersed with small areas of Florina soils	Tall open forest 40–70 ft (*E. miniata, E. tetrodonta, E. dichromophloia*); shrubs variable and spinifex–tall grass (*Plectrachne pungens*, annual sorghum, *Chrysopogon* spp.)
4	Very small	**Sandy lower slopes:** concave, 2–5%, and up to 200 yd long; sandy surfaces sparsely strewn with ironstone gravel	Brownish and reddish sand with concretions (Florina and Venn)	Mixed open forest 35–60 ft (*E. miniata, E. tetrodonta, E. tectifica, E. foelscheana*); sparse shrubs and tropical tall grass (*Themeda australis, Sorghum plumosum*) with patches of *Plectrachne pungens* and annual sorghum
5	Very small	**Alluvial drainage floors:** up to 100 yd wide, gradients up to 1 in 40, with marginal slopes up to 0·5%; lightly sealed surfaces	Strongly mottled soils, mainly clayey subsoils (Elliott, Marrakai, Cullen)	Tall open forest 35–60 ft (*E. tetrodonta, E. miniata, E. ferruginea, Grevillea* sp.), with sparse shrubs, and spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
6	Very small	**Channels:** up to 50 ft wide and 20 ft deep; incised in alluvium	Deep sand bed-loads	Fringing communities 40–80 ft (*E. camaldulensis, Tristania suaveolens, Melaleuca* sp.)

(3) Yungman Land System (400 sq miles)

Gently undulating sandy terrain and low hills with mixed open forests. Spinifex country. Mainly spinifex–tall grass pasture on skeletal soils or sandy brown earths, with valleys carrying tropical tall grass pasture on sandy red earths, estimated potential arable area 100 sq miles.

Geology.—Deeply weathered, subhorizontal or gently dipping sandstone and siltstone of Cretaceous age, and deeply weathered, dipping Cambrian sandstone, siltstone, and limestone.

Geomorphology.—Formed by dissection of the Maranboy surface—plateaux and undulating terrain: gently undulating terrain, relief up to 25 ft, with sandy and stony upper slopes underlain by ironstone, and sandy lower slopes which also occur in marginal hill lands where slopes underlain by pallid-zone rock form hills and rounded interfluves up to 50 ft high; moderately dense, irregular pattern of unchannelled, sandy alluvial floors.



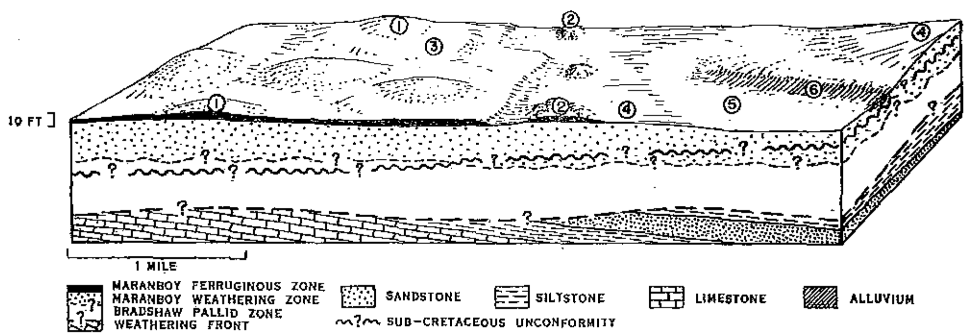
Unit	Area	Land Forms	Soils	Vegetation
1	Very small	**Sandy upper slopes underlain by ironstone:** up to $\frac{1}{2}$ mile in extent; sandy slopes up to 0·5%, sparsely strewn with ironstone gravel	Brownish and reddish sand with many ferruginous concretions (Elaine, Coralie, Florina)	Cypress pine forest (*Callitris columellaris*)
2	Medium	**Stony upper slopes underlain by ironstone:** up to 1 mile in extent; cobble-mantled slopes up to 3%, with frequent ironstone exposures	Frequent outcrop and skeletal soils, and brownish and reddish sand with many ferruginous concretions (Florina, Vivienne)	Tall open forest 35–45 ft (*E. bleeseri*, *E. tetrodonta*, *E. miniata*), with sparse low shrubs, and spinifex–tall grass (*Plectrachne pungens* with local annual sorghum)
3	Small	**Lower slopes:** sandy slopes up to 3% and 250 yd long, with patches of ironstone gravel	Mainly reddish sand over red loam (Venn) and sand with concretions (Coralie, Florina)	Tall open forest 35–45 ft (*E. miniata*, *E. tetrodonta*, *E. bleeseri*), with sparse shrubs, and spinifex–tall grass (annual sorghum and *Plectrachne pungens*)
4	Small	**Slopes underlain by pallid-zone rock:** boulder-covered hill slopes up to 60%, with minor vertical faces, or interfluve crests up to $\frac{1}{2}$ mile across, comprising sandy slopes up to 2% between bouldery outcrops	Mainly outcrop with pockets of brownish soils with concretions (Elliott and Florina)	Savannah woodland 25–45 ft (*E. tectifica*, *Erythrophleum chlorostachys*, *E. grandifolia*, with *E. umbrawarrensis* in low-rainfall parts), with shrubs sparse or absent, and tropical tall grass (*Sorghum plumosum*, *Sehima nervosum*, *Chrysopogon* spp.) with local patches of spinifex–tall grass
5	Very small	**Hill-foot slopes:** up to 2% and less than 200 yd long; sandy surfaces with pebble patches	Brownish sand over mottled brownish subsoil with concretions (Florina)	Tall open forest 35–45 ft (*E. dichromophloia*, *E. bleeseri*), with sparse shrubs, and spinifex–tall grass (*Plectrachne pungens*, *Aristida browniana*)
6	Very small	**Headwater floors:** up to $\frac{1}{4}$ mile wide, gradients up to 1 in 50; firmed sandy surfaces	Deep red sand (Cockatoo)	Very open, tall open forest 35–40 ft (*E. tetrodonta* and various eucalypts), with patchy shrub layer (*Calytrix microphylla*), and spinifex–tall grass (*Plectrachne pungens*, annuals, and much bare ground)
7	Medium	**Main floors:** up to $\frac{3}{4}$ mile wide, gradients between 1 in 60 and 1 in 300, with marginal transverse slopes up to 2%; loose to firmed sandy surfaces locally strewn with ironstone gravel	Mainly reddish sand over red clay (Blain); locally reddish loam over red clay (Tippera)	Mixed open forest 35–45 ft (*E. tetrodonta*, *E. dichromophloia*, *Erythrophleum chlorostachys*), with sparse shrubs, and moderately dense tropical tall grass (*Chrysopogon* spp., *Sehima nervosum*, *Sorghum plumosum*), local patches of *Plectrachne pungens*

(4) MARANBOY LAND SYSTEM (80 SQ MILES)

Gently undulating plains with tall open forests and woodlands. Tropical tall grass–spinifex country. Mainly tropical tall grass pastures on loamy red and yellow earths with medium areas of spinifex–tall grass on sandy brown earths (potential arable soils 30 sq miles).

Geology.—Deeply weathered, subhorizontal Cretaceous sandstone and siltstone, unconformably overlying deeply weathered, dipping Cambrian sandstone, siltstone, and limestone.

Geomorphology.—Formed by dissection of the Maranboy surface — plains: gently undulating plains forming low divides up to 15 miles wide, with extensive lower slopes, slightly higher stony crests, and marginal, low, rocky rises; red earth slopes and slightly lower yellow earth slopes occur in marginal stripped areas; sparse, irregular pattern of ill-defined drainage floors and depressions; relief up to 10 ft.



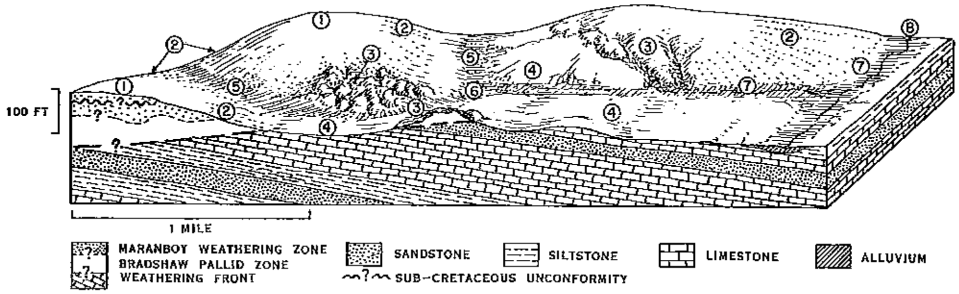
Unit	Area	Land Forms	Soils	Vegetation
1	Very small	**Stony crests:** gravel-covered surfaces up to ½ mile wide with marginal slopes up to 2%; ironstone exposures locally	Sandy skeletal soils and outcrop; some brownish sand over mottled brownish subsoil with concretions (Florina)	Tall open forest 35–45 ft (*E. bleeseri* and scattered *E. tetrodonta*, *E. dichromophloia*), with sparse low shrub layer and spinifex–tall grass (*Plectrachne pungens*)
2	Very small	**Rocky rises:** cobble-strewn slopes up to 15% and ¼ mile long; frequent ironstone exposures	Much outcrop and minor pockets of sandy skeletal soils	Tall open forest 35–45 ft (*E. bleeseri*, *E. dichromophloia*, *E. tetrodonta*), patches of lancewood forest (*Acacia shirleyi*), with sparse spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
3	Medium	**Lower slopes:** sandy slopes mainly less than 1% and up to 1 mile long, with patches of ironstone gravel	Brownish sand over mottled brownish subsoil with concretions (Florina)	Tall open forest 40–60 ft (*E. tetrodonta*, *E. dichromophloia*, *E. bleeseri*), with sparse shrubs, and spinifex–tall grass (*Plectrachne pungens*, annual sorghum, *Sorghum plumosum*, *Chrysopogon* spp.)
4	Medium	**Red earth slopes:** less than 0·5% and up to ½ mile in extent	Reddish loam over red clay (Tippera)	Mixed open forest 30–50 ft (*E. tetrodonta*, *E. dichromophloia*, *E. tectifica*), with shrubs sparse or absent, tropical tall grass (*Chrysopogon* spp. and various other grasses)
5	Medium	**Yellow earth slopes:** up to 1% and 1 mile in extent; firmed surfaces with minor patches of ironstone gravel	Brownish loam over mottled yellow clay, commonly with concretions (Elliott)	Savannah woodland 30–45 ft (*E. tectifica*, *E. latifolia*), with tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*)
6	Very small	**Drainage floors and depressions:** up to 200 yd wide, gradients less than 1 in 300; firmed to lightly sealed surfaces	Mottled dark grey loam over mottled clay (Marrakai)	Savannah woodland 30–45 ft (*E. latifolia*, *E. alba*), with tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*)

(5) Beemla Land System (100 sq miles)

Undulating terrain with tall open forest and woodland. Spinifex country. Mainly spinifex–tall grass **pasture,** only minor scattered areas of tropical tall grass on loamy soils, generally non-arable.

Geology.—Deeply weathered, subhorizontal or gently dipping sandstone and siltstone of Cretaceous age; deeply weathered and relatively unweathered, dipping Cambrian limestone, sandstone, and siltstone.

Geomorphology.—Undulating terrain eroded between the Maranboy and Tipperary surfaces: rounded interfluves comprising crests, upper slopes, and marginal stony slopes, with lower slopes on unweathered rock; sparse to moderately dense pattern of branching drainage with unchannelled, sandy upper and lower floors, and with channelled floors of finer-textured deposits in the lowest sectors; relief up to 100 ft.



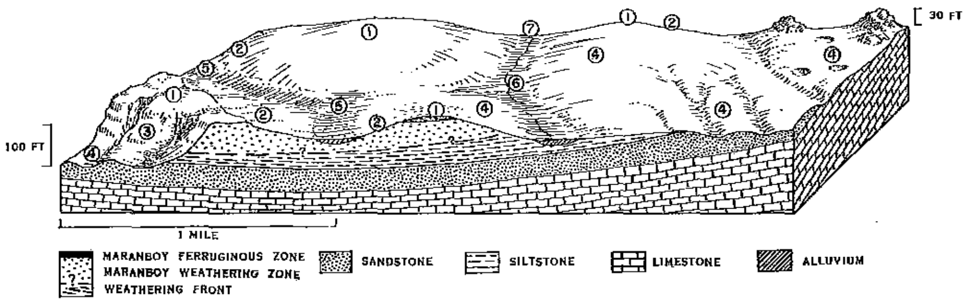
Unit	Area	Land Forms	Soils	Vegetation
1	Large	**Crests:** up to ½ mile wide; sandy slopes mainly less than 3% but locally up to 10%, with patches of ironstone gravel, and minor exposures of ironstone and pallid-zone rock	Mainly brownish sand over mottled brownish subsoil with concretions (Florina); sandy skeletal soils and outcrop, mainly on steeper slopes	Tall open forest 35–60 ft (*E. bleeseri, E. miniata, E. tetrodonta*), with shrubs sparse to moderate and spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
2	Small	**Upper slopes:** up to 3% and ¼ mile long; sandy to loamy surfaces with pebble patches and minor outcrop in upper sectors	Brownish loam over mottled yellow clay commonly with concretions (Elliott); sandier soil (Elizabeth) and outcrop in upper sectors	Savannah woodland 35–40 ft (*E. tectifica*, scattered *E. confertiflora, E. latifolia, Erythrophleum chlorostachys*), with tropical tall grass (*Themeda australis*)
3	Very small	**Stony slopes:** up to ⅛ mile long and attaining 25%, locally dissected up to 10 ft into rounded spurs; cobble-strewn surfaces with frequent bouldery outcrops of silicified or relatively unweathered rock	Mainly outcrop with minor Florina and Tippera soils	Savannah woodland 35–50 ft (*E. tectifica*, scattered *E. foelscheana, E. grandifolia, Erythrophleum chlorostachys*), with moderately dense shrubs and tropical tall grass (*Themeda australis*, sparse *Sorghum plumosum, Sehima nervosum, Chrysopogon* spp.)
4	Small	**Lower slopes on unweathered rock:** mainly less than 1% and up to ½ mile long, with pebble patches and outcrop locally	Reddish loam over red clay (Tippera)	Savannah woodland 50–60 ft (species similar to unit 3)
5	Very small	**Sandy upper floors:** up to ¼ mile wide, gradients up to 1 in 60, with transverse marginal slopes up to 2%; loose to firmed sandy surfaces	Reddish sandy to loamy soils (Blain, Venn, Cockatoo)	Mixed open forest 40–60 ft (*E. tetrodonta, E. tectifica, E. ferruginea, Erythrophleum chlorostachys, Gyrocarpus americanus*), with mixed tropical tall grass (annual sorghum, *Aristida* spp., and scattered *Chrysopogon* spp., *Sorghum plumosum*, and *Themeda australis*)
6	Small	**Sandy lower floors:** up to ½ mile wide, gradients below 1 in 300; firmed sandy surfaces	Brownish sand over mottled brownish subsoil with concretions (Florina)	Mixed open forest 40–60 ft (*E. miniata*, sparse *E. foelscheana, E. grandifolia, E. tectifica, E. alba*), with moderate tall shrub layer and tropical tall grass (annual sorghum, *Panicum airoides, Heteropogon triticeus, Aristida browniana*)
7	Very small	**Floors of finer-textured alluvium:** up to ¼ mile wide, gradients below 1 in 250, with transverse slopes up to 0·5%; firmed surfaces locally with linear depressions up to 5 ft deep and 60 ft wide	Reddish loam over red clay (Tippera) with some Elliott	Savannah woodland (*E. bigalerita*, scattered *E. terminalis, E. latifolia, Terminalia platyphylla*), with patchy shrubs and tropical tall grass (*Themeda australis, Sorghum plumosum*)
8	Very small	**Channels:** mainly up to 50 ft wide and 6 ft deep but locally up to 10 ft deep; gradients up to 1 in 20	Bed-loads range from sand to boulders	The above community extends as a fringe to channels and billabongs

(6) Jindara Land System (950 sq miles)

Undulating terrain with savannah woodlands. Tropical tall grass country. Mainly tropical tall grass pastures on loamy red and yellow earths of which an estimated 200 sq miles is arable; spinifex–tall grass pastures on sandy brown earths with outcrop, probably one-fifth arable land.

Geology.—Deeply weathered and relatively unweathered, dipping sandstone, siltstone, and limestone of Cambrian age; minor Upper Proterozoic sandstone, siltstone, and limestone.

Geomorphology.—Undulating terrain eroded between the Maranboy and Tipperary surfaces: gently sloping crest surfaces comprising interfluve crests up to ½ mile wide, summit plains up to ¾ mile wide, or restricted plateaux up to ¼ mile wide in more dissected areas; marginal sandy slopes or rocky hill slopes in more dissected areas, and extensive lower slopes; sparse to dense, branching or rectangular pattern of drainage floors, comprising sandy alluvium in the upper parts and finer-textured alluvium downvalley; relief up to 100 ft.



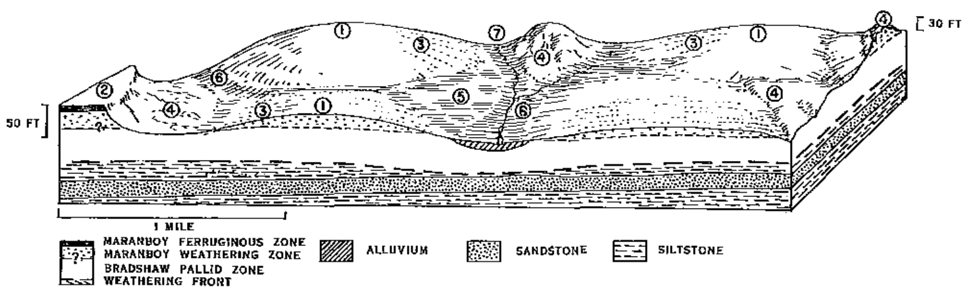
Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Crest surfaces: sandy slopes mainly less than 1%, but marginal stripped slopes attain 7%; cobble patches and ironstone exposures locally	Mainly brownish sand over brownish mottled subsoil with concretions (Florina); small areas of reddish soils (Xanthippe, Cockatoo)	Tall open forest 40–60 ft (*E. miniata, E. confertiflora, E. tectifica, E. tetrodonta, E. bleeseri, Erythrophleum chlorostachys*), with moderately dense tall shrub layer (*Cochlospermum fraseri, Planchonia careya*), and spinifex–tall grass and open tropical tall grass
2	Small	Sandy upper slopes: sandy slopes up to 3% and ½ mile long, with cobble patches	Mainly reddish sand over red loam or clay subsoil (Venn, Blain)	Mixed open forest 35–40 ft (*Erythrophleum chlorostachys, E. tetrodonta*), with prominent tall shrubs (*Livistona humilis, Grevillea* sp., *Buchanania obovata, Acacia* spp., *Terminalia* sp.), and tropical tall grass (*Heteropogon triticeus, Sorghum plumosum*)
3	Very small	Rocky hill slopes: benched, boulder-strewn slopes up to 60%, locally with vertical upper faces	Outcrop with pockets of skeletal soils	Mixed savannah woodland (*E. tectifica, E. dichromophloia, E. alba*), with sparse tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*) and patches of spinifex–tall grass
4	Large	Lower slopes: concave, up to 10% and 1 mile long, locally dissected up to 15 ft into rounded spurs; cobble patches and minor benched outcrops of weathered and unweathered rock in the upper parts, with extensive colluvial slopes less than 1%, in the lower sectors; scattered, low outcrop hills and water sinks up to 10 ft deep occur in areas underlain by limestone	Mainly reddish loam over red clay (Tippera); skeletal soils and outcrop in higher parts; locally Xanthippe and Elliott	Savannah woodland 25–45 ft (*E. tectifica, E. foelscheana, E. confertiflora*), with tropical tall grass (*Themeda australis, Sorghum plumosum, Chrysopogon* spp., *Heteropogon triticeus*)
5	Small	Drainage floors of sandy alluvium: up to ¼ mile wide, gradients up to 1 in 40, locally with marginal transverse slopes up to 3%; loose to firmed sandy surfaces with grit patches	Brownish sand over mottled brownish subsoil with concretions (Florina)	Savannah woodland 25–45 ft (*E. tectifica, E. latifolia, E. bigalerita*), with tropical tall grass (*Sorghum plumosum, Themeda australis, Heteropogon triticeus*, annual sorghum)
6	Small	Drainage floors of finer-textured alluvium: up to ½ mile wide, gradients up to 1 in 60; unchannelled in upper sectors, with minor linear depressions up to 5 ft deep and 100 ft wide, channelled in lower parts; firmed to sealed surfaces, locally hummocky and cracking	Various loamy to clayey soils, locally calcareous (mainly Marrakai, Tippera, Cununurra)	Savannah woodland 30–60 ft (*E. papuana, E. polycarpa, E. confertiflora*) with frontage and tropical tall grass (*Coelorachis rottboellioides, Bothriochloa intermedia, Arundinella nepalensis, Sorghum plumosum*, and *Themeda australis*)
7	Very small	Channels: up to 100 ft wide and 20 ft deep with restricted levees up to 2 ft high; locally incised in alluvium and bed-rock	Loamy brown alluvial regosols on levees; bedloads range from sand to cobbles	Fringing forests and woodlands (*Tristania suaveolens, Ficus* spp., *Melaleuca* spp., *Nauclea orientalis*), with *Pandanus* palms and other tall shrubs, and patchy frontage grasses

(7) Woggaman Land System (500 sq miles)

Undulating terrain with shallow soils and tall and low open forests. Spinifex country. Mainly spinifex–tall grass pasture on sandy brown earths, only minor scattered areas of tropical tall grass pastures on non-arable loamy soils.

Geology.—Deeply weathered, subhorizontal or gently dipping Cretaceous sandstone and siltstone.

Geomorphology.—Undulating terrain eroded between the Maranboy and Tipperary surfaces: gently sloping crests and extensive sandy slopes with restricted stony slopes and minor plateau remnants; restricted alluvial plains in lower sectors; sparse to moderately dense pattern of branching drainage floors, unchannelled in headwater areas; relief up to 50 ft.



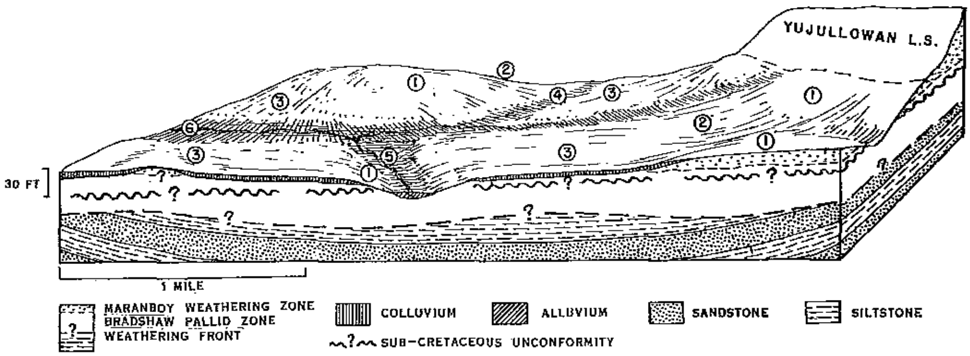
Unit	Area	Land Forms	Soils	Vegetation
1	Medium	**Crests:** up to ½ mile in extent; sandy slopes less than 3%, with gravel patches and exposures of ironstone and pallid-zone rock locally	Brownish sand over brownish mottled subsoil with concretions (Florina), commonly shallow with outcrop locally	Tall open forest 25–45 ft (*E. bleeseri*, *E. tetrodonta*), with shrubs sparse or patchy (*Calytrix microphylla*) and spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
2	Very small	**Plateau remnants:** cobble-strewn surfaces less than 1% and up to ¼ mile wide, with frequent exposures of ironstone and pallid-zone rock; short, rocky marginal slopes up to 7% and delimiting benched escarpments up to 55%	Sandy skeletal soils and much outcrop with some Florina	Tall open forest 50–60 ft (*E. miniata*, *E. tetrodonta*, *E. bleeseri*), with prominent *Livistona* palms in high-rainfall parts, and spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
3	Large	**Sandy slopes:** up to 3% and ½ mile long; sandy surfaces with scattered cobbles	Brownish sand over brownish mottled subsoil with concretions (Florina), commonly shallow with scattered outcrop; minor Elliott on lower parts	Low open forest 25 ft (*E. ferruginea*, *E. setosa*, *E. tetrodonta*), with abundant shrubs (*Melaleuca viridiflora*, *Calytrix microphylla*, *Acacia* spp.) and sparse spinifex–tall grass (annual sorghum, *Sorghum plumosum*, *Plectrachne pungens*)
4	Small	**Stony slopes:** cobble-mantled slopes up to 10% and ½ mile long, locally dissected up to 25 ft into narrow rounded spurs and low hills; bouldery exposures of pallid-zone rock	Commonly skeletal soils; minor Elliott, Tippera, Elizabeth, and Coralie soils	Low open forest 15–30 ft (*E. tectifica*, *Erythrophleum* sp., and *Melaleuca viridiflora*), with abundant shrubs 5–10 ft (*Calytrix microphylla*, *Petalostigma quadriloculare*, *Terminalia volucris*, *Gardenia* spp.) and spinifex–tall grass (annual sorghum, much bare ground). Local shrublands
5	Small	**Alluvial plains:** up to 1 mile wide, gradients up to 1 in 60; firmed surfaces	Mainly loam over mottled clay (Elliott, Marrakai); minor brownish loamy sand over mottled yellow sand or loam (Cullen)	Savannah woodland 25–35 ft (*E. tectifica*, locally *E. grandifolia*, *E. foelscheana*), with tropical tall grass (*Sorghum plumosum*, *Themeda australis*) and annual sorghum
6	Very small	**Alluvial drainage floors:** up to 300 yd wide, gradients up to 1 in 80, with marginal transverse slopes up to 3%; firmed to lightly sealed surfaces	Mainly loam over mottled clay (Marrakai, Elliott)	Shrubland 10–15 ft (*Acacia* spp., *Melaleuca viridiflora*), with spinifex–tall grass (*Plectrachne pungens*, *Aristida hygrometrica*)
7	Very small	**Channels:** up to 50 ft wide and 10 ft deep; incised in alluvium	Deep sand bed-loads	Various fringing communities

(8) Wallingin Land System (250 sq miles)

Gently undulating sandy terrain with tall open forest and savannah woodland. Tropical tall grass country. Tropical tall grass pastures on sandy yellow earths (potential arable area 45 sq miles); medium areas of spinifex–tall grass pastures on sandy brown earths.

Geology.—Deeply weathered, subhorizontal or gently dipping sandstone and siltstone of Cretaceous and locally of Cambrian age.

Geomorphology.—Undulating terrain eroded between the Maranboy and Tipperary surfaces: steeper slopes at the upper margin, or flanking incised channels, or forming rounded interfluve crests, and lower slopes forming narrow valley plains which are steeper and more sandy in the upper sectors than in the lower parts; sparse to moderately dense pattern of branching or rectangular drainage with ill-defined, unchannelled tributary floors; relief up to 50 ft.



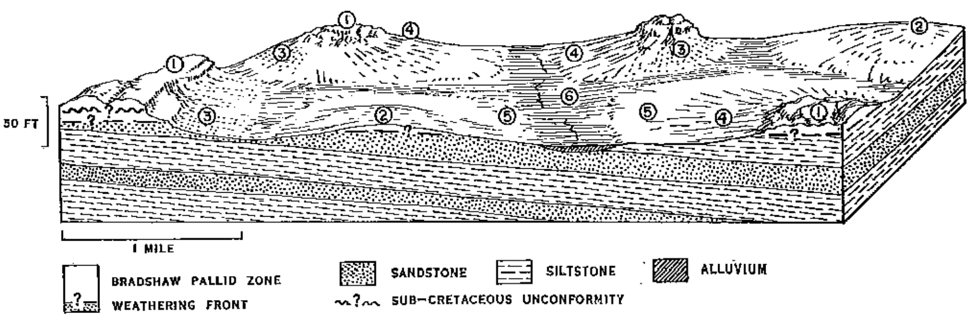
Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Steeper slopes: sandy slopes up to 5% and 1 mile in extent, sparsely strewn with ironstone gravel; exposures of ironstone and pallid-zone rock locally	Mainly brownish sand over mottled brownish subsoil with concretions (Florina); some reddish sand over red loam (Venn)	Tall open forests 25–35 ft (*E. tetrodonta*, *E. miniata*, *E. bleeseri*, *E. dichromophloia*), with patchy shrubs and open spinifex–tall grass (*Plectrachne pungens*, annual sorghum, patches of *Sorghum plumosum*)
2	Small	Lower slopes in upper sectors: up to 2% and ½ mile long; sandy surfaces with patches of ironstone gravel	Mainly brownish loamy sand over mottled yellowish sand or loam (Cullen); some reddish sand over red clay (Blain)	Tall open forests 30–40 ft (*E. miniata*, *E. bleeseri*, *E. dichromophloia*, *E. tetrodonta*), with spinifex–tall grass (*Plectrachne pungens*, patches of annual sorghum)
3	Large	Lower slopes in lower sectors: mainly less than 1% and up to 1 mile long; sandy surfaces with patches of ironstone gravel	Brownish loamy sand over mottled yellowish sand, loam, or clay (Elizabeth, Cullen)	Savannah woodland 20–35 ft (*E. tectifica*, *E. grandifolia*, *Erythrophleum chlorostachys*), with patchy tropical tall grass (*Aristida* spp.) and spinifex–tall grass
4	Very small	Tributary drainage floors: up to ¼ mile wide, gradients up to 1 in 80, with transverse slopes up to 1%; firmed surfaces	Brownish loam over mottled yellow clay with concretions (Elliott)	Savannah woodland 25–35 ft (*E. bigalerita*, *E. dichromophloia*, *Erythrophleum chlorostachys*), with tropical tall grass (*Sorghum plumosum*, *Chrysopogon* spp.)
5	Very small	Main drainage floors: up to ½ mile wide, gradients below 1 in 200; firmed to sealed surfaces		Savannah woodland 20–35 ft (*E. latifolia*, *E. alba*, *E. tetrodonta*), with tropical tall grass (*Sorghum plumosum*, *Chrysopogon* spp., patches of *Plectrachne pungens*)
6	Very small	Channels: up to 50 ft wide and 12 ft deep, with restricted levees; incised in alluvium and bed-rock	Stratified alluvial regosols on levees; bedloads range from sand to cobbles	Fringing community of open *E. camaldulensis*

(9) Chinaman Land System (40 sq miles)

Undulating terrain with tall open forests and scattered grasslands. Spinifex country. Mainly spinifex–tall grass pasture on sandy brown earths; small areas of better pastures on loamy or clayey soils; no significant areas of arable land.

Geology.—Deeply weathered and relatively unweathered, subhorizontal or dipping sandstone and siltstone of Cretaceous or Cambrian age.

Geomorphology.—Undulating terrain eroded between the Maranboy and Tipperary surfaces: rocky crests with fringing sandy slopes, or cracking clay slopes, low stony rises, and restricted lower slopes; moderately dense, irregular pattern of ill-defined drainage floors; relief up to 50 ft.



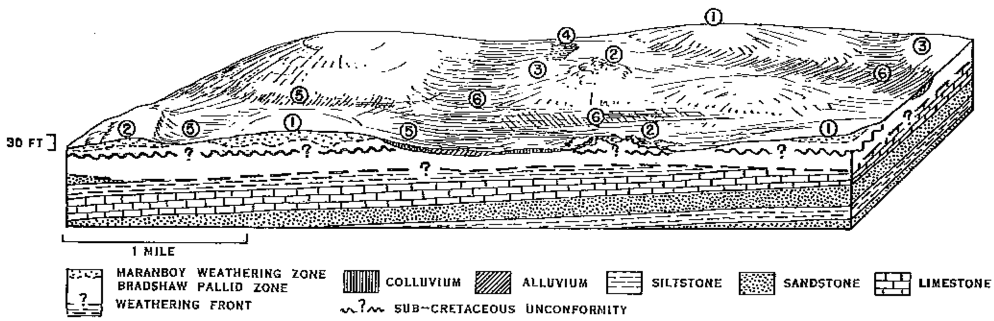
Unit	Area	Land Forms	Soils	Vegetation
1	Small	**Rocky crests:** outcrop surfaces up to 1½ miles in extent; marginal benched, boulder-covered slopes up to 20%	Mainly outcrop and skeletal soils; some brownish sand over mottled brownish subsoil with concretions (Florina) on fringing slopes	Low savannah woodland 20–30 ft (*E. tectifica*, *E. grandifolia*, *Erythrophleum chlorostachys*), with moderate to dense shrubs, and sparse spinifex–tall grass (annual sorghum, *Aristida* sp., *Chrysopogon* spp., *Plectrachne pungens*)
2	Medium	**Stony rises:** up to 1 mile wide; cobble-strewn slopes up to 3%	Shallow Florina soils	Tall shrubland 10–15 ft (*Melaleuca viridiflora*, *Hakea lorea*, and *Terminalia* spp.) and scattered eucalypts 20–30 ft (*E. ferruginea*, *E. confertiflora*), with sparse spinifex–tall grass (*Plectrachne pungens*, *Chrysopogon* spp., *Eriachne* sp.)
3	Medium	**Sandy mid slopes:** sandy slopes up to 3% and ½ mile long	Brownish sand over mottled brownish subsoil with concretions (Florina)	Savannah woodland 25–35 ft (*E. tectifica*), with sparse spinifex–tall grass (*Sorghum plumosum*, *Chrysopogon* spp., *Plectrachne pungens*)
4	Medium	**Cracking clay slopes:** up to 4% and ½ mile long; sealed, hummocky surfaces with cobble patches	Stony dark cracking clay (Cununurra)	Grassland (*Sorghum plumosum*), with sparse low trees and shrubs
5	Small	**Lower slopes:** less than 1% and up to ½ mile long	Brownish loam over mottled yellow clay commonly with concretions (Elliott)	Savannah woodland 30–35 ft (*E. tectifica*), with mixed tropical grass (*Aristida browniana*) and scattered tropical tall grass (annual sorghum, *Sorghum plumosum*, *Aristida latifolia*)
6	Small	**Drainage floors:** up to ⅜ mile wide, gradients mainly below 1 in 200, with central linear depressions up to 1 ft deep and locally with discontinuous channels; sealed, locally cracking surfaces	Mottled dark grey loam over mottled clay (Marrakai); dark cracking clay (Cununurra) in depressions	Savannah woodland 25–35 ft (*E. latifolia*), with tropical tall grass (*Themeda australis*, *Sorghum plumosum*, patches of *Chrysopogon* spp.)

(10) Claravale Land System (750 sq miles)

Gently undulating sandy terrain with tall open forest. Spinifex country. Mainly spinifex–tall grass pasture on sandy brown earths, medium areas of better pastures on sandy red earths of which an estimated 150 sq miles is arable.

Geology.—Deeply weathered, subhorizontal Cretaceous sandstone and siltstone unconformably overlying deeply weathered, dipping sandstone, siltstone, and limestone of Cambrian age.

Geomorphology.—Forming part of the Tipperary surface — undulating terrain: extensive, gentle upper slopes, restricted lower slopes with minor depressions, and stony surfaces comprising low hills and interfluve crests; colluvial–alluvial slopes form tributary floors and also occur marginally to main floors; sparse, ill-defined pattern of mainly unchannelled drainage floors; relief mainly less than 30 ft but attaining 75 ft.



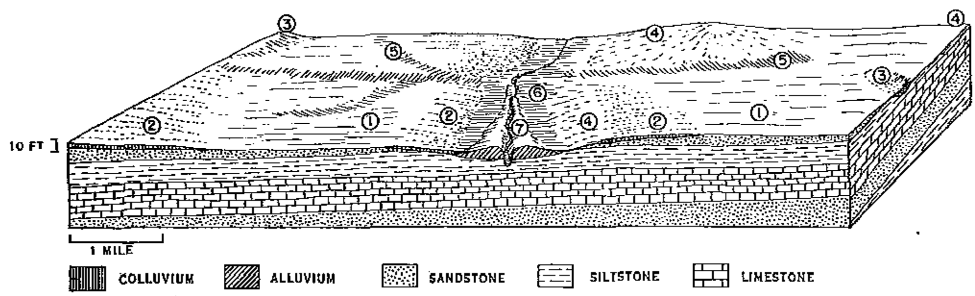
Unit	Area	Land Forms	Soils	Vegetation
1	Large	Upper slopes: up to 1 mile in extent; sandy slopes less than 3%, with patches of ironstone gravel and locally with bouldery exposures of ironstone and pallid-zone rock	Brownish sand over mottled brownish subsoil with concretions (Florina), mainly shallow with outcrop	Tall open forest 40–60 ft (*E. miniata, E. tetrodonta, E. bleeseri, Erythrophleum chlorostachys*), with spinifex–tall grass (*Plectrachne pungens*, annual sorghum, locally *Sehima nervosum, Heteropogon triticeus*)
2	Small	Stony surfaces: boulder-covered hill slopes up to 60% and interfluve crests up to ½ mile wide, with marginal slopes up to 2%; frequent exposures of pallid-zone rock	Mainly outcrop; pockets of sandy skeletal soils; minor Florina	Savannah woodland 30–40 ft (*E. tectifica, E. confertiflora, Erythrophleum chlorostachys*), with mixed tropical tall grass (*Themeda australis, Sorghum plumosum*) and spinifex–tall grass (*Plectrachne pungens*, annual sorghum)
3	Small	Lower slopes: up to ¾ mile long and mainly less than 1%, but locally up to 5%; sandy surfaces with pebble patches	Mainly reddish sandy soils (Cockatoo, Venn, some Cullen)	Tall open forest 40–50 ft (*E. miniata, E. tetrodonta*), with mixed tropical tall grass (*Themeda australis, Sorghum plumosum*, annual sorghum, *Aristida* spp.)
4	Very small	Depressions: very shallow and up to ¼ mile wide, with marginal slopes up to 2%; firmed, sandy surfaces	Brownish loamy sand over mottled yellowish sand or loam (Cullen)	Tall shrubland 10–20 ft (*Acacia* spp.) and tall savannah woodland 30–40 ft (*E. polycarpa*), with dense shrubs (*Acacia* spp.), and sparse spinifex–tall grass (annual sorghum)
5	Very small	Colluvial–alluvial slopes: tributary floors up to 300 yd wide, gradients above 1 in 200, locally with channels up to 40 ft wide and 5 ft deep; slopes marginal to main floors to 2% and 200 yd long; loose to firmed sandy surfaces	Loams over red or yellow mottled clay (Elliott and Tippera)	Savannah woodland 35–50 ft (*E. tectifica, E. confertiflora, E. patellaris*), with tropical tall grass (*Themeda australis, Chrysopogon* spp., *Sorghum plumosum*)
6	Medium	Main drainage floors: up to ½ mile wide; loose to firmed sandy surfaces in upper sectors with gradients up to 1 in 60, and firmed surfaces of finer sand in lower sectors with gradients below 1 in 250	Reddish sands over red clay or loam (Blain, Venn)	Mixed open forest 40–60 ft (*E. tetrodonta, E. tectifica, Erythrophleum chlorostachys, Gyrocarpus americanus, E. ferruginea*), with mixed tropical grass (annual sorghum, *Aristida* spp., and scattered *Chrysopogon* spp., *Sorghum plumosum*, and *Themeda australis*)

(11) Wriggley Land System (400 sq miles)

Plains with loamy soils and savannah woodlands. Tropical tall grass country. Almost exclusively tropical tall grass pastures on loamy red and yellow earths of which two-thirds (250 sq miles) is probably potentially arable.

Geology.—Relatively unweathered, gently dipping Cambrian limestone, sandstone, and siltstone; minor Upper Proterozoic sandstone, siltstone, and limestone.

Geomorphology.—Forming part of the Tipperary surface — plains: gently sloping plains with sandy colluvial slopes at the upper and lower margins, and with slopes of fine-textured colluvium occurring locally at the upper margin and in very shallow depressions; restricted stony slopes occur adjacent to incised channels and also form low rises; sparse to moderately dense branching pattern of through-going alluvial drainage floors with ill-defined, unchannelled tributary floors; relief mainly less than 10 ft, but drainage is locally entrenched up to 40 ft.



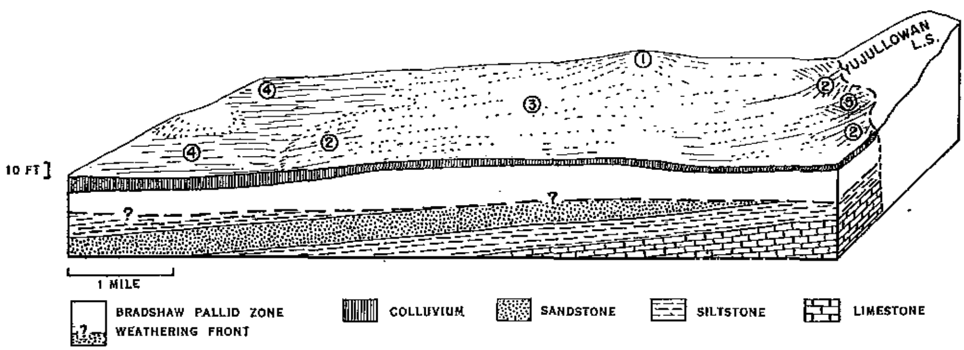
Unit	Area	Land Forms	Soils	Vegetation
1	Very large	**Plains:** mainly less than 1% and extending up to 3 miles downslope; locally with concave slopes, 2–6% and less than ½ mile long, at the upper margin; firmed surfaces with minor patches of ironstone gravel	Mainly reddish loam over red clay (Tippera); locally with concretions (Xanthippe); some brownish loam over mottled yellow clay, commonly with concretions (Elliott)	Savannah woodland 25–35 ft (*E. foelscheana*, *E. tectifica*, *E. confertiflora*, *E. tetrodonta*), with dense tropical tall grass (*Themeda australis*, *Sorghum plumosum*, *Sehima nervosum*, *Heteropogon triticeus*)
2	Small	**Sandy colluvial slopes:** up to 1½ miles long and mainly less than 2%, but locally up to 3%; loose to firmed sandy surfaces	Mainly reddish sand over red clay (Blain, minor Florina)	Mixed open forest 35–45 ft (*E. tetrodonta*, *E. tectifica*, *E. foelscheana*, *Erythrophleum chlorostachys*), with tropical tall grass (*Themeda australis*, *Sorghum plumosum*, *Sehima nervosum*, *Heteropogon triticeus*)
3	Very small	**Slopes of fine-textured colluvium:** concave, up to 5% and ½ mile long; firmed surfaces with pebble patches	Loam over red or mottled yellow clay	Tall open forest 45–60 ft (*E. tetrodonta*, *E. miniata*), with tropical tall grass (*Sorghum plumosum*, *Sehima nervosum*, *Heteropogon triticeus*)
4	Small	**Stony slopes:** cobble-strewn slopes up to 20% and less than ¼ mile long	Mainly skeletal soils; some Blain, Venn, and Florina	Savannah woodland 25–40 ft (*E. tectifica*, *E. foelscheana*, *E. polycarpa*), with various tropical tall grasses
5	Very small	**Tributary floors:** less than ½ mile wide, gradients below 1 in 250, with marginal transverse slopes up to 1%; firmed surfaces	Reddish loam over red clay (Tippera)	Savannah woodland 30–45 ft (*E. papuana*, *E. patellaris*, *E. confertiflora*), with tropical tall grass (*Sorghum plumosum*, *Themeda australis*, *Sehima nervosum*). Local grassland (*Sorghum plumosum*)
6	Small	**Main drainage floors:** up to ½ mile wide, gradients below 1 in 200; locally with water sinks and linear depressions up to 50 ft wide and 3 ft deep; firmed to lightly sealed surfaces with sealed, heavily cracking, hummocky areas in the lowest parts	Mainly dark grey loam over mottled clay (Marrakai); minor Elliott and Cununurra in lowest parts	Savannah woodland 30–45 ft (*E. papuana*, locally *E. polycarpa*, *E. latifolia*), with complex of tropical tall grass (*Themeda australis*, *Sorghum plumosum*) and frontage grass (*Coelorachis rottboellioides*, *Arundinella nepalensis*, *Bothriochloa* spp., *Heteropogon contortus*)
7	Very small	**Channels:** up to 100 ft wide and 20 ft deep, commonly incised in bed-rock; levees up to 3 ft high with back slopes up to 1%; firmed surfaces	Brownish loam over reddish clay (Edith) on levees; bed-loads range from sand to boulders	Fringing communities (*Tristania suaveolens*, *Terminalia platyphylla*, *Acacia* sp.), with dense lower layer (*Bambusa* spp., *Melaleuca* spp., *Pandanus* sp.) and patchy frontage grass (*Bothriochloa* spp., *Arundinella nepalensis*)

(12) Blain Land System (650 sq miles)

Sandy plains with mixed open forest. Mixed tropical tall grass country. Mainly mixed tall grass and tropical tall grass pastures on sandy red earths, probably two-thirds (450 sq miles) potentially arable.

Geology.—Sandy colluvium mainly overlying deeply weathered and silicified, gently dipping Cambrian sandstone, siltstone, and limestone.

Geomorphology.—Forming part of the Tipperary surface — plains: gently undulating plains with restricted higher crests, extensive gentle slopes, and slightly steeper slopes at the upper and lower margins and also forming low crests; flats occur in the lowest parts and there are restricted slopes with subsurface calcareous influence; relief less than 10 ft.



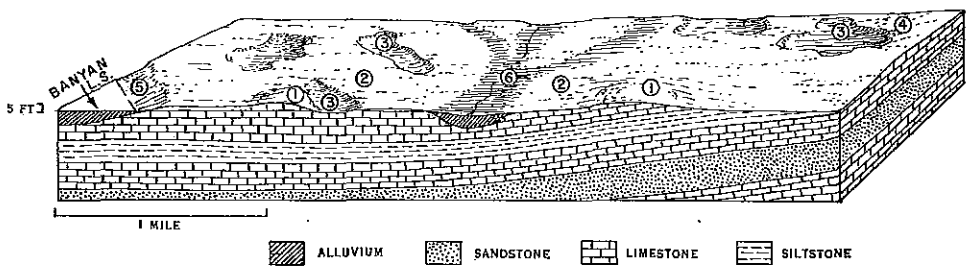
Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Higher crests: up to ¼ mile in extent; sandy slopes less than 3%, sparsely strewn with ironstone gravel, with local bouldery exposures of ironstone and pallid-zone rock	Brownish sand over brownish mottled subsoil with concretions (Florina); some outcrop	Tall open forest 35–45 ft (*E. bleeseri*, scattered *E. tetrodonta*, *E. miniata*), with moderately dense low shrub layer, and spinifex–tall grass (*Plectrachne pungens*)
2	Medium	Steeper slopes: sandy slopes up to 4% and 1 mile long; minor bouldery exposures of pallid-zone rock with restricted, fringing stony slopes up to 5%	Mainly reddish sand over red loam (Venn); minor Cockatoo and skeletal soils	Mixed open forest 45–70 ft (*E. tetrodonta*, scattered *E. miniata*, *Erythrophleum chlorostachys*, *Gyrocarpus americanus*), with moderately dense shrub layer, and mixed tropical tall grass (annual sorghum, *Aristida* spp., and scattered *Sorghum plumosum*, *Sehima nervosum*)
3	Large	Gentle slopes: sandy slopes mainly less than 1% and up to 5 miles long	Mainly reddish sand over red clay (Blain); minor Tippera and Venn	Mixed open forest 40–60 ft (*E. tetrodonta*, *Erythrophleum chlorostachys*, *E. dichromophloia*, *E. foelscheana*), with mixed tropical grass (annual sorghum and local *Sorghum plumosum*, *Themeda australis*, and *Chrysopogon* spp.)
4	Medium	Flats: less than 0·2% and up to 2 miles wide; firmed sandy surfaces	Reddish sand or loam over red clay (Blain, Tippera)	Mixed open forest 40–60 ft (*E. papuana*, *Erythrophleum chlorostachys*, *E. tetrodonta*, *E. confertiflora*, *Gyrocarpus americanus*), with moderately dense shrub layer (including *Livistona* and *Pandanus* palms), and mixed tropical grass (annual sorghum, *Setaria* sp., *Panicum* spp.)
5	Very small	Slopes with subsurface calcareous: sandy slopes up to 4% and ½ mile long	Mainly Blain with some Tippera	Mixed open forest 30–45 ft (*E. tetrodonta*, *E. tectifica*, *E. foelscheana*), with tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*, and *Sehima nervosum*)

(13) Douglas Land System (80 sq miles)

Plains with loamy and clayey soils carrying savannah woodland and grassland. Tropical tall grass country. Exclusively tropical tall grass pastures on mainly red and yellow earths, estimated arable area 40 sq miles.

Geology.—Dipping Cambrian limestone, sandstone, and siltstone.

Geomorphology.—Forming part of the Tipperary surface — plains: gently undulating plains with low rises, extensive gentle slopes, scattered depressions, and restricted marginal slopes; sparse pattern of irregular ill-defined drainage floors; relief less than 10 ft.



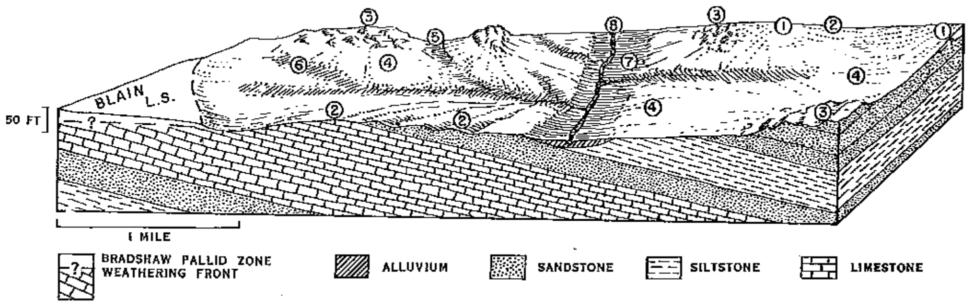
Unit	Area	Land Forms	Soils	Vegetation
1	Small	Rises: gently rounded crests up to 5 ft high, with marginal slopes up to 2%; lightly firmed surfaces sparsely strewn with ironstone gravel	Mainly brownish loam over mottled yellow clay, commonly with concretions (Elliott); some Tippera	Savannah woodland 35–50 ft (*E. foelscheana, E. confertiflora, Erythrophleum chlorostachys*), with tropical tall grass (*Themeda australis, Sehima nervosum, Sorghum plumosum*)
2	Large	Gentle slopes: up to 1 mile long and mainly less than 0·5%, but locally up to 2%; minor hollows up to 2 ft deep and 50 ft across, with sealed, cracking, hummocky surfaces, occur locally in the lowest parts	Mainly reddish loam over red clay (Tippera); some Elliott; minor Cununurra in hollows	Savannah woodland 15–25 ft (*E. foelscheana, E. confertiflora*), with dense tropical tall grass (*Sorghum plumosum, Sehima nervosum, Heteropogon triticeus, Chrysopogon* spp., *Themeda australis*)
3	Medium	Depressions: circular or elongate, up to 10 ft deep and ½ mile across; sealed, cracking, and hummocky surfaces	Mainly dark cracking clay (Cununurra)	Tall shrubland 10–25 ft (*Terminalia platyptera, Melaleuca viridiflora, Acacia bidwillii*), with moderately dense tropical tall grass (*Sorghum plumosum*)
4	Very small	Slopes adjacent to depressions: up to 3% and 100 yd long; firmed surfaces	Brownish loam over mottled yellow clay, commonly with concretions (Elliott)	Savannah woodland 50–70 ft (*E. polycarpa, E. papuana, Tristania suaveolens*), with moderately dense shrub layer 6–15 ft (*Petalostigma quadriloculare, Persoonia falcata, Grevillea dimidiata, Buchanania obovata, Planchonia careya*), and tropical tall grass (*Sorghum plumosum*, annual sorghum)
5	Very small	Marginal slopes: up to 1% and ¼ mile long; firmed to lightly sealed surfaces with minor calcrete exposures; shallowly dissected stony surfaces occur locally		Grassland, tropical tall grass (annual sorghum, *Heteropogon contortus, Sorghum plumosum*), with patchy open tall shrub layer (*Terminalia platyptera, Planchonia careya, Cochlospermum fraseri*)
6	Small	Drainage floors: up to ¼ mile wide, gradients below 1 in 250, locally with shallow channels; firmed to sealed, locally hummocky and cracking surfaces with grit patches	Brown stratified alluvial regosols	Savannah woodland 30–50 ft (*E. papuana, E. foelscheana, Planchonia careya*), with tropical tall grass (*Sorghum plumosum, Sehima nervosum*, patches of *Coelorachis rottboellioides* and *Heteropogon contortus*)

(14) Tagoman Land System (500 sq miles)

Undulating tracts with shallow soils and savannah woodland. Tropical tall grass country. Mainly tropical tall grass pastures on loamy red earths mixed with outcrop, only scattered areas of arable soils (estimated 50 sq miles).

Geology.—Gently dipping Cambrian sandstone, siltstone, and limestone.

Geomorphology.—Eroded below the Tipperary surface — undulating terrain: sandy crests and gentle upper slopes, with extensive lower slopes forming gently undulating terrain with scattered shallow depressions and relief up to 10 ft; rocky surfaces form low bouldery rises up to ¼ mile wide, hills and cuestas up to 40 ft high, and valley slopes; moderately dense to dense pattern of branching or rectangular drainage; relief up to 50 ft.



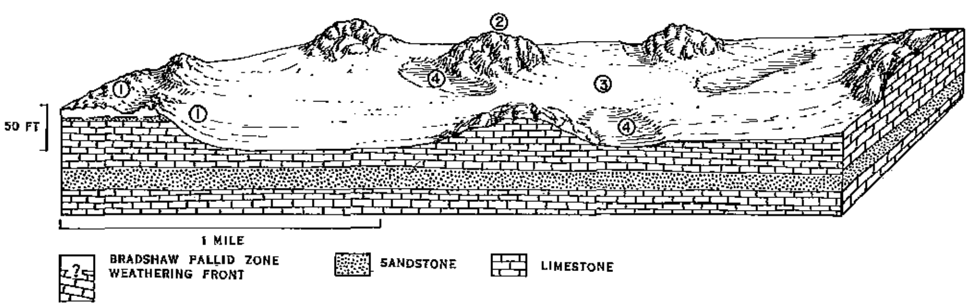
Unit	Area	Land Forms	Soils	Vegetation
1	Small	Sandy crests: up to ½ mile in extent; sandy slopes up to 1% sparsely strewn with pebbles	Brownish sand over mottled brownish subsoil with concretions (Florina)	Open savannah woodland 20–30 ft (*E. foelscheana*, *E. confertiflora*, *Erythrophleum chlorostachys*), with moderately dense shrubs (*Grevillea dimidiata*, *Terminalia grandiflora*, *T. ferdinandiana*, *Livistona humilis*, *Planchonia careya*, *Cochlospermum fraseri*), and spinifex–tall grass (annual sorghum, *Plectrachne pungens*, *Sorghum plumosum*)
2	Small	Upper slopes: up to 3% and 1 mile long, with cobble patches; locally dissected up to 50 ft into gently rounded spurs up to ½ mile wide, with stony marginal slopes up to 15% and with minor outcrop	Reddish loam or sand over red clay (Tippera, Blain); skeletal soils and outcrop	Savannah woodland 20–40 ft (*E. tectifica*, *E. foelscheana*, *E. confertiflora*, *Erythrophleum chlorostachys*), with moderately dense shrub layer, and mixed tropical grass (*Panicum delicatum*, *Eragrostis* spp., *Eriachne* spp., *Schizachyrium* sp.)
3	Medium	Rocky surfaces: benched, cobble-strewn outcrop slopes up to 45% and ½ mile in extent	Much outcrop; pockets of shallow Tippera soils	Very open savannah woodland 20–35 ft (*E. tectifica*, *E. grandifolia*, *E. confertiflora*, *E. foelscheana*), with sparse tropical tall grass (*Themeda australis*, *Chrysopogon* spp.) and much bare ground
4	Medium	Lower slopes: up to 2% and 1½ miles long; cobble patches and minor outcrop	Mainly reddish loam over red clay (Tippera), commonly shallow; some Elliott	Savannah woodland 25–35 ft (*E. tectifica*, *E. foelscheana*, *E. patellaris*, locally *E. oligantha*), with sparse tropical tall grass (*Themeda australis*, *Chrysopogon* spp.) and locally mixed tropical grass (*Aristida* spp., *Eriachne obtusa*)
5	Very small	Depressions: linear, up to 200 yd wide, with marginal slopes up to 2%; firmed surfaces	Tippera and some Elliott	Savannah woodland 50–70 ft (*E. bigalerita*, *E. polycarpa*, and scattered *E. confertiflora*, *E. patellaris*, *E. papuana*), with complex of tropical tall grass (*Sorghum plumosum*) and frontage grass (*Bothriochloa intermedia*, *Coelorachis rottboellioides*, *Arundinella nepalensis*, *Heteropogon contortus*)
6	Very small	Tributary drainage floors: less than ¼ mile wide, locally with marginal transverse slopes up to 3%; firmed surfaces with gradients up to 1 in 30 in upper sectors, and sealed surfaces with gradients below 1 in 100 in lower parts	Mainly reddish loam over red clay (Tippera)	Mixed open forest 45–60 ft (*E. tetrodonta*, scattered *E. confertiflora*), with frontage grass (*Coelorachis rottboellioides*, *Heteropogon triticeus*, *Sorghum plumosum*)
7	Small	Main drainage floors: up to ½ mile wide, gradients below 1 in 200; sealed surfaces	Dark or grey, mainly calcareous soils (Witch Wai, Phillips, Ingrid); some Marrakai	Savannah woodland 45–50 ft (*E. papuana*, *Tristania suaveolens*), with tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*)
8	Very small	Channels: mainly up to 40 ft wide and 5 ft deep, locally up to 10 ft deep and incised in bedrock	Deep sand and grit bed-loads	Open fringing communities (*Tristania suaveolens*, *Terminalia platyphylla*, *Acacia* sp., patches of *Pandanus* palms), with sparse frontage grass

(15) Budbudjong Land System (90 sq miles)

Undulating limestone terrain with savannah woodland and grassland. Tropical tall grass country. Mainly tropical tall grass pastures on loamy red earths mixed with outcrop, only scattered areas of arable soils (estimated 15 sq miles).

Geology.—Gently dipping Cambrian limestone with some sandstone; minor silicified pallid-zone rock.

Geomorphology.—Eroded below the Tipperary surface — undulating terrain: scattered outcrop hills up to 40 ft high, with intervening lower slopes and very shallow depressions, and with gently sloping crest surfaces at the upper margin; surface drainage absent; relief up to 50 ft.



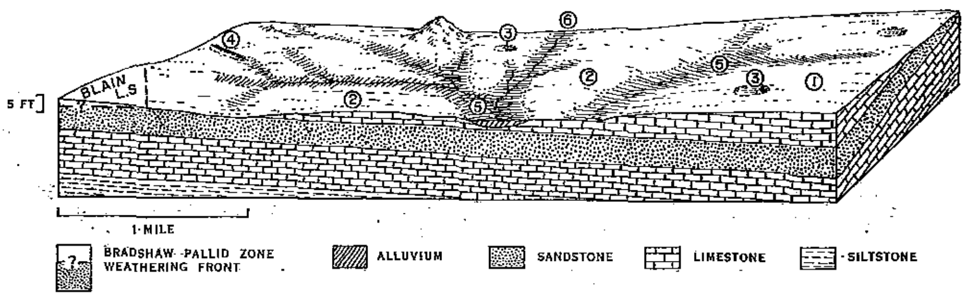
Unit	Area	Land Forms	Soils	Vegetation
1	Small	Crest surfaces: stony slopes mainly less than 2% and up to 2½ miles long; dissected margins comprise rocky slopes up to 10% with bouldery outcrops up to 20 ft high	Reddish loam over red clay (Tippera), commonly shallow; skeletal soils and outcrop on marginal slopes	Savannah woodland 25–35 ft (*E. foelscheana*, *E. confertiflora*, *Bauhinia cunninghamii*), sparse tropical tall grass (*Sehima nervosum*, *Themeda australis*, annual sorghum). Deciduous woodlands on bouldery outcrops
2	Medium	Rocky hills: bouldery outcrop slopes up to 50%, locally vertical; pitted and fluted rock surfaces	Outcrop and pockets of skeletal soils	Deciduous woodlands 15–25 ft (*Bauhinia cunninghamii*, *Gyrocarpus americanus*, *Owenia* sp., *Ficus* sp., *E. confertiflora*), with moderately dense shrub layer (*Buchanania obovata*, *Terminalia* spp., *Planchonia careya*, locally *Cycas media*) and sparse tropical tall grass (annual sorghum)
3	Very large	Lower slopes: less than 0·5% and up to ½ mile long; firmed surfaces with scattered, low outcrop and cobble patches	Mainly reddish loam over red clay (Tippera); some Elliott and scattered outcrop	Savannah woodland 25–30 ft (*E. foelscheana*, *E. tectifica*, *E. argillacea*, *Erythrophleum chlorostachys*), with dense tropical tall grass (*Themeda australis*, *Sorghum plumosum*, *Sehima nervosum*)
4	Very small	Depressions: up to ¼ mile wide; hummocky, cracking surfaces with microrelief	Dark cracking clays (Cununurra)	Grassland, tropical tall grass 7–10 ft (*Sorghum plumosum*), with sparse trees and shrubs

(16) Kimbyan Land System (900 sq miles)

Mainly stony plains with mixed open forest, and moderately extensive soil-covered plains with savannah woodland. Tropical tall grass country. Almost exclusively tropical tall grass pastures on loamy red earths with limestone outcrop, probably one-third (300 sq miles) potentially arable.

Geology.—Dipping limestone, sandstone, and siltstone of Cambrian age.

Geomorphology.—Eroded below the Tipperary surface — plains: erosional plains with outcrop in the lower parts, and less extensive soil-covered plains in the upper sectors with little outcrop; scattered water sinks and shallow depressions; sparse to moderately dense pattern of rectangular or branching drainage, unchannelled in the upper sectors; relief mainly less than 10 ft.



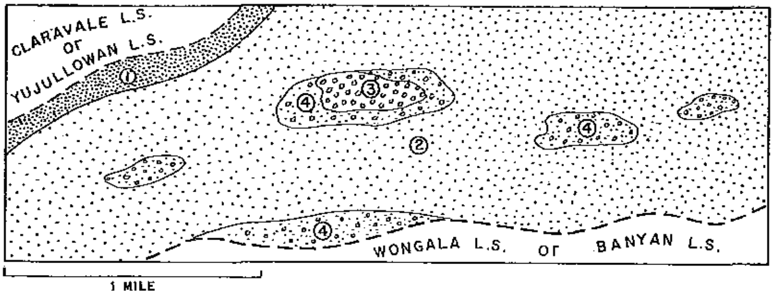
Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Plains in higher sectors: up to 2 miles in extent, slopes mainly less than 0·5%, with very shallow, ill-defined linear depressions up to ¼ mile wide; lightly firmed sandy surfaces with outcrop locally	Mainly reddish loam over red clay (Tippera); some Elliott; locally shallow	Savannah woodland 20–35 ft (*E. foelscheana, E. tectifica, E. latifolia, E. oligantha*, scattered *E. tetrodonta*), with dense tropical tall grass (*Sorghum plumosum, Themeda australis, Sehima nervosum, Heteropogon triticeus*)
2	Very large	Plains in lower sectors: up to 3 miles wide, slopes up to 1%, with very shallow, ill-defined linear depressions up to ½ mile wide; firmed surfaces with scattered outcrop; minor hills up to 40 ft high with bouldery slopes up to 50%, and stony rises up to 5 ft high	Reddish loam over red clay (Tippera) interspersed with outcrop; minor Elliott	Savannah woodland 35–50 ft (*E. foelscheana, E. tectifica*), with tropical tall grass (*Sorghum plumosum, Themeda australis, Sehima nervosum*). Deciduous woodland on rocky hills. Local mixed open forest
3	Very small	Water sinks: circular or elongate, up to 10 ft deep and 100 yd across; discontinuous, marginal outcrop walls	Tippera and Elliott soils with dark organic surface horizons	Savannah woodland 50–70 ft (*E. papuana, E. patellaris, Tristania suaveolens*), with numerous shrubs, and frontage grass (*Coelorachis rottboellioides, Dichanthium fecundum*)
4	Very small	Depressions: linear, up to 1 ft deep and 200 yd wide; cracking surfaces	Dark cracking clays (Cununurra)	Grassland, tall tropical grass (*Sorghum plumosum*)
5	Very small	Drainage floors: up to ¼ mile wide, gradients below 1 in 250; firmed to sealed surfaces, with pebble patches	Dark or grey mainly calcareous soils (Witch Wai, Phillips, Ingrid)	Savannah woodland 40–50 ft (*E. papuana, E. patellaris*), with tropical tall grass (*Sorghum plumosum*)
6	Very small	Channels: up to 100 ft wide and 5 ft deep; locally incised in bedrock	Deep sand bed-loads	Fringing community (*Terminalia platyphylla, Tristania suaveolens*), with tropical tall grass (*Themeda australis, Heteropogon contortus*)

(17) Karaman Land System (80 sq miles)

Sandy plains with savannah woodland. Tropical tall grass country. Exclusively tropical tall grass pastures on sandy red earths of which probably half (40 sq miles) is potentially arable.

Geology.—Quaternary alluvium and gravel.

Geomorphology.—Depositional surfaces — tributary alluvial plains: extensive sandy slopes with restricted lower slopes and depressions of finer-textured deposits, steeper slopes locally at the upper margin, and minor stony rises; gradients mainly below 1 in 200.



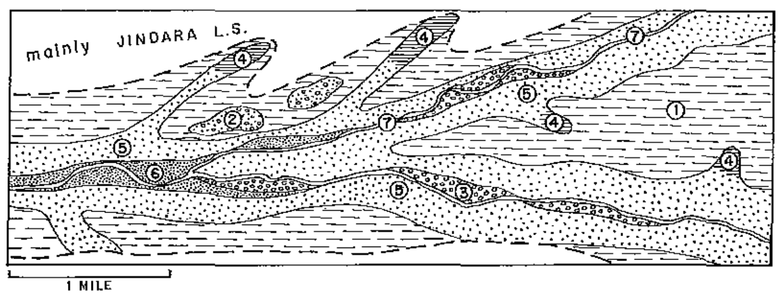
Unit	Area	Land Forms	Soils	Vegetation
1	Small	**Steeper slopes:** up to 3% and ¼ mile long; loose sandy surfaces	Mainly brownish loamy sand over mottled yellow clay (Elizabeth); locally with concretions (Elliott)	Savannah woodland 30–40 ft (*E. tectifica, E. confertiflora, Erythrophleum chlorostachys*), with tropical tall grass (*Sorghum plumosum, Chrysopogon* spp.)
2	Very large	**Sandy slopes:** up to 1 mile long and mainly less than 1%, but locally up to 5% in the upper sectors and with extensive slopes less than 0·2% in the lower parts; loose to firmed sandy surfaces with exposures of river gravels locally	Reddish sandy soils locally with concretions (Venn, Cockatoo, Coralie)	Savannah woodland 40–50 ft (*E. papuana, E. ferruginea, Gyrocarpus americanus, Erythrophleum chlorostachys*), with tropical tall grass (*Sorghum plumosum, Sehima nervosum, Aristida browniana*)
3	Very small	**Stony rises:** cobble-strewn rises up to 300 yd wide and less than 10 ft high, with marginal slopes up to 3%	Brownish sand over mottled brownish subsoil with concretions (Florina), commonly shallow	Savannah woodland 25–35 ft (*E. tectifica, Erythrophleum chlorostachys, Terminalia* sp.), with tropical tall grass (*Sorghum plumosum*) and patches of *Plectrachne pungens*
4	Small	**Lower slopes and depressions:** up to ½ mile in extent with slopes less than 0·5%; firmed surfaces with cobble patches	Loam over mottled clay (Elliott, Marrakai)	Grassland, tropical tall grass (*Chrysopogon* spp., *Sorghum plumosum*, annual sorghum)

(18) Green Ant Land System (80 sq miles)

Tributary river plains, mainly with clayey soils, carrying grassland and very open savannah woodland. Frontage country. Tropical tall grass and frontage pastures. Suitability of major soils for crops and pastures not known.

Geology.—Quaternary alluvium; minor Cambrian limestone, sandstone, and siltstone.

Geomorphology.—Depositional surfaces — mainly stable tributary flood-plains: flood-plains comprising stable plains, minor stony rises, sandy slopes, and slopes of older alluvium, flanking active levee zones; sparse pattern of through-going channels with unchannelled tributary floors; gradients below 1 in 300.



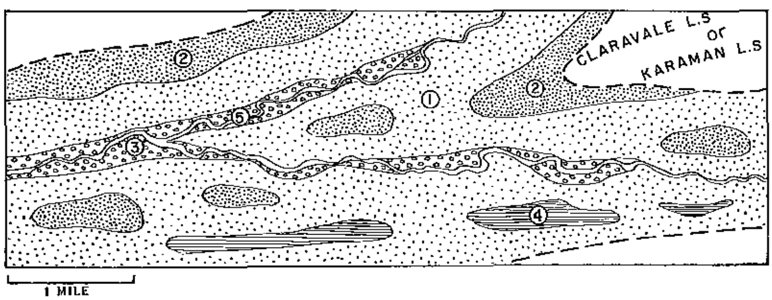
Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Stable plains: up to 1 mile wide, slopes less than 1%; firmed surfaces with minor patches of ironstone gravel	Brownish sand over mottled brownish subsoil with concretions (Florina)	Mixed open forests and savannah woodland 40–60 ft (*E. papuana, Erythrophleum chlorostachys,* scattered *E. tectifica, E. foelscheana, E. confertiflora*), with dense tropical tall grass (*Sorghum plumosum, Themeda australis, Sehima nervosum, Heteropogon triticeus*)
2	Very small	Stony rises: up to 250 yd wide and 10 ft high; pebble-strewn slopes up to 5% with outcrop locally	Mainly skeletal soils	Shrubby low open forest 20–35 ft (*E. confertiflora, Erythrophleum chlorostachys,* scattered *E. tectifica* and *E. polycarpa*) with dense shrub layer (*Petalostigma* sp., *Cochlospermum fraseri, Grevillea dimidiata*), and sparse mixed grasses (*Chrysopogon* spp., *Coelorachis rottboellioides, Aristida* spp.)
3	Very small	Old alluvial slopes: up to 1% and ½ mile long; firmed surfaces	Brownish loam over mottled yellow clay commonly with concretions (Elliott)	Shrubby low open forest 15–25 ft, species as in unit 2 but with tropical tall grass (*Sorghum plumosum, Heteropogon triticeus*)
4	Very small	Tributary floors: up to 300 yd wide with marginal slopes up to 4%; sealed, locally cracking surfaces; spring zones up to ¾ mile wide and 10 ft deep with marginal outcrop locally	Dark or grey mainly calcareous soils (Witch Wai, Phillips, Ingrid); some Marrakai	Savannah woodland 50–60 ft (*Erythrophleum chlorostachys, E. papuana, E. polycarpa*), with moderately dense shrub layer (*Pandanus* palms and *Melaleuca viridiflora*), and frontage grass (*Coelorachis rottboellioides, Arundinella nepalensis*). Rain forest 70–80 ft (*Nauclea orientalis, Tristania suaveolens,* and other rain-forest elements). Dense *Pandanus* palm fringes to margins
5	Large	Main drainage floors: up to ¾ mile wide, locally with marginal transverse slopes up to 0·5% and ½ mile long; sealed, cracking surfaces with microrelief	Mainly dark cracking clay (Cununurra); also some soils as in unit 4	Complex of grassland and open savannah woodland (*E. papuana*), with frontage grass (*Coelorachis rottboellioides, Bothriochloa intermedia, Heteropogon contortus, Arundinella nepalensis*) and tropical tall grass (*Sorghum plumosum* and *Themeda australis*)
6	Very small	Levees: up to 2 ft high, with back slopes up to 1% and 200 yd long; firmed surfaces	Sand or loam over red clay or loam (Tippera, Daly)	Savannah woodland 30–50 ft (*E. grandifolia, E. confertiflora, Erythrophleum chlorostachys*), with tropical tall grass (*Themeda australis, Chrysopogon* spp.)
7	Very small	Channels: up to 100 ft wide and 15 ft deep, locally incised in bedrock	Deep sand bed-loads	Fringing forest (*Tristania suaveolens, Terminalia* spp., *Melaleuca* spp.), with dense lower layers of *Pandanus* sp., *Bambusa* sp., and other tall shrubs

(19) Wongalla Land System (150 sq miles)

Tributary river plains with clayey loamy soils and savannah woodland. Frontage country. Tropical tall grass and frontage pastures, mainly heavy clay soils, some red and yellow earths of which an estimated 30 sq miles are potentially arable.

Geology.—Quaternary alluvium; indurated basal gravels.

Geomorphology.—Depositional surfaces — mainly stable tributary flood-plains: extensive back plains with broad, low rises and scattered depressions; slightly lower, narrow levee zones flanking meandering and anastomosing through-going channels; gradients below 1 in 500.



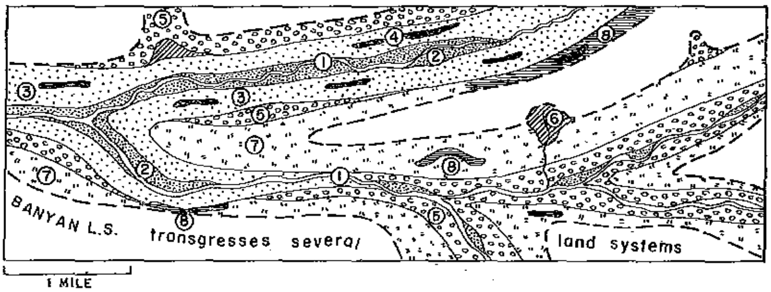
Unit	Area	Land Forms	Soils	Vegetation
1	Large	**Back plains:** up to 1½ miles wide; locally with shallow linear depressions up to 200 yd wide and billabongs up to 200 yd wide and 10 ft deep	Mainly dark cracking clays (Cununurra); some Elliott and Marrakai	Grasslands, tropical tall grass (*Sorghum plumosum, Dichanthium fecundum, Sehima nervosum*). Savannah woodland (*E. microtheca*) with ground storey as above. Locally deciduous woodland (*Bauhinia cunninghamii, Acacia bidwillii*) with *Sorghum plumosum* ground storey
2	Medium	**Rises:** up to 5 ft high and ½ mile wide, with marginal slopes up to 1%; firmed surfaces sparsely strewn with grit	Brownish loam over mottled yellow clay, commonly with concretions (Elliott); some Tippera; minor Elizabeth	Savannah woodland 25–35 ft (*E. argillacea, E. tectifica*), with *Acacia* sp. thickets, and complex of tropical tall grass and mixed tropical grass (*Aristida* spp., *Heteropogon contortus, Themeda australis, Chrysopogon* spp.)
3	Very small	**Levees:** up to 3 ft high, with back slopes up to 2% and ¼ mile long; firmed to lightly sealed surfaces	Loam over yellow or red mottled clay (Elliott, Tippera)	Savannah woodland 25–35 ft (*Erythrophleum chlorostachys, E. ferruginea, E. polycarpa, Gyrocarpus americanus*), with tropical tall grass (*Chrysopogon* spp., *Themeda australis, Aristida* spp.)
4	Small	**Depressions:** up to 2 miles in extent with short marginal slopes up to 1%; sealed, hummocky, heavily cracking surfaces, frequently waterlogged	Dark cracking clay (Cununurra)	Grassland, frontage grass (*Dichanthium fecundum, Chrysopogon* spp.)
5	Very small	**Channels:** up to 100 ft wide and 20 ft deep, incised in alluvium	Deep sand bed-loads	Fringing forests 40–55 ft (*E. camaldulensis, Melaleuca* sp., *Nauclea orientalis, Ficus* spp., *Barringtonia* sp.), with patchy frontage grass (*Heteropogon contortus, Coelorachis rottboellioides, Aristida* spp.)

(20) Banyan Land System (350 sq miles)

Main river plains with savannah woodland and grassland. Frontage country. Tropical tall grass and frontage pastures. Some potentially arable red earths on alluvium (estimated 70 sq miles), some clayey soils, patchy distribution and dissected by gullies.

Geology.—Quaternary alluvium.

Geomorphology.—Depositional surfaces — flood-plains: narrow flood-plains comprising back plains with linear billabongs and levee zones; older deposits form restricted levees and also survive in tributary floors, and younger deposits form levees and lower alluvial banks adjacent to channels and levee zone depressions; minor stony slopes adjacent to deeply incised tributary channels; main channels are deeply incised and consist of remarkably straight sectors, up to 2½ miles long, separated by rounded or slightly angular inflexions; gradients mainly below 1 in 1000.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Channels: mainly up to 200 yd wide, locally up to 300 yd, and up to 60 ft deep; incised in alluvium and bed-rock	Bed-loads range from sand to boulders	Fringing forest 60–100 ft, with tall shrub layer (*Pandanus* sp., *Bambusa* sp.), and sparse frontage grasses
2	Very small	Alluvial banks: concave slopes up to 7% and 250 yd long; firmed surfaces	Brownish sand or loam over reddish loam or clay (Daly, Edith); some stratified alluvial regosols	Savannah woodland 30–40 ft (*E. papuana*), with sparse grasses mostly annuals
3	Small	Younger levees: up to 6 ft high with back slopes up to 2% and mainly less than ¼ mile long, but locally attaining ½ mile; loose to firmed surfaces	Brownish loam or sand over reddish subsoil (Edith, Katherine, Manbulloo, Daly)	Savannah woodland 40–50 ft (*E. papuana, Tristania suaveolens*), with tropical tall grass (*Themeda australis, Chrysopogon* spp., *Sehima nervosum*)
4	Very small	Levee zone depressions: linear, up to 100 yd wide and 15 ft deep, with short marginal slopes up to 15%; sealed, cracking surfaces with microrelief	Dark cracking clay (Cununurra)	Grasslands, frontage grasses (*Dichanthium fecundum* with *Imperata* sp. fringe)
5	Medium	Older levees and tributary floors: levees up to 3 ft high with back slopes up to 1% and ¼ mile long; floors up to ¼ mile wide, gradients mainly below 1 in 500	Reddish sandy soils (Blain, Venn)	Savannah woodland 30–40 ft (*E. tectifica, E. foelscheana, E. patellaris, E. grandifolia*), with tropical tall grass (*Themeda australis*, annual sorghum, *Chrysopogon* spp., *Heteropogon contortus*)
6	Very small	Stony slopes: up to 10% and less than ¼ mile long, dissected up to 30 ft into narrow spurs with marginal, benched slopes up to 25%, stony surfaces with much outcrop	Undifferentiated skeletal soils	Savannah woodland 30–40 ft (*E. papuana, E. microtheca*), with tropical tall grass (annual sorghum, *Chrysopogon* spp.)
7	Medium	Back plains: up to 1 mile wide with sealed, cracking, hummocky surfaces but with slightly higher non-hummocky areas up to ¼ mile in extent; slopes up to 4% and ¼ mile long occur at the upper margin or form rises up to 2 ft high	Mainly dark cracking clay (Cununurra); some Marrakai and Elliott	Open savannah woodland 25–35 ft (*E. microtheca, E. papuana, E. polycarpa*), with complex of tropical tall grass (*Sorghum plumosum, Themeda australis*) and frontage grasses (*Bothriochloa intermedia, Coelorachis rottboellioides*, annual sorghum, *Sesbania* sp.). Local grasslands
8	Very small	Billabongs: up to ¼ mile wide, 1 mile long, and 10 ft deep, with marginal slopes up to 10% and with permanent pools; sealed, cracking, locally hummocky surfaces	Mainly mottled dark grey loam over mottled clay (Marrakai); minor Elliott	Fringing communities (*Tristania suaveolens, E. camaldulensis, Terminalia platyphylla, Casuarina cunninghamiana, Barringtonia* sp., *Pandanus* palms)

PART IV. CLIMATE OF THE TIPPERARY AREA

By E. A. FITZPATRICK*

I. INTRODUCTION

(a) *Objectives and Available Data*

Climatic characteristics in this area have previously been described in some detail (Christian and Stewart 1953; Slatyer 1960; Anon. 1961) and need not be elaborated. Mean monthly values for several elements at Katherine are reproduced from Slatyer (1960) in Table 1. The purpose here is primarily to identify and assess,

TABLE 1

METEOROLOGICAL ELEMENTS AT KATHERINE EXPRESSED ON A MEAN MONTHLY BASIS*

Month	Mean Maximum Temperature (°F)	Mean Minimum Temperature (°F)	Mean 9 a.m. Relative Humidity (%)	Mean 3 p.m. Relative Humidity (%)	Mean 9 a.m. Saturation Deficit (mb)	Evaporation (in.)
January	94·7	74·5	81	55	6·8	6·81
February	93·0	73·7	85	60	4·9	5·79
March	94·9	72·1	80	50	4·7	6·61
April	94·2	65·7	62	34	10·3	6·44
May	91·2	60·9	60	32	10·1	6·80
June	86·7	55·9	58	31	9·1	6·24
July	87·1	54·8	59	33	8·8	6·69
August	90·3	58·2	55	32	11·0	7·82
September	95·9	66·2	53	27	15·1	8·90
October	100·2	73·7	55	27	16·5	9·53
November	100·1	75·9	65	37	14·9	8·81
December	98·0	76·3	68	42	10·9	7·65
Year	93·9	67·3	65	38	10·3	88·10

* Data from Katherine Post Office (Bureau of Meteorology) for standard periods of years (1911-40) except for evaporation data, which are from a standard Australian tank evaporimeter at CSIRO Katherine Research Station for the years 1948-59.

in selected features of climate, areal differences which are of major significance to plant growth and to land use. Emphasis has been given to differences in the character of rainfall throughout the area and, in particular, to differences in the extent to which rainfall satisfies crop or pasture water needs.

Since rainfall stations are sparse and unevenly situated, the interpretations given here are of necessity based mainly upon data from stations in peripheral areas. Orographic controls upon climate are not large and extrapolations can be made from the data of the few stations having lengthy records, without risk of incurring large errors.

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(b) Principal Climatic Controls

The broad character of climate within the area is strongly conditioned by seasonal shifting of the prevailing winds and consequent marked changes in air mass properties. Two distinct seasons can be identified: the wet season with dominant winds from north-west to west and the dry season with prevailing south-easterly winds. Separating these are short transition periods which have no established prevailing wind systems.

The commencement of the wet season is preceded by a period of rising temperatures—normally from October to December—during which variable light winds and widespread intense daytime convection are characteristic. Local thunderstorms occur on occasions; rainfall during this period is normally patchy and unreliable.

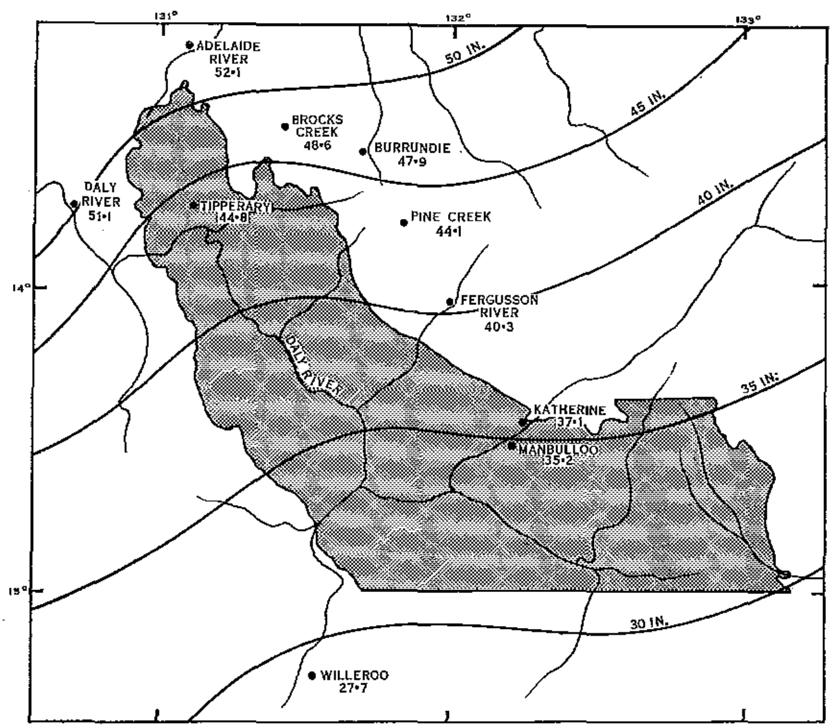

Fig. 2.—Isohyet map.

With the southward progression of the intertropical convergence zone, the true wet season or so-called wet "monsoon" is established normally in early January. Throughout January and February irregular intrusions of very moist maritime air associated with low-pressure trough development over the area are characteristic. Widespread overcast conditions and general rain usually characterize this period, making January and February the rainiest months of the year. It should be emphasized that during the intervals between these moist air intrusions, a return to south-easterly winds bringing hot, dry weather may occur. Such reversals usually do not persist for long periods, but may on occasions extend over several weeks. This feature in the

TABLE 2

MEAN RAINFALL FOR ELEVEN STATIONS WITHIN OR NEAR THE TIPPERARY AREA*

Station	No. of Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Adelaide River	17	1125	1246	879	302	51	27	12	5	63	219	532	749	5210
Brocks Creek	44	1179	1000	983	169	23	20	6	3	52	155	475	797	4862
Burrundie	45	1129	1045	812	228	18	17	12	7	46	212	449	814	4789
Daly River (Police Station)	37	1113	1284	892	174	40	8	4	0	33	208	446	908	5110
Fergusson River	13	1223	960	516	102	15	3	0	0	26	121	460	605	4031
Katherine (CSIRO)	12	726	705	681	178	17	3	3	9	9	108	300	765	3504
Katherine (P.O.)	86	903	800	632	118	20	9	3	2	24	120	332	810	3773
Manbulloo	33	836	748	613	127	7	10	1	5	15	103	296	761	3522
Pine Creek	78	1066	911	793	169	21	11	4	4	34	172	423	798	4406
Tipperary	17	982	1126	656	145	1	10	1	3	22	186	456	810	4398
Willeroo	37	767	587	500	40	12	7	2	3	12	68	258	514	2770

* From data published by Commonwealth Bureau of Meteorology (1961).

weather pattern presents some risk of drought even during what is normally the wettest part of the year. As well as those widespread rains which are associated with trough development, some very heavy falls over large areas result from tropical cyclones reaching the area from nearby oceanic regions.

With the northward return of the intertropical convergence zone during March, maritime influences become weaker and less frequent. Both the incidence of rainy

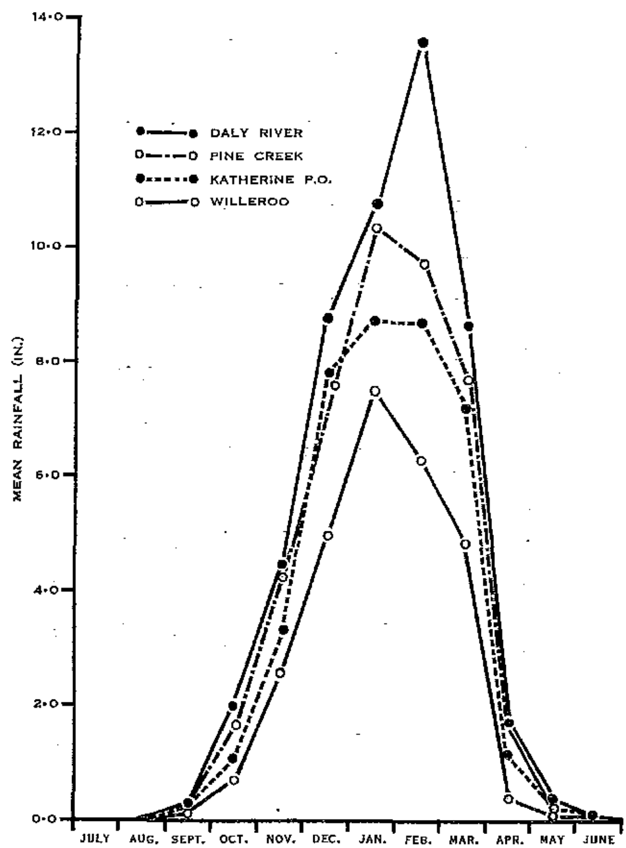

Fig. 3.—Mean rainfall curves for four stations (values adjusted to equivalent 30-day interval).

periods and the amount of rain occurring in them normally decrease rapidly during late March, and this decline continues throughout April. With decreased cloudiness somewhat higher daytime temperatures are typical and occasional thunderstorms at this time impart to the daily weather characteristics not unlike those of the months preceding the establishment of the wet season.

Sustained south-easterly winds and strong continental influences are normally well established in May, bringing the very stable, dry, and sunny weather conditions characteristic of the cooler months of the year.

(c) *General Rainfall Characteristics*

Average rainfall differs considerably over the area as seen from the data given in Table 2 and in Figure 2. Mean annual rainfall increases generally from south-east to north-west, being somewhat less than 30 in. at Willeroo and about 45 in. at Pine Creek and Tipperary homestead. Although the values shown in Figure 2 are the annual means, these also approximate to the mean conditions over the wet season since the drier part of the year is virtually rainless.

Seasonal distribution of rainfall varies very little throughout the area. This uniformity is particularly evident in the time of onset and termination of the "normal" wet season. This is seen in the mean curves shown in Figure 3 for four stations. Over most of the area, the normal rainfall maximum occurs in January. The only exception to this is in the extreme north-west (e.g. Daly River, Adelaide River, and Tipperary), where February has the highest average.

Annual rainfall variability increases from the coast to the interior. The coefficients of variation of annual rainfalls for Daly River, Pine Creek, Katherine, and Willeroo calculated from annual totals over an identical 27-year period are 17·3, 17·2, 20·6, and 27·5% respectively. From these it would appear that over the whole of the north-western half of the area, rainfall variability is relatively low and uniform, whereas over the south-eastern half, variability increases rapidly toward the interior. These measures of variability may be accepted as generally representative of the wet season as well as for the year.

II. Climate, Plant Growth, and Land Use

(a) *General Approach and Method*

From an ecological point of view, the variable nature of rainfall *within* the wet season is of interest as well as the variability of total annual or seasonal rainfall. To assess these variations realistically, data for time units shorter than a month must be considered, and these data must also be interpreted with some view to the changing rates of water use as governed by plant, soil, and climatic factors. With the aid of computer processing, an assessment of the balance between water input (rainfall) and withdrawal (evapotranspiration) on a week-by-week basis over a number of years at several stations is practicable. In the assessment with respect to agriculture, the methods developed by Slatyer (1960) have been adopted in unmodified form. To assess the character of rainfall in relation to pasture growth, a similar approach has been made but a modified water-usage model has been used.

(b) *Rainfall in Relation to Agriculture without Irrigation*

In the absence of stored water for irrigation, crops are necessarily restricted to the wet season. Agricultural operations are best timed to make efficient use of rainfall during the development of the crop and also should, as far as possible, avoid practical difficulties which may be related to the nature of rainfall or some other element. The method of Slatyer as applied here can be considered generally applicable to most annual crops established in the early or middle wet season, and with rooting habit and soil properties allowing up to 4·00 in. of stored soil water to be utilized.

As well as providing a basis for estimating the length of the agricultural growing period, the method includes criteria for estimating the dates on which seed-bed preparation is feasible on heavier soils (ploughing rains) and on which sowing may be carried out (sowing rains). The incidence of water-deficient intervals within the period of crop development can also be assessed.

Evapotranspiration rates which have been assumed in this analysis are expressed in terms of evaporation from a free water surface as observed with the standard Australian tank. Tank evaporation data are available for Katherine Research

TABLE 3

PRIMARY CHARACTERISTICS OF THE ESTIMATED AGRICULTURAL GROWING PERIOD AT FOUR STATIONS OVER THE SEASONS 1910–11 TO 1939–40

	Daly River	Pine Creek	Katherine	Willeroo
Estimated date of ploughing rains				
Mean	Nov. 16	Nov. 16	Nov. 30	Dec. 14
Standard deviation (wk)	3·4	3·2	2·8	3·1
Estimated date of sowing rains				
Mean	Nov. 30	Dec. 7	Dec. 14	Dec. 28
Standard deviation (wk)	2·0	2·8	2·4	3·1
Length of estimated agricultural growing period (wk)				
Mean	22·8	22·2	20·2	14·9
Standard deviation	5·2	3·2	3·6	4·9
Mean number of weeks with accumulated deficit >1·00 in. (within 12 wk following sowing date)	0·5	1·0	2·1	4·4
% of seasons with estimated agricultural growing period >8 wk	97	97	100	90
>12 wk	97	97	100	67
>16 wk	97	70	76	30
>20 wk	73	67	50	17
>24 wk	40	33	17	0

Station. The values used for other stations have been estimated by interpolation from regional maps of mean evaporation constructed from the observations at Katherine and Kimberley Research Stations and at Darwin, and also upon estimates for additional localities where maximum temperature and vapour pressure data were available (Fitzpatrick 1963).

Weekly rainfall data were available over the period 1910-40 for three stations: Pine Creek, Katherine, and Willeroo. Approximately 22 years of data during this period were also available for Daly River. To obtain a valid comparison based upon data from a uniform period, weekly rainfalls for the missing years at Daly River were estimated by assuming a constant ratio between this station and Pine Creek in the manner described by Conrad (1944). From all years having overlapping records, the mean ratio of rainfall (both annual and seasonal) at Daly River to that at Pine Creek was found to be approximately 1·25 to 1·00, and this relationship has been used for estimating rainfall over the missing years at Daly River. Although this procedure gives a better basis for comparison than one which refers to records of unequal length or which represents different years, it must be accepted that the final results obtained for Daly River are somewhat less reliable than those of the three other stations.

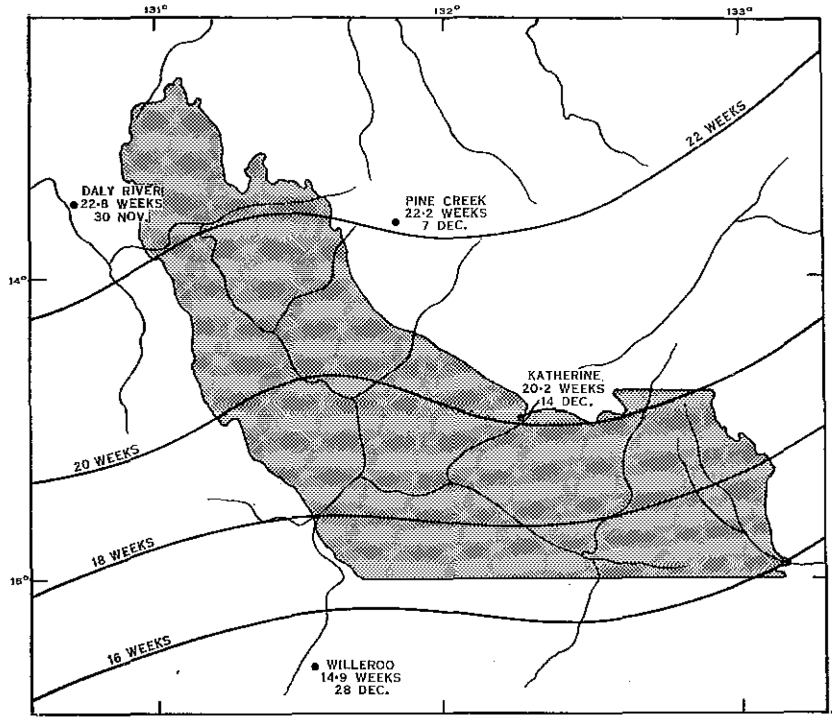

Fig. 4.—Mean length of estimated agricultural growing season.

Primary characteristics of the estimated agricultural growing period determined by these methods are given in Table 3. The values for Katherine differ slightly from those of Slatyer (1960). This is because a shorter period has been accepted here in order to obtain a standard basis for comparison between stations.

Estimated dates of ploughing rains and sowing rains differ by about one month over the area, being earliest in the north-west and latest in the extreme south. The mean interval between estimated dates of ploughing and sowing is about 2 to 3 wk.

The estimated mean length of the agricultural period is shown in Figure 4. This ranges from about 23 wk at Daly River to 15 wk at Willeroo. It is notable that, whereas the mean length differs very little between Daly River and Pine Creek and only by about 2 wk between Pine Creek and Katherine, the difference between Katherine and Willeroo is about 5 wk. Also of interest is the apparent higher season-to-season variability in these lengths at Daly River and Willeroo than in the central part of the area represented here by Pine Creek and Katherine.

The incidence of water-deficient periods within an assumed 12-wk crop development period following the estimated sowing date has also been examined. The values in Table 3 represent the average number of weeks within this 12-wk interval during which the estimated soil water deficit was more than 1 in. below the assumed maximum soil water storage of 4·00 in., including weeks with exhausted soil water reserves. A marked increase in the frequency of these intraseasonal water deficiencies toward the interior is evident. This increase is again greatest between Katherine and Willeroo, and the figures indicate clearly the much greater likelihood of crops being

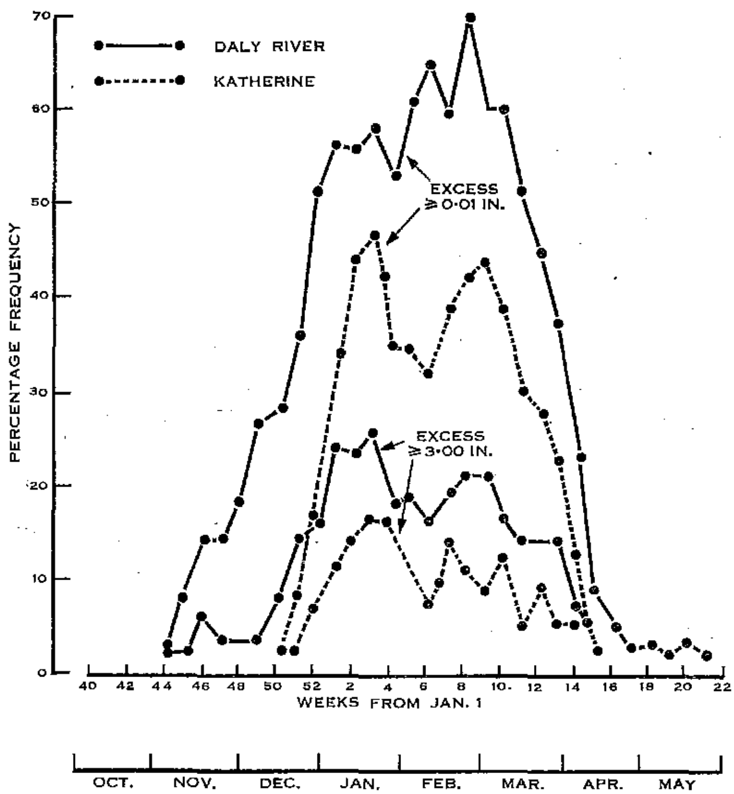

Fig. 5.—Percentage frequency of weeks with water in excess of the assumed maximum available water storage.

subjected to intervals of water stress in this southern part of the area. At Willeroo, these conditions occur on more than one-third of the weeks within the 12-wk interval, but at all other stations the proportion is less than one-sixth.

The percentage of years with an estimated agricultural growing period longer than specified limits may be interpreted as a measure of the assurance that water will be available over a period long enough to allow successful completion of crop development. These values show that, except in the southern part of the area, a 12-wk period can be relied upon. Furthermore, in about 70–75 % of all seasons, agricultural growing periods longer than 16 wk can be expected and at Daly River almost all seasons have estimated periods longer than 16 wk.

It is of interest that the agricultural growing periods as estimated here generally agree well with estimates obtained by the method of Prescott (Anon. 1961) within the higher-rainfall areas to the north-west of Katherine. However, at Willeroo, which may be regarded as representative of the drier parts of the area to the south and east, the mean length of the agricultural period estimated by the methods adopted here is about 4 wk shorter. This lends support to the view of Christian and Stewart (1953) that precipitation–saturation deficit relationships should be regarded with caution in those parts of the area having lower rainfall and higher evaporation.

If extended over some time, excessively wet conditions may be detrimental to crops either directly or through interference with necessary agricultural operations. The agronomic difficulties encountered in this respect depend to a large extent upon existing soil and drainage conditions, but beyond these factors the risk of such conditions occurring is basically a feature of climate. To assess these risks, the frequency of weeks having rainfalls large enough to cause excesses of water beyond the needs of evapotranspiration and the maintenance of the assumed maximum storage has been tabulated for Katherine and Daly River. The percentage frequency of excesses, irrespective of amount (i.e. $>0 \cdot 01$) and greater than $3 \cdot 00$ in., is shown for these stations in Figure 5. The values plotted have been smoothed over running 3-wk intervals. Risk of excesses during the early wet season, when seed-bed preparation and cultivation of young crops are normally carried out, is apparently much greater in the north and western part of the area than in the vicinity of Katherine. This feature may be troublesome from an agronomic point of view, especially on heavier soils. Excesses after the first week in April are very rare over the whole of the area. For both Daly River and Katherine there is some evidence of two distinct periods of maximum risks, one in mid January and the other in late February or early March; however, since the record examined covers only 22 years, it cannot be definitely stated from these data alone that a real condition is in fact represented.

(*c*) *Rainfall in Relation to Pasture Growth*

Although many factors may cause contrasts in the character of pasture growth from one season to another, the effect of differences in soil moisture is very conspicuous. Further experimental work is needed to gain better understanding of the water-use characteristics of native pastures within the area and their response to changes in soil moisture. However, a general interpretation is possible by methods similar to those adopted previously.

A tentative simple working model has been used here. This assumes that evapotranspiration is $0 \cdot 8$ times the tank evaporation for those weeks with storage plus rainfall exceeding $2 \cdot 50$ in., or $0 \cdot 4$ times the tank evaporation when it is below this level. The model is a more generalized version of that used by Slatyer for crops, and is based upon the principle of decreasing evapotranspiration as available water is reduced. The model may tend to underestimate the evapotranspiration when the upper parts of an otherwise dry soil profile are wetted by rains of less than $2 \cdot 5$ in., and overestimate this during weeks without rainfall when stored soil water in the upper profile is nearing depletion. However, the effect of this is not likely to be of great significance for purposes of general assessment over a number of years. A maximum storage of $4 \cdot 00$ in. has again been assumed. These relationships have

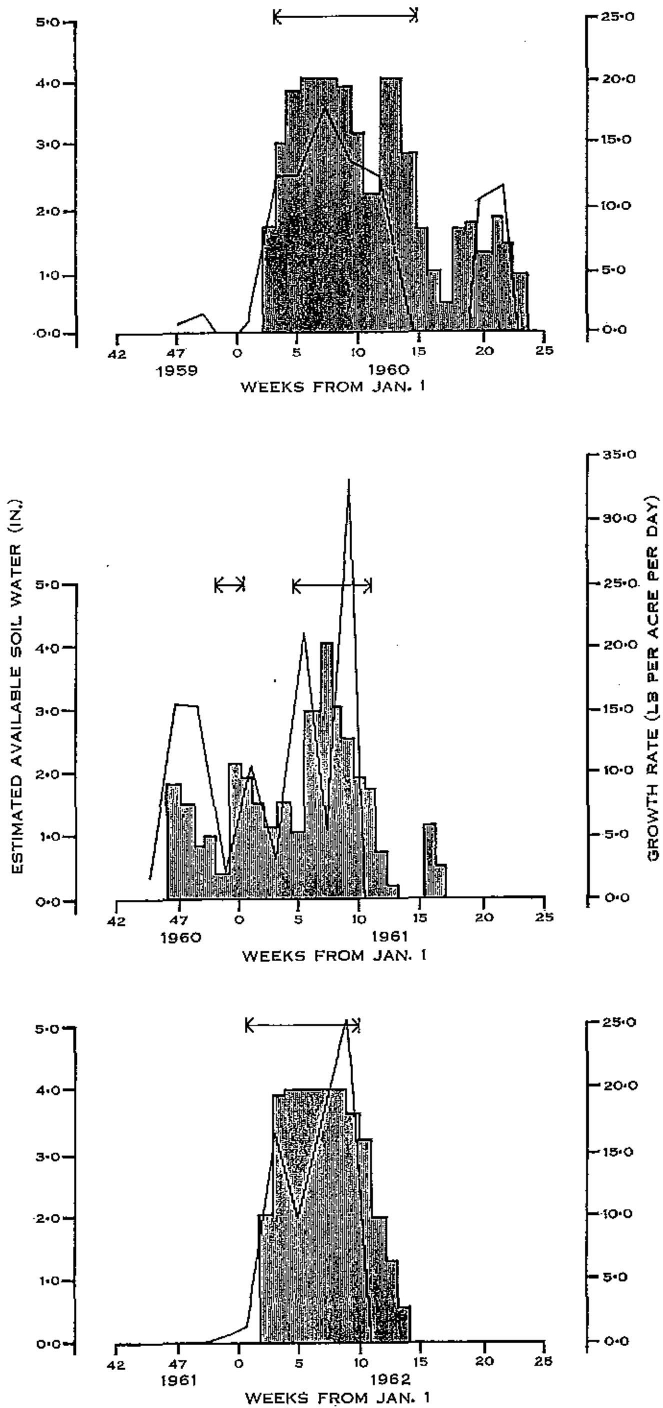

Fig. 6.—Estimated soil water parameters over three seasons at Katherine in relation to observed growth of native pasture. Only positive growth rates are included, and arrows indicate intervals over which estimated storage plus rainfall exceeds 2–5 in.

been used elsewhere (Fitzpatrick and Arnold 1964; Slatyer 1964) for interpreting weekly rainfall data in northern Australia in relation to pasture growth.

In Figure 6 the weekly estimates of available soil water obtained from this model applied with rainfall data for Katherine Research Station are shown in relation to positive increments in the dry-matter yield of native pastures measured at fortnightly intervals over three seasons (Norman 1963). It is seen that in each of the seasons no significant growth occurred before the first week with estimated available soil water, and also that growth in all cases fell sharply during the late-season decline in the estimated weekly values. The periods during which rainfall plus storage was in excess of 2·50 in. (i.e. with evapotranspiration coefficient assumed to be 0·8)

TABLE 4

CHARACTERISTICS OF THE PERIOD OF USEFUL PASTURE GROWTH AT FOUR STATIONS ESTIMATED FROM DATA OVER THE SEASONS 1910–11 TO 1939–40

	Daly River	Pine Creek	Katherine	Willeroo
Commencement of estimated dominant pasture growth period				
Mean date	Nov. 23	Nov. 30	Nov. 30	Dec. 21
Standard deviation (wk)	3·3	3·3	2·7	3·5
Total duration (wk) of estimated useful pasture growth				
Mean	25·2	24·0	22·4	17·7
Standard deviation	2·8	2·8	2·8	3·7
Total duration (wk) of estimated pasture growth with available water exceeding 2·50 in.				
Mean	18·7	16·8	14·5	10·0
Standard deviation	3·0	2·7	3·0	3·8
% of years with estimated total duration of useful pasture growth >8 wk	100	100	100	93
>12 wk	100	100	100	90
>16 wk	100	100	97	67
>20 wk	93	83	77	27
>24 wk	70	50	27	0

represent with reasonable agreement the more active phases of growth. Considering that the growth data reflect complex biological as well as other climatic controls, the number of weeks with available soil water is considered here to give a good approximation of the total period during which some useful growth might be expected, and the more restricted duration with available water exceeding 2·50 in. is taken to represent the length of time over which more active growth conditions prevail. In some seasons, a temporary failure in rainfall may be long enough for existing soil moisture reserves to be depleted. The date of commencement in these cases has been taken to be the middle of the first week of the *dominant* (longest) period.

Results of this analysis are given in Table 4, and a map showing the estimated mean total duration of useful pasture growth is given in Figure 7.

The mean estimated date of commencement of the dominant period of pasture growth occurs in late November over the entire area except in the extreme south where it occurs about 3 wk later. These dates are roughly equivalent to the estimated dates for ploughing given in Table 3.

The estimated mean total duration of growth differs considerably over the area, being about 25 wk in the north-west and about 18 wk in the south. The variability of this parameter is uniform at all stations except Willeroo, where departures from the mean are much larger. Active growth conditions can be expected on the average over about 18 wk in the north-west but only over 10 wk in the extreme south.

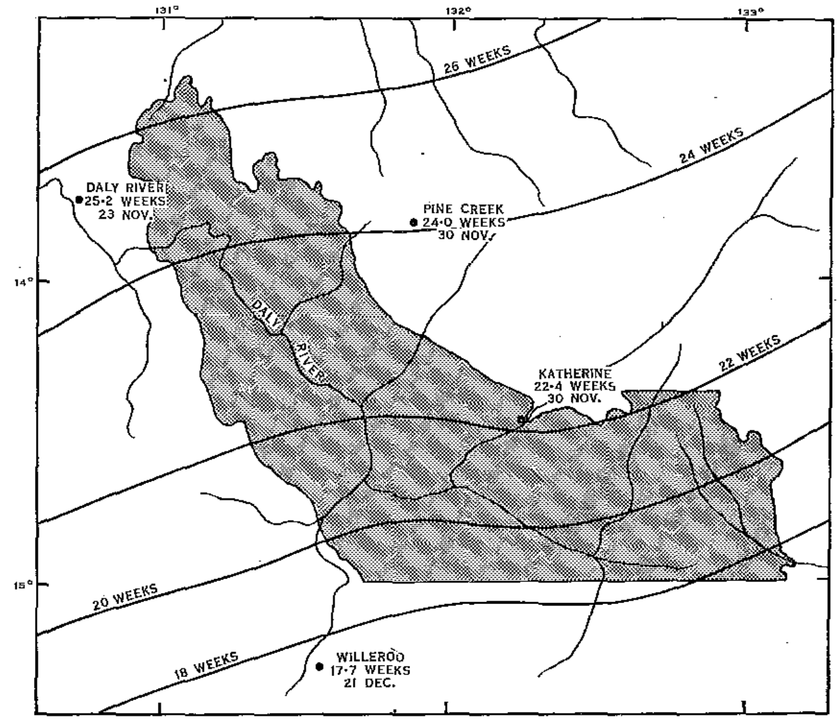

Fig. 7.—Estimated mean total duration of useful pasture growth.

From the percentage frequencies given in Table 4, it can be seen that over all but the driest parts of the area at least a 16-wk period of useful pasture growth is assured. The marked contrast between the conditions for growth in the better-watered areas of the north-west and those in the drier interior portions is clearly evident in the percentage of seasons with an estimated total duration of useful pasture growth exceeding 24 wk.

(*d*) *Irrigated Agriculture*

With irrigation, crop yields may be increased by eliminating periods of acute water stress which occur during the wet season, and cropping may be extended into the dry season. Water requirements for these purposes are therefore of interest even though irrigation agriculture is not a significant feature in the existing land use.

To obtain estimates of these irrigation requirements, methods similar to those used previously for rain-dependent agriculture have been applied, using data for Katherine. The models employed have, however, been modified so that the estimates obtained are more appropriate to crops having an active growth period extending over 16 wk. Estimates are obtained on the assumption that crops would be established either before or after the normal wet season. It is realized that an initial period of pre-irrigation may be necessary to facilitate land preparation on heavier soils, but the quantity of water required for this purpose will depend strongly upon physical soil properties. To assess the variable nature of supplementary irrigation needs with wet-season cropping, the analysis has been applied using actual weekly rainfalls for all seasons between 1910–11 and 1939–40. For irrigated dry-season crops, it has

TABLE 5

WET-SEASON IRRIGATION CHARACTERISTICS AT KATHERINE AND KUNUNURRA

Seasonal Irrigation Need	Katherine	Kununurra*
Mean seasonal need (in.)	3·5	8·6
Standard deviation (in.)	2·3	3·1
Highest in one season (in.)	7·2	15·7
Lowest in one season (in.)	0·6	3·8
Mean number of weeks in one season having irrigation need	5·0	9·0
Smallest number of weeks in one season having irrigation need	1 (in 2 cases)	6 (in 3 cases)
Largest number of weeks in one season having irrigation need	10 (in 1 case)	13 (in 1 case)

* Data for Kununurra are from daily rainfall records at Ivanhoe and Kimberley Research Station. All of these stations are within 9 miles of each other.

been assumed that rainfall during the 16-wk growth period following planting (in late April) would be nil. The methods adopted here are those used by Fitzpatrick and Arnold (1964) except that the pre-irrigation requirement is not included in this case.

Estimates relating to supplementary irrigation requirements for a wet-season crop at Katherine are set out in Table 5. With these are given the comparable values for Kununurra. The mean of the total supplementary irrigation over the 30 years is 3·5 in., or approximately 5 in. less than the mean estimated requirement at Kununurra. As seen from the table, both the number of weeks over which irrigation would be required and the total seasonal amount differ greatly from year to year. It would appear that at Katherine in the most favourable seasons (i.e. from the point of view of overall water economy) no supplementary irrigation would be necessary even where crops of long growing period are considered. On the other hand, supplementary irrigation estimates for the least favourable seasons indicate a need of about 7 in. Although this is less than half the estimated amount during the least favourable seasons at Kununurra, it seems likely that crop yields would benefit substantially under such conditions by irrigation practice.

Assuming that 2 in. of stored soil water would be available after the wet season, the estimated total irrigation requirement at Katherine for a crop sown during the last week in April and irrigated over 16 wk thereafter is about 20 in. This compares with 23 in. at Kununurra.

It is important to note that all the estimates given here represent only the actual water usage of the crop. They do not include losses which may result from inefficiencies in the irrigation system employed, and further allowance would have to be made for pre-irrigation as needed under existing soil conditions.

III. Acknowledgments

All preparation of the data for computer processing and other calculations upon which this study is based have been carried out by Mrs. A. Komarowski. The author wishes to express his appreciation for this assistance.

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PART V. GEOLOGY OF THE TIPPERARY AREA

By J. A. MABBUTT*

I. INTRODUCTION

The area has been geologically mapped and described by Noakes (1949), Malone (1962), and Randall (1962, 1963) and references to structure and lithology in this report are largely based on their work. The stratigraphic succession is given in Table 6.

II. GEOLOGICAL HISTORY

The Tipperary area is almost conterminous with a structural entity, the Daly River basin, and its boundaries are mainly drawn on the limits of an associated geological unit, the Daly River group. Where the survey area locally extends onto older rocks, land systems have been mapped as in the earlier Katherine–Darwin survey (Christian and Stewart 1953) but have not been described; e.g. in the east, Volcanics land system occurs on gently dipping sandstone and basalt of Upper Proterozoic age.†

The sedimentary history of the Daly River basin begins in the Upper Proterozoic, following the folding, and intrusion by the Cullen granite, of the trough sediments of the Pine Creek geosyncline, which limits the basin on the north-east. It was this folding which imparted to the basin its north-westerly structural trend; no later orogeny has significantly affected the region, and younger rocks are everywhere relatively undisturbed.

The early phase of Upper Proterozoic sedimentation was followed by uplift and vulcanicity during the Lower Cambrian, with the extrusion of the basaltic Antrim Plateau volcanics which generally form the western limit of the Daly River basin.

The Daly River group was then laid down with slight unconformity on the lavas and sediments, overlapping onto the Cullen granite in the north-east. It consists of limestone, sandstone, and siltstone formed in shallow water in the subsiding basin. In general, these rocks have gentle depositional dips, with slump structures and minor faults.

Following the deposition of the Daly River group the region underwent general uplift and planation prior to complete inundation by the Cretaceous sea. Sandstone, siltstone, and minor conglomerate of the Lower Cretaceous Mullaman beds then accumulated. With the exception of local intraformational folding, these formed a subhorizontal sheet.

Regression was followed by renewed planation, and the oldest land surface elements—plateau surfaces preserved only on the Mullaman beds—truncate local Cretaceous structures.

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†Small areas of Waterbag Creek formation in the west of the region are mapped in Wriggley land system.

TABLE 6

STRATIGRAPHIC COLUMN IN THE TIPPERARY AREA AND ALONG ITS BORDERS

Age	Rock Unit	Lithology	Thickness (ft)	Structure
Lower Cretaceous	Mullaman beds	Undifferentiated marine and minor freshwater sandstone, siltstone, and conglomerate. Lateritized	200	Horizontal with minor intraformational folds
		Unconformity		
Middle Cambrian (Daly River group)	Oolloo limestone	Silicified limestone	100–200	Shallow depositional dips
	Jinduckin formation	Medium- and fine-grained sandstone and siltstone	200	
	Manbulloo limestone member	Silicified flaggy limestone lenses in Jinduckin formation	200	
	Tindall limestone	Limestone with chert bands and nodules	500	
		Unconformity		
Lower Cambrian	Antrim Plateau volcanics	Mainly basalt with some tuffaceous sandstone	100–200	Very gentle dips; minor faults
		Unconformity		
Upper Proterozoic (Mt. Rigg group)	Beswick Creek formation	Sandstone, chert, siltstone, and basalt		Gentle dips, mainly depositional
		Not in contact		
	Waterbag Creek formation	Ferruginous sandstone and siltstone with limestone lenses	500	
	Hinde dolomite	Dolomite	200	
(Tolmer group)	Buldiva sandstone	Mainly quartz sandstone	2000	
		Unconformity		
Lower Proterozoic (Agicondian system)	Cullen granite	Grey to pinkish grey or red, coarse-grained, massive or gneissic rocks		
	Burrell Creek formation	Siltstone, greywacke, and greywacke siltstone	8000	Broad folds

III. Geology and Land Systems

As described below under landscape history, the present land systems result from partial removal of the Mullaman cover and staged planation on the rocks of the Daly River group, complicated by deep lateritic weathering.

The partial survival of the Mullaman beds accounts for the distribution of major relief within the basin, since it is on these beds that the high plateau surfaces are preserved, largely near the margins of the basin, particularly in the south-west, and also north of Maranboy police station in the east. In the centre and south-east, they form low plateaux and undulating terrain.

Overall geological structure has had an important control over major land forms. For instance, the horizontal bedding of the Mullaman beds is expressed in the plateau forms, whilst the gentle basinward dips on the underlying rocks and their relatively unresistant character have aided planation within the Daly River basin so that the structural entity accords closely with the drainage catchment.

Differences between rock units have played little part in the determination of land systems formed on the Daly River group, and the relief differences on which these land systems are delimited are more closely related to stages in the geomorphic evolution of the region than to lithological contrasts.

Apart from the absence of major contrasts in resistance to erosion within the Daly River group, there are two additional reasons why original lithology has exercised little control over land system patterns. The first is the widespread deep lateritic weathering which occurred during the late Mesozoic and Tertiary eras. As a result, bed-rock contrasts at the surface have been masked by widespread ferruginous duricrusts and related mantles, whilst associated silicification has subsequently controlled resistance to erosion offered by the lower weathering zones. Porcellanites have formed in fine-grained rocks, generally in the lower pallid zone, and quartzites have formed at still lower levels near the weathering front, probably in suitable arenaceous horizons (Wright 1963). These silicified horizons have exercised important control on erosion within and beneath the Cretaceous cover rocks.

Exposure of the quartzitic horizon has left tors of various sizes on stripped surfaces. Previously, many such silicified rocks of the Daly River group may have been mapped in error as relict Mullaman beds.

A second reason why bed-rock lithology has played little part in land system determination is to be found in the widespread cover of superficial deposits. These include not only the alluvial plains flanking the main rivers (about 10% of the area), but also the widespread mantles of colluvial–alluvial origin on lower erosional plains (25% of the area) and the mantle of lateritic detritus in areas of less advanced planation (20% of the area). Areas in which unweathered bed-rock is extensively exposed are confined to the youngest lowlands, which probably amount to only 20% of the area.

Below the land system level are to be found differences induced by the major lithological contrast within the Daly River group, namely between the mainly siliceous Jinduckin formation and those formations which consist predominantly of limestones. The Jinduckin formation is associated with terrain in which areas of shallow fine sandy clay soils broadly alternate with extensive tracts of low rock outcrop. In contrast, the limestones have weathered unevenly, and relatively deep pockets of fine-textured soil give place abruptly to irregular rocky surfaces.

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PART VI. GEOMORPHOLOGY OF THE TIPPERARY AREA

By R. L. WRIGHT*

I. INTRODUCTION

The survey area, which was termed the "Daly River basin" by Christian and Stewart (1953), mainly comprises the inland three-quarters of the Daly River catchment in the Northern Territory. It consists of remnants of ancient plains with associated deep weathered mantles, together with younger plains and dissected tracts in which the weathered mantles have been truncated or removed and the underlying fresh rock has been exposed locally. Consequently, the area contains a wide range of erosional and depositional sites of differing ages, formed in a variety of weathered and relatively fresh parent materials, which occur in characteristic assemblages—land systems—with an associated cover of soils and vegetation.

This account aims to provide the geomorphological basis for an understanding of the land systems. It begins with a regional description of the area followed by an outline of active land-forming processes. Then follows a summary of the evolution of the physical landscape, which forms the framework for the genetic classification of the land systems. The geomorphology of the land systems is then summarized.

II. GEOMORPHIC REGIONS

The area has been divided into two geomorphic "provinces" (Fig. 8), each with characteristic major relief due to the survival of the Cretaceous cover in one province and to the removal of this cover exposing the underlying Cambrian rocks in the other province. The provinces can be subdivided into geomorphic "regions" which, although embracing a diversity of rock types, have a unity of relief which is expressive of a unity of geomorphic history.

(a) *Daly Plateaux Province*

This province is mainly underlain by lateritized Cretaceous rocks and it forms most of the south and east of the survey area. Its margins consist of high sandy plateaux, mainly between 800 and 1000 ft above sea level, and its central parts comprise mainly sandy low plateaux and undulating terrain which decline along the Daly River from 700 ft in the south-east to about 250 ft above sea level in the north-west. The province contains five regions.

(i) *Western High Plateaux*.—This region comprises extensive gently sloping plateaux, with rocky escarpments up to 400 ft high, and broad valley plains. It forms the divide between drainage to the Daly River and that which flows west to the Joseph Bonaparte Gulf.

(ii) *Eastern High Plateaux*.—Only the southern part of this region is included in the survey area. It consists of a broad plateau surface which falls gently southwards to marginal rocky surfaces and escarpments, and it is distinguished from the

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western high plateaux by less relief and by the absence of valley plains. Drainage is deeply entrenched up to 250 ft in narrow valleys. The region forms the northern part of the divide between Daly River drainage and that which flows east to the Gulf of Carpentaria.

(iii) *Eastern Low Plateaux.*—This region consists of gently undulating plateaux with discontinuous rocky escarpments up to 60 ft high, and marginal, slightly lower, sandy undulating terrain with relief up to 50 ft. It lies at the head of the basin,

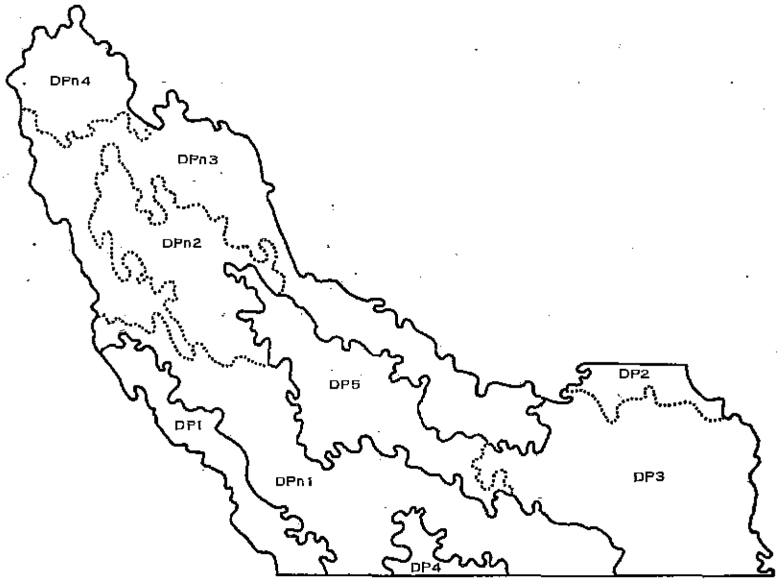

Fig. 8.—Geomorphic regions.

Daly Plateaux Province		*Daly Plains Province*	
DP1	Western high plateaux	DPn1	Southern plains
DP2	Eastern high plateaux	DPn2	Central plains
DP3	Eastern low plateaux	DPn3	Northern plains
DP4	Southern low plateaux	DPn4	Northern benchlands
DP5	Central low plateaux		

forming the southern part of the divide between drainage west to the Daly River and that which flows east to the Gulf of Carpentaria, and extends southwards beyond the survey area.

(iv) *Southern Low Plateaux.*—This region comprises gently undulating plateaux with rocky, marginal surfaces dissected up to 100 ft. It extends south beyond the limits of the survey area.

(v) *Central Low Plateaux.*—This is the most varied of the regions. It consists of stony plateaux interspersed with lower sandy or stony undulating terrain and restricted sandy plains, and relief is mainly less than 100 ft. The lower Fergusson and Katherine Rivers flow across the region in narrow alluvial plains.

(*b*) *Daly Plains Province*

This province is formed on both relatively unweathered and lateritized Cambrian rocks, locally with remnants of the Cretaceous cover. It mainly comprises extensive plains and undulating terrain which are drained by the Daly River and its main tributaries and which decline from about 650 ft in tributary headwater areas to less than 100 ft above sea level downvalley. In addition, minor plateaux up to about 900 ft above sea level occur in the north of the province. It contains four regions.

(i) *Southern Plains*.—This is the most complex region in the Daly plains province. It mainly consists of plains of residual soils in the upper sectors, plains characterized by outcrop in the lower parts, and sandy or stony undulating tracts forming low divides. In addition, narrow alluvial plains occur along the main rivers and there are minor stony plateaux in the west. Relief is mainly less than 30 ft but is locally up to 100 ft. The region is traversed along much of its length by the lower King River which is tributary to the Katherine River in the north-west.

(ii) *Central Plains*.—These comprise broad sandy plains and gently undulating terrain with relief generally less than 30 ft. Low stony plateaux occur locally. Stray Creek crosses the region to join the Daly River, which trends north-westwards through the western part.

(iii) *Northern Plains*.—Stony plains and undulating terrain characterize this extensive region. However, restricted cracking clay plains occupy the lower parts in the north, narrow flood-plains occur along the main rivers, and minor sandy undulating tracts form low divides. Relief is mainly less than 30 ft. The region is drained by the lower Daly River and the Douglas River in the west and by the subparallel middle sectors of Stray Creek, the Fergusson River, and the Katherine River in the east.

(iv) *Northern Bench Lands*.—Residual soils occur extensively in this region, which consists of valley plains, slightly higher undulating terrain, and restricted low and high plateaux. Broad alluvial drainage floors descend southwards. Relief is mainly less than 50 ft but the plateaux are locally dissected up to 300 ft.

III. Active Land-forming Processes

Under the tropical savannah climate which prevails in the survey area, chemical decay is the dominant weathering process and rock breakdown and the secondary comminution of debris are relatively rapid.

Active erosion is confined to two main landscape situations—hill slopes and the main rivers. Hill slopes are of two types: those formed in deep lateritic weathering profiles on the margins of the main valleys, and those eroded in relatively unweathered rock in the central parts. Hill slopes of the first type comprise steep escarpments with resistant ironstone or silicified pallid-zone rock exposed in upper faces, but with complete boulder mantles below. There is normally a gentle, concave slope break at the hill foot and a rapid transition from the coarse hill-slope debris to the fine detritus on the adjacent plain. Hill slopes of the second type, which are associated with strongly incising streams, are commonly smooth and rounded, and only the most pronounced lithological differences are etched out. Colluvial mantles indicate that the rate of waste production here generally exceeds the rate of removal. However, hill slopes of this type on limestone are characteristically steep and rocky, with a relatively sharp slope break at the hill foot to gently sloping plains. This is probably due to the importance of rock solution, particularly at the base, where poor drainage is evidenced by the presence of shallow cracking clay depressions between the hill foot and the characteristic red soil of the plains.

The main rivers are perennial but are subject to considerable fluctuations of level as testified by high flood banks. However, debris lines indicate that the levees are rarely topped, and mature levee and back plain soils testify to the relative unimportance of overbank deposition. Channels are relatively narrow—mainly up to 200 yd wide and locally up to 300 yd—and follow angular courses with remarkably straight sectors up to 2½ miles long, separated by sharp inflexions. The channels are confined between steep alluvial banks up to 60 ft high and are in most cases actively incising into bed-rock.

Extensive, gently undulating plains occur between the two main erosional zones. Run-off in these plains is low because of gentle slopes and sandy mantles. This is corroborated by the stability and maturity of the soil surfaces and is reflected in the poor development of tributary streams. It would appear that the plains are naturally relatively stable even during exceptional rains, probably because of the protective cover of natural vegetation. However, destruction of the vegetation cover quickly results in vigorous sheet erosion and gullying.

It is evident that a large part of the area consists of inherited land forms such as staged, old erosion surfaces with relict soils and fossil deep-weathering profiles. Furthermore, as will be seen, the achievements of each older stage have influenced subsequent achievements of landscape formation. Therefore, the present landscape can only be fully understood in terms of its geomorphic history, which is outlined below.

IV. History of the Physical Landscape

(a) *Bradshaw Planation and Deep Weathering*

The oldest landscape element in the survey area is that termed the Bradshaw surface (Wright 1963), and it survives as plateau summits more perfectly planed than younger erosion surfaces, forming main divides in the eastern high plateaux, western high plateaux, and northern bench lands. In the areas referred to, the surface is mainly between 850 and 1000 ft above sea level with marginal escarpments up to 400 ft high; it slopes gently towards the major valleys, and dissected outliers occur at about 400 ft above sea level in the central part of the basin.

The nature, distribution, and altitudinal relationships of remnants of the Bradshaw surface suggest that it originally consisted of an extensive, very gently sloping plain with broad undulations and with an internal relief of up to 200 ft, and that the Daly River and its major tributaries already occupied broad, shallow valleys within it.

In this area the Bradshaw surface is everywhere preserved on the Cretaceous rocks, and the occurrence of these relatively unresistant, flat-lying strata appears to have facilitated its formation and perfection. However, the Bradshaw surface bevels these beds in the north of the area where they are locally moderately to strongly dipping.

Deep weathering, typically to a depth of 150 ft, is associated with the Bradshaw surface. The profile consists of between 10 and 20 ft of pisolitic ironstone which becomes vermicular or nodular and concretionary in the lower parts, overlying up to 40 ft of mottled zone and 100 ft of pallid zone. Throughout the area, Bradshaw weathering has extended through the Cretaceous rocks into the underlying strata. Thus, in the north much of the pallid zone is in Lower Proterozoic greywacke and siltstone, and elsewhere the lower part of the pallid zone is formed in the Cambrian rocks.

Wherever observed, the lower part of the Bradshaw pallid zone was strongly silicified, forming porcellanite and quartzite. The porcellanite is characteristically developed in the Cretaceous beds but also in the Cambrian succession. In many areas it is underlain by the quartzite which occurs both in the basal part of the Cretaceous and also in the Cambrian succession. The quartzite was always seen to be underlain by the Cambrian calcareous rocks.

(b) Maranboy Planation and Reweathering

During a subsequent stage of erosion the Bradshaw surface was stripped of the upper, less silicified parts of the pallid zone and a lower surface, separated from the Bradshaw surface by prominent escarpments, was produced. This lower surface is termed the Maranboy surface.

The most likely cause of this dissection of the Bradshaw surface is uplift. Such uplift would have been greatest in the north of the area, since here the Bradshaw surface has been most extensively destroyed, and because only in the north has the Maranboy surface been cut below the Bradshaw weathering front. Such uplift may have been a reactivation of the movements which locally tilted the Cretaceous strata in the north of the area, prior to their truncation and deep weathering during the Bradshaw stage of erosion.

The Maranboy surface has been extensively stripped and now survives as either broad, gently undulating, secondary divides with extensive areas of relict lateritic soils, or low plateaux and interfluve crests commonly with stony surfaces. Related rock-cut terraces continue up the larger tributary valleys as valley-side benches, remnants of which also survive as accordant spur and hill crests. Maranboy remnants characterized by relict soils occur extensively at about 700 ft above sea level in the eastern low plateaux region. The stony Maranboy remnants are common in the southern low plateaux and central low plateaux regions, and they also survive locally in the Daly plains province.

The Maranboy surface carries up to 10 ft of ironstone which is pisolitic in the upper parts, nodular and concretionary below, and characteristically has a sandy matrix. The ironstone is partly detrital and contains angular, broken fragments of recemented ironstone and inclusions of pallid-zone rock. Except in the north, the ironstone is underlain by between 60 and 100 ft of Bradshaw pallid-zone rock which has undergone reweathering and desilicification to a depth of between 30 and 60 ft.

This reweathered pallid-zone rock is commonly powdery in argillaceous rocks and crumbly and honeycombed in coarser rocks, with secondary iron enrichment in the upper parts. In the north the ironstone is underlain by between 30 and 40 ft of weathered Cambrian sandstone, siltstone, and limestone.

The occurrence of a Maranboy lateritic weathering profile, both within and locally below the Bradshaw weathering profile, suggests that during the Maranboy stage of erosion the climate was probably similar to that which prevailed earlier. However, the fact that the Maranboy profile is shallower than the Bradshaw profile suggests that the period of Maranboy weathering was shorter.

(c) *Tipperary Etch-planation*

The Maranboy surface was in turn dissected during a third stage of erosion and an extensive younger erosion surface, the Tipperary surface, was produced. Little can be said concerning the cause of this dissection, although it implies rejuvenation of drainage throughout the basin. The Tipperary surface is separated from the Maranboy surface by low, discontinuous escarpments or by dissected undulating or hilly terrain. It comprises three main types of terrain. For the most part it consists of broad plains extending downslope from the foot of Bradshaw and Maranboy escarpments and their flanking dissected tracts, which have formed mainly by the stripping of the Maranboy reweathered layer from the unaffected Bradshaw silicified rocks beneath. Tors up to 30 ft high of rounded boulders occur locally at the foot of Maranboy escarpments and in the plains downslope. Such tors consist mainly of the quartzite from the Bradshaw profile beneath the pallid zone, left by the removal of the surrounding weathered material.

A second type of Tipperary terrain, occurring within the plains, consists of gently undulating surfaces with relief mainly less than 30 ft, in which remnants of Maranboy leached pallid-zone rock — locally with ironstone detritus — survive on the low crests.

The third type comprises headwater valley floors, occurring in the west and north of the area, which grade downvalley into the plains which extensively characterize the Tipperary surface. These floors are up to 200 ft below terrace remnants of the Maranboy surface and are hence cut below the level of prior weathering.

Weathering on the Tipperary surface has mainly resulted in the formation of red and yellow, locally lateritic, earths developed from unweathered rock in the headwater valley floors. Such weathering is shallow or negligible in comparison with the depths of Bradshaw and Maranboy weathering. Therefore, it is possible that the climate was drier during the formation of the Tipperary surface, for the extent of the surface suggests that there may otherwise have been sufficient time for at least some lateritic profile development in excess of that which has occurred locally.

(d) *Post-Tipperary Dissection and Deposition*

(i) *River Rejuvenation and Hill Slope Instability*.—This substage was initiated by rejuvenation of the rivers and downcutting into the Tipperary surface. The Daly River became entrenched up to about 40 ft in its lower sectors, downstream from

Banyan Farm homestead, and up to about 60 ft in the middle sectors. Drainage rejuvenation also reached the headwater valley floors of the Tipperary surface, which were dissected up to 30 ft.

This dissection is likely to have been caused by uplift which appears to have been greatest in the north of the area since dissection has been strongest and most widespread here. Whilst dissection was mainly limited to drainage incision throughout most of the area, extensive planation occurred along the northern margins of the basin where stony outcrop plains and undulating terrain were formed. However, limited planation also occurred along the King River and other southern tributaries of the Daly River.

River gravels were subsequently deposited in the entrenched valleys. These gravels are up to 15 ft thick along the Daly River and are commonly between 6 and 8 ft thick in tributary channels. However, up to 12 ft of gravels were deposited in headwater tributaries in the south and east of the area. The gravels were then lateritized, and therefore the climate during the early part of this substage was relatively humid.

Subsequently the climate became drier resulting in a reduced vegetation cover and inducing conditions of surface instability. This led to the movement of weathered material on slopes and to a reduction in the competence of streams to carry away the derived material. Thus, relatively uniform colluvial mantles, commonly more than 10 ft thick, formed extensively on the Tipperary surface.. In the higher parts of the gently undulating tracts in this surface and in the dissected headwater valley floors, the material is mainly medium- to coarse-grained and contains broken, derived lateritic concretions; downslope on the plains it is characteristically fine- to medium-grained and grades into alluvial plains which formed extensively in the south-eastern part of the area and locally elsewhere.

In addition, deep sandy fills accumulated in the entrenched valleys. These fills are up to 40 ft thick along the Daly River and its main tributaries, and up to 10 ft thick in headwater areas.

During the latter part of this substage the sandy valley fills were calcreted in the extreme south-east of the area, and solonetz-like soils with columnar structure formed in the main valley floors elsewhere.

(ii) *River Rejuvenation and Alluvial Deposition.*—This substage was initiated by moderate rejuvenation of the rivers which led to shallow entrenchment — probably no more than 10 ft — into the sandy alluvia of the valley floors. Up to 6 ft of river gravels were then deposited along the Daly River but only locally in tributary floors. A change to a wetter climate is a possible cause of this rejuvenation and this postulate is supported by the fact that the gravels are lateritized.

Flood-plain deposition then occurred along the main rivers. This deposition was greatest along the Daly River downstream from its confluence with the Katherine and Flora Rivers, and here the sandy alluvium of the first substage was completely buried by up to 50 ft of younger deposits downvalley as far as Banyan Farm homestead. Downstream from here the older alluvium remained exposed along the margins of the flood-plains. These resultant younger flood-plains comprise narrow sandy levees and gently sloping, finer-textured back plains of irregular width.

The older alluvium was also completely buried by younger, mainly fine-textured deposits in the southward-flowing drainage floors which are tributary to the lower Daly and Douglas Rivers in the north of the area; but relatively little deposition occurred along tributary streams in the south and east of the area, where narrow levees formed locally within the existing broad alluvial floors.

(iii) *River Rejuvenation*.—Subsequently a further climatic change led to increased run-off and to drainage rejuvenation of much greater magnitude than that of the previous substage, and the rivers are actively incising at the present day. The Daly River is narrowly entrenched up to about 60 ft through the alluvium and is cutting into bed-rock in many areas. This rejuvenation has extended along headwater tributaries which are commonly incised up to 20 ft through alluvium and into bed-rock.

Restricted levees and alluvial flats are, however, forming below the level of the older flood-plains along the lower Daly River downstream from Banyan Farm homestead.

(*e*) *Denudation Chronology*

There is little evidence for the ages of the surfaces described. Clearly the Bradshaw surface is post-Lower Cretaceous. The alluvial–colluvial mantles described as overlying the Tipperary surface, together with subsequent phases of river rejuvenation and deposition, may have resulted from climatic fluctuations similar to those dated as Pleistocene and later in other parts of Australia. Accordingly, the Tipperary surface is regarded as mainly pre-Pleistocene. The shallowness of dissection of the Tipperary surface and the limited extent of the younger surfaces formed below suggest that the latter are geologically extremely young.

V. Geomorphology of the Land Systems

The foregoing geomorphic history forms a basis for a classification of the land systems into five erosional classes and one depositional class. The erosional land systems are classified according to whether they form part of, or have been produced by dissection of, the Bradshaw, Maranboy, and Tipperary surfaces. Where the classes embrace a wide range of land forms they are subdivided according to these land forms and listed according to amount of relief. The depositional land systems are subdivided according to the characteristics and proportions of the different deposits.

In this way the relationships of inherited land forms to their soil and vegetation cover are made clear.

(*a*) *Plateaux Formed by Dissection of the Bradshaw Surface*

This class is distinguished by extensive remnants of the Bradshaw surface which carry a characteristic, relatively uniform, soil–vegetation cover. The uniformity of this cover is expressive of the stability of the Bradshaw surface and is probably due to its perfection.

There is only one land system in this class and it contains the strongest relief in the area.

(1) *Mullaman land system* consists of extensive, gently sloping plateaux, underlain by deeply weathered sandstone and siltstone, with narrow valleys entrenched up

to 400 ft. Marginal rocky surfaces and high escarpments are characteristic. It forms main divides and is extensive in the eastern high plateaux and western high plateaux regions.

(b) *Land Systems Formed by Dissection of the Maranboy Surface*

This and the succeeding class of land systems have a unity within the diversity of erosional and depositional sites produced by dissection of the Maranboy surface. These sites range from intact Maranboy remnants with their associated relict lateritic soils to stony erosional sites on ironstone or weathered rock, soil-covered erosional sites mainly underlain by weathered rock, and depositional sites formed in sandy lateritic detritus; and each has a characteristic soil–vegetation cover.

The land systems of this class form secondary divides consisting of low plateaux, undulating terrain, and plains, mainly occurring in the low plateaux regions of the Daly plateau province. They are distinguished from the succeeding class in that intact or lightly stripped remnants of the Maranboy surface are extensively preserved, and in that they are mainly underlain by deeply weathered sandstone and siltstone.

(i) *Plateaux and Undulating Terrain.*—The two land systems in this group are characterized by stony crests and sandy lower slopes. Differences between the land systems appear to be related to differences in the amount of dissection. Relief is mainly between 25 ft and 100 ft but locally attains 200 ft.

(2) *Yujullowan land system* consists of strongly dissected stony plateaux with restricted lower slopes.

(3) *Yungman land system* consists of moderately dissected undulating terrain with marginal hill lands, and is distinguished by extensive lower slopes.

(ii) *Plains.*—There is only one land system in this group.

(4) *Maranboy land system* comprises intact or lightly stripped plains with extensive, relict lateritic soils. Relief is up to 10 ft.

(c) *Undulating Terrain Eroded between the Maranboy and Tipperary Surfaces*

This class of land systems is distinguished from the previous class by the almost entire destruction of the Maranboy surface and by relatively unweathered rock locally exposed in lower slopes. It consists of undulating terrain with relief up to 100 ft, in which sandy upper slopes with minor outcrop and lateritic detritus are characteristic. The individual land systems are mainly distinguished according to the nature of the lower slopes, which carry either derived or residual soils, the latter varying with lithology. They occur mainly in the central low plateaux region and in the Daly plains province.

(5) *Beemla land system* is distinguished by restricted lower slopes cut in limestone.

(6) *Jindara land system* has extensive lower slopes masked with colluvium, and limestone occurs at or near the surface in some areas.

(7) *Woggaman land system* is distinguished by minor lateritic plateaux remnants, by sandy valley fills, and by restricted alluvial plains in the lowest sectors.

(8) *Wallingin land system* consists of stony upper slopes with extensive, sandy valley fills.

(9) *Chinaman land system* is distinguished by steep rocky upper slopes and by residual and alluvial cracking clays in the lower parts.

(*d*) *Land Systems Forming Part of the Tipperary Surface*

These land systems consist of the headwater valley floors, the gently undulating terrain, and the extensive plains of the Tipperary surface. Relatively uniform, sandy colluvial–alluvial mantles are widespread, and there are local exposures of strongly silicified and deeply weathered, or relatively unweathered, sandstone, siltstone, and limestone.

(i) *Undulating Terrain*.—There is only one land system in this group.

(10) *Claravale land system* consists of gently undulating terrain with sandy or stony crests, scattered low bouldery hills, and sandy lower slopes. Relief is mainly less than 30 ft. It occurs in the central low plateaux and in the central and southern plains regions.

(ii) *Plains*.—Gently sloping plains with relief less than 10 ft constitute this group of land systems.

(11) *Wriggley land system* consists of the headwater valley floors of the Tipperary surface and it is distinguished by plains of residual soils formed on relatively unweathered rocks. It occurs in the northern benchlands, southern plains, and western high plateaux regions.

(12) *Blain land system* constitutes the greater part of the Tipperary surface and is characterized by deep sandy mantles. It occurs extensively in the central plains region and locally in the southern plains and central plateaux regions.

(13) *Douglas land system* consists of the lower parts of the Tipperary surface flanking the Douglas River. Shallow, cracking clay depressions are general.

(*e*) *Land Systems Eroded below the Tipperary Surface*

This class of land systems consists of undulating terrain and plains cut in relatively unweathered limestone, sandstone, and siltstone, and it mainly occurs in the northern plains region. Erosional slopes with scattered outcrop are characteristic.

(i) *Undulating Terrain*.—The two land systems in this group consist of undulating terrain with relief up to 50 ft, comprising relatively steep rocky slopes and gentle lower slopes with discontinuous soil covers. Differences between the two land systems appear to be due mainly to differences in rock type.

(14) *Tagoman land system* comprises rounded hills with sandy or rocky crests and extensive gently undulating lower slopes. It is formed on sandstone, siltstone, and limestone.

(15) *Budbudjong land system* is distinguished by scattered steep-sided limestone hills with restricted gentle lower slopes, and it is less extensive than Tagoman land system.

(ii) *Plains*.—There is only one land system in this group.

(16) *Kimbyan land system* comprises gently sloping plains with relief less than 10 ft. Erosional surfaces with outcrop typify the lower parts, but relatively stable soil surfaces occur in the upper sectors. It is extensive in the northern plains region.

(*f*) *Depositional Surfaces*

These land systems consist of tributary alluvial plains, mainly stable tributary flood-plains, and the main flood-plains. The deposits range from sand to silt but sandy alluvium is widespread.

(i) *Tributary Alluvial Plains*.—The single land system in this group consists of tributary alluvial plains and aprons lying mainly on the Tipperary surface. Gradients locally exceed 1 in 200 but are mainly less.

(17) *Karaman land system* is characterized by sandy alluvium with mature soils. It has restricted occurrences in the southern plains region.

(ii) *Mainly Stable Tributary Flood-plains*.—The two land systems in this group consist of stable flood-plains of older deposits, with very restricted active levee zones. Gradients are below 1 in 300.

(18) *Green Ant land system* mainly consists of plains of fine-textured alluvium with hummocky surfaces in central drainage zones and with local exposures of underlying sandy deposits. It occurs in the northern plains region.

(19) *Wongalla land system* comprises back plains of fine-textured deposits with low sandy rises, flanking narrow levee zones. It is restricted to the southern plains region.

(iii) *Main Flood-plains*.—The single land system in this group consists of the flood-plains of the Daly River and its main tributaries. Gradients are mainly below 1 in 1000.

(20) *Banyan land system* comprises relatively stable back plains of fine-textured deposits, flanking narrow, sandy levee zones which are mainly inactive in the upper sectors but which include active inner levees along the lower course of the Daly River.

VI. References

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PART VII. SOILS OF THE TIPPERARY AREA

By R. H. M. van de Graaff*

I. Introduction

The first records of soil information from this area are those of Prescott (1938), but these were confined to observations of soils along the levee of the Katherine River and an assessment of their suitability for peanut growing. Prescott and Skewes (1941) gave descriptions and analytical data on a red earth soil along the Willeroo road. Stewart (1956) described the soils of this and adjoining areas, based on information collected during the survey of the Katherine–Darwin area in 1946 (Christian and Stewart 1953). Litchfield (1952, 1954) carried out semi-detailed surveys of two experimental farm areas near Katherine.

This survey enabled much further information to be collected on the soils of the Tipperary area. Soil samples taken during the survey have been analysed only for mineralogy of the fine sand fraction of several soils and further information on the clay mineralogy. Other analytical data are from earlier reports, particularly Stewart (1956).

Almost all soil profile examinations were by auger observation and, as most of the observations were only to 3½ ft, the characteristics to this depth have been used in the definition of soil groups and their description. From limited deeper augering and observations of exposed profiles it appeared that most soils were commonly more than 6 ft deep, and in some places much deeper, but the characteristic features were generally observable in the top 3½ ft.

From the pedological point of view the most important characteristics of the climate are:

(1) Rainfall during the wet season appreciably exceeds evapotranspiration and normal soil storage, thus leaching of soluble materials from the soil profile is likely.

(2) Temperatures are high throughout the wet season, hence weathering is likely to be rapid.

(3) The average rainfall per wet day is 0·60 in. and rapid erosion resulting from this high intensity is probably responsible for the occurrence of shallow skeletal soils or outcrop on most slopes of more than 5%.

(4) In the dry season all soils except those in the immediate vicinity of springs and permanent streams dry out completely over the full depth of sampling and probably much deeper. Precipitation of dissolved materials and oxidation are therefore important processes in these soils.

The rocks of the survey are entirely sedimentary rocks, i.e. they have already passed through at least one cycle of weathering. In Part VI Wright pointed out that

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there are two old erosion surfaces with associated deeply weathered mantles, and younger surfaces have in part been formed by the erosion, transportation, and deposition of strongly weathered materials.

In eight samples the clay minerals were identified by X-ray analysis by the Australian Mineral Development Laboratories, Adelaide, but their relative proportions could only be estimated as no reference standards were used. The results suggest a predominance of kaolinite in all samples except one, where quartz takes this place with kaolinite and illite subdominant. In the other samples the remaining clay minerals are illite and quartz in varying proportions and usually subdominant. In two samples from the oldest soils (Bradshaw surface) some vermiculite or vermiculite–chlorite was found in addition to the kaolinite, but illite was entirely absent. These results are similar to those of Stewart (1956) from the same general area.

More than 90% of the soil cover of the area has "earth-type" profiles characterized by the following general characteristics:

(1) There are no sharply defined colour, textural, or structural horizons, but they merge gradually one with the next.

(2) Generally clay content increases gradually with depth but some soils have little change in clay content throughout the profile.

(3) The soils lack pedality. Very sandy horizons may have single-grain structure but otherwise the soils are massive with varying amounts of visible pores which, in lower horizons, characteristically have thin clay-skin linings.

(4) Subsoil colours range from dark red through yellow-red, yellow-brown, brown, and greyish brown, and rusty mottling is general in the last three colours.

(5) The soils are medium acid to neutral in reaction and normally there is little change throughout the profile.

(6) The soils have a low ability to store water. Arndt, Phillips, and Norman (1963) present data showing a range of 4·3 to 6·8% available water in various horizons of a Tippera family soil and 1·8 to 4·7% in various horizons of a sandy member of Blain family.

II. Soil Classification

The classification of soils used in this report is not intended primarily to have taxonomic standing, as it is based on convenient and easily observable characteristics that appear to be of pedogenetical or practical significance. The groups and their constituent families are shown in Table 7. The group names have been chosen to be descriptive and brief, and their relationship with other names that have been used is given in their description. The family names used by Stewart (1956) have been retained where pertinent, but in most cases have been defined more narrowly.

The first seven groups are arranged in order according to decreasing internal drainage. The first four groups are all leached "earth" soils and their differences in colour reflect their internal drainage. The grey-brown cracking clays and dark or grey soils of depressions occur mainly in poorly drained low-lying sites and are mostly calcareous. Alluvial regosols are of minor extent, being confined to the youngest terraces along the river banks.

The main characteristics that have been used in the differentiation of the soil families are soil texture and the presence or absence of moderate to high amounts of ferruginous concretions. Soil texture strongly influences water infiltration rates, range of available moisture, and ease of cultivation. Generally, textural differences between profiles appear to result from differences in parent material and do not appear to have great pedogenetic significance. However, the characteristic gradual increase in

TABLE 7

SOIL GROUPS AND THEIR CONSTITUENT FAMILIES

Soil Group	Soil Family
Red earths	Tippera Xanthippe Blain Elaine Venn Vivienne Cockatoo Coralie
Alluvial red earths	Katherine Daly Edith Manbulloo
Yellow earths	Elliott Elizabeth Cullen
Sandy brown earths	Florina
Mottled greyish brown earths	Marrakai
Grey-brown cracking clays	Cununurra
Prairie–rendzina complex	Witch Wai Ingrid Phillips
Alluvial regosols	

clay content with depth in earth soils appears to be of pedogenetic significance. The clay skin lining the fine pores in the subsoil suggests that these are argilliac B horizons (United States Department of Agriculture 1960) produced by downward leaching of clay. Sheet wash of clay material from the surface, possibly assisted by transfer of clay to the surface by termites, may also contribute to the gradual increase in clay content. Termite activity in moving soil material to the surface, where it is subject to loss of clay due to sheet wash when the termitaria are abandoned, could well affect the upper parts of the soil profile to a stronger degree than the deeper parts.

The textural differences described in the next section have been chosen arbitrarily to a degree, but from the evidence available it appeared that there were natural discontinuities in the broad spectrum of profile textures of the selected criteria.

From the practical point of view the presence of moderate to high amounts of ferruginous concretions means that the amount of available water held in that horizon will be reduced by approximately a quarter to a half. The pedological significance of these amounts of concretions is not clear. Many of the soils with high amounts of concretions in the upper 3 ft of the profile occur on the more or less intact remnants of the Bradshaw and Maranboy surfaces. In those soils the concretions occur over mottled and pallid deeply weathered materials and the concretions are probably largely ancient and inherited. Concretions are also common in soil materials that have apparently been transported only short distances in landscapes eroded below those surfaces. Direct transport of concretions may have taken place but generally there is no clear evidence of smoothed or broken concretionary material such as would occur in water transport. The concretions mostly are too large to be readily transported and too soft to be water transported over large distances. Possibly some occurrence of concretions in those locations may in part be due to the supply of transported pulverized concretionary material from which the sesquioxides are readily retranslocated to form new concretions.

The mottled clay layer of at least some yellow earths and sandy brown earths contains a gradation from soft clayey mottles through soft concretions to hard concretions, indicating that concretions are forming at present in some situations.

Some soils have no, or low amounts of, concretions in the upper 3 ft and medium to high amounts in the 3–6-ft part of the profile. Red earths with medium to high amounts of concretions in the upper 3 ft have never been observed on limestone but appear to occur mainly on older, more weathered, geomorphic land surfaces. Thus, to some degree this arbitrary criterion, used only to differentiate families in the red earth group, tends to separate out the shallower and the older soils.

III. Description of Soils

The terminology used with the descriptions is in accordance with the Soil Survey Manual (United States Department of Agriculture 1960). The names of soil colours in the descriptions refer to moist colours unless otherwise mentioned, and are those used in the Munsell Soil Color Charts. Concentrations of gravel or ferruginous concretions are expressed as high amounts (40% or more of soil volume), medium amounts (20–40%), low amounts (10–20%), or, if their concentration falls below this percentage, as a few individual concretions. The term laterite is used for highly weathered material rich in secondary forms of iron, aluminium, or both; poor in humus; depleted of bases and combined silicon; with or without non-diagnostic substances such as quartz, limited amounts of weatherable primary minerals, or silicate clays; and either hard or subject to hardening upon exposure or alternate wetting and drying (Sivarajasingham *et al.* 1962).

Skeletal soils have not been given group status. They show no profile differentiation other than slight accumulation of organic matter, contain high amounts of rock fragments, and generally are less than 2 ft deep.

(*a*) *Red Earths*

The origin of this name and a summary of the characteristics of these soils is given by Stewart (1956), who in following Stephens (1953) added the prefix "lateritic" to this name. The red earths have gradational or uniform texture profiles and have no sharply defined colour or structural horizons.

General description

Dark reddish brown to dark brown to brownish surface soils of textures ranging from sands to clay loams; structure massive and vesicular, or single-grain in some very sandy soils; consistence when dry is hard to slightly hard, soft or sometimes loose if sandy; reaction slightly acid to neutral (pH 6·1–7·3)

Gradual transition

Dark red, dark reddish brown, red, reddish brown, or yellowish red subsoils ranging from sands to sandy clays and light clays; massive and vesicular; hard (sometimes very hard) to slightly hard or soft when dry; slightly acid to neutral; ferruginous concretions ranging up to high amounts may occur, generally increasing with depth; depth usually at least 36 in.

The red earths have been subdivided into eight families according to their texture and the presence of moderate to high amounts of ferruginous concretions.

In comparison with red earths of finer textures such as the Tippera and Blain soils, there is a noticeable shift in subsoil colours towards lighter shades of red (higher values and/or chroma, less red hues) in the more sandy red earths (e.g. Cockatoo soils).

(i) *Tippera family* (123 records) characteristically has gradational texture profiles with dark reddish brown sandy loam to clay loam surface horizons which merge before or at 12 in. depth into dark red, dark reddish brown, or red clay. The surface horizon when dry is soft to hard, depending on texture and organic matter content, but the subsoils are typically hard when dry. Ferruginous concretions occur in many profiles but only in low amounts or a few individual nodules. In sites receiving considerable run-on the surface horizon is commonly darker and less reddish. This is probably due to higher organic matter content. Less red but browner subsoil colours were sometimes found in sites such as filled-in sinkholes and valley floors. The soils of this family are rarely shallow and stony. Where stones occur in the profile and as a surface cover, they consist of chert or weathered sandstone, siltstone, or limestone.

(ii) *Xanthippe family* (25 records) is equivalent to the Tippera family in regard to texture and colour, but it contains medium to high amounts of ferruginous concretions. The concretions generally increase in amount with depth. In places the soils are shallow. Associated rock outcrops or stones always consist of weathered rock or laterite.

(iii) *Blain family* (75 records) consists of gradational texture profiles typically having dark reddish brown or dark brown sand to sandy loam surface horizons which merge between 12 and 36 in. depth into dark red clay. In addition a few individual ferruginous concretions or rarely low amounts of these may be present at any depth in the subsoil. The soil surface is sometimes covered with a thin veneer of uncoated quartz sand. Shallow soils have rarely been observed in this family.

(iv) *Elaine family* (4 records) is equivalent to the Blain soils in profile and colour, but it has medium to high amounts of ferruginous concretions throughout or in some part of the profile.

(v) *Venn family* (30 records) characteristically has gradational texture profiles with dark reddish brown or sometimes brownish sand to sandy loam surface horizons which grade before 36 in. depth into dark red or sometimes yellowish red loam to silty clay loam. Ferruginous concretions up to low amounts occur in some profiles. The soil surface may be covered with a thin veneer of uncoated quartz sand.

(vi) *Vivienne family* (6 records) is equivalent to the Venn soils in texture and colour, but it has medium to high amounts of ferruginous concretions in the profile.

(vii) *Cockatoo family* (18 records) consists of uniform texture profiles, typically with brownish or reddish brown sands to sandy loams, grading at depth into red, dark red, or yellowish red horizons of similar texture. A few ferruginous concretions commonly occur in the subsoil or throughout the profile, and the soil surface is sometimes covered by a thin veneer of uncoated quartz sand. Cockatoo soils are usually deep.

(viii) *Coralie family* (9 records) is equivalent to the Cockatoo soils in colour and texture, but it has medium to high amounts of ferruginous concretions in some part of the profile.

(*b*) *Red Earths on Alluvium*

This group includes red earths which have formed on younger alluvial deposits. They were included in lateritic red earths by Stewart (1956) but have been separated here because they differ somewhat in soil characteristics and potential agricultural use.

Their less red subsoil colours (5YR hue) are believed to mean that the soils have not reached a state of advanced maturity. An increase in redness with increasing age in alluvial or aeolian deposits is general experience in Australia (Stephens 1961, p. 36; Litchfield, personal communication) and in the U.S.A. (Norris and Norris 1961; Price 1962), although it is not a universal phenomenon (Cline, personal communication). Also their sand fraction is commonly dominated by fine sand and their silt content is higher than in other red earths. Their clay mineralogy is not known, but in the subsoil their total exchangeable cations per 100 g of clay is 25–40 m-equiv. compared with 10–20 m-equiv. in other red earths. If this is attributed to illite it would mean that the amount of kaolinite in the clay fraction must be very small.

General description

Dark brown or reddish brown surfaces of textures ranging from fine sands to silty clay loams; structure massive and vesicular; consistence slightly hard to hard; reaction neutral; merging gradually into yellowish red or reddish brown subsoils ranging from fine sands to clays; massive and vesicular; slightly hard to very hard when dry; neutral to mildly alkaline

The group has been subdivided into four families on the basis of textural profiles. They all occur mainly in Banyan land system with minor areas on alluvial units of other land systems.

(i) *Edith family* (6 records) has typically gradational texture profiles with dark brownish sandy loam to silty clay loam surface soils which grade between 6 and 12 in. depth into yellowish red or reddish brown clay. Apart from the less red subsoil colours this family is morphologically more or less equivalent to the Tippera family.

(ii) *Katherine family* (4 records) has typically gradational texture profiles with dark brown or sometimes reddish brown sands to sandy loams in the surface horizon, merging between 12 and 36 in. depth into yellowish red or reddish brown clay. The Katherine soils are morphologically similar to the Blain soils, except for the less red subsoil colours.

(iii) *Daly family* (12 records) has typically gradational or uniform texture profiles with dark brown or sometimes somewhat reddish brown sands to sandy clay loams which grade between 6 and 36 in. depth into yellowish red or reddish brown sandy clay loam to sandy loam. The Daly soils fall more or less in the same textural group as the Venn soils.

(iv) *Manbulloo family* (7 records) has typically uniform texture profiles with dark brown sands to sandy loams which grade at depth into yellowish red to dark reddish brown horizons of similar texture. This family is texturally equivalent to the Cockatoo soils.

(*c*) *Yellow Earths*

These soils are described by Stewart (1956) under the name of yellow podzolic soils, although they differ from the yellow podzolic soils described by Stephens (1953). The yellow earths have mainly gradational texture profiles without sharply defined colour or structural horizons, but very clayey or very sandy types may have uniform textural profiles.

General description

Very dark grey-brown, dark brown, or brown surface soils of textures ranging from sands to clays to massive vesicular structure, but single-grain in very sandy soils; hard to slightly hard when dry; soft if sandy; strongly acid to slightly acid

Gradual transition

Yellowish brown (but sometimes lighter, browner, greyer, or slightly more reddish) and usually mottled subsoils ranging from sands to sandy or light clays; mottles usually prominent and red but also brownish or greyish and less contrasting with yellowish brown matrix; massive and vesicular; when dry, hard to very hard, but slightly hard or soft if sandy; strongly acid to neutral; depth usually at least 36 in.

Also these soils usually contain small amounts of ferruginous concretions. Sometimes, and then only in the Elliott family, these occur in high amounts. Such concretions may be found throughout or only in certain parts of the profile. The mottles which normally occur in the subsoil sometimes harden on drying to form concretions. Stewart (1956) ascribes the yellow colours, mottling, and ferruginous concretions to poor internal drainage. This condition would concentrate the free iron oxides in concretions and mottles and leave a yellow matrix lower in free iron oxides, which are also more highly hydrated than those in the red earths. This process may be operative at present or it may have been operative in the past and yellow earths may therefore vary appreciably in age. Mottles in undisturbed soil often had angular shapes which would seem to support the hypothesis of their contemporary development in the soil. Similarly, the range from angular mottles to hard concretions in an Elliott soil near Katherine was interpreted by G. A. Stewart and G. D. Smith as indicative of current segregation of iron (Stewart, private communication). This does not exclude the possibility suggested by some geomorphological evidence that in certain yellow earths this process was initiated much earlier than in others, which are believed to be contemporaneous with red earths in the Tippera family. At the same time it does not appear that the amount of concretions in the yellow earths bears any relationship to their distribution over younger and older land surfaces, in contrast to the Tippera soils. Initial low free iron oxide contents are likely to be the main cause of yellow or other light soil colours where the parent material consisted of pallid-zone rocks. Impeded internal drainage could be associated with a low porosity of the soil, but it could also be caused by less permeable underlying rock strata.

Subdivision into three soil families is based on an arbitrary textural grouping, but takes into account the Elliott soils as defined by Stewart (1956), which are approximately similar in texture to red earths of the Tippera family. For reasons outlined above the presence of smaller or larger amounts of concretions in yellow earths does not seem to have as much pedological significance as in the red earths. Therefore, although of practical importance to the water-holding capacity, it has not been used as a criterion to distinguish between soil families.

(i) *Elliott family* (107 records) characteristically has gradational texture profiles with a very dark grey-brown to brown sandy loam to sandy clay loam surface horizon which merges before or at 18 in. depth into yellowish brown, usually red mottled clay subsoils. However, some soils with surface textures finer or coarser than is characteristic, such as clays and sands, were included in this family when they conformed in other properties. In most profiles mottling commenced above 30 in.

(ii) *Elizabeth family* (20 records) consists of gradational texture profiles typically having brownish loamy sand to sandy loam surface horizons which merge between 18 and 36 in. depth into yellowish brown mottled clay. The soils may contain low amounts of ferruginous concretions. A few profiles contain gravel or ferruginized fragments of pallid zone or other weathered rock. Also in most cases it seems evident that they developed on transported deposits. The Elizabeth soils are approximately similar in texture to the Blain soils. However, most recorded profiles come from the Woggaman, Karaman, and Wongalla land systems, in which Blain soils have not been observed.

(iii) *Cullen family* (10 records) usually has gradational and uniform texture profiles with brownish sand to sandy loam surface horizons which merge before 36 in. depth into yellowish, brownish, or greyish sand to sandy clay loam. It may contain low amounts of ferruginous concretions.

(*d*) *Sandy Brown Earths*

These soils were described by Stewart (1956), who called them lateritic podzolic soils, following the use of this name for similar soils by Stephens (1953) and Prescott and Skewes (1941). They have uniform or gradational texture profiles that are coarse or medium-textured to more than 12 in. depth, are brownish in colour, and contain moderate to high amounts of ferruginous concretions throughout the profile or in a major part of it.

Only one family — Florina — is proposed because of the similarity in many soil properties and similarities in their place of occurrence and in their vegetation. The Florina family was defined (Stewart 1956) as having deep subsoils of clay loam or clay texture, but in this report the texture may be coarse to 36 in. depth. Subdivision of this group into more than one soil family on the basis of subsoil texture is not warranted. Shallow soils are sandy throughout and overlie laterite or weathered rock.

(i) *Florina family* (128 records) has greyish brown, dark greyish brown, yellowish brown, or dark yellowish brown surface horizons of sand to sandy loam texture, single-grain or massive, loose to slightly hard, up to high amounts of ferruginous concretions. There is a gradual transition to the subsoil which is a light shade of brown or yellowish brown and is strongly mottled with red. Texture may range from sand to clay, structure is massive, and consistence is soft to hard. The subsoils are reputed (Stewart 1956) to be waterlogged and boggy for appreciable periods during the wet season.

(*e*) *Mottled Greyish Brown Earths*

These soils were called meadow podzolic soils by Stewart (1956), following the terminology of Stephens (1953). They have gradational profiles and are characterized by mottling or rusty staining on roots in the surface horizon, and the subsoil is light yellowish, brownish, or greyish in colour and strongly mottled with red, yellow, or yellowish brown. The soils occur in depressions with slow or ponded external drainage and, apparently, slow internal drainage.

Only one family — Marrakai — has been defined.

(i) *Marrakai family* (50 records) has a surface soil that is characteristically light grey when dry, but is grey or dark grey when moist and has yellowish brown or yellowish red mottles along roots or root channels. It may range from loamy sand to silty clay loam, massive or weak platy structure, slightly hard to hard, and may have low amounts of concretions. There is gradual transition to the light-coloured strongly mottled subsoil, normally of clay texture, massive, and hard to extremely hard, which may have varying amounts of ferruginous concretions.

The soils are generally more than 36 in. deep. The extreme hardness of some subsoils may be due to cementation by silica or to a solodized solonetz condition in the subsoil. Solodized solonetz having subsoil reactions of 7·8–8 and containing small amounts of lime have been described by Litchfield (1952) from similar sites near Katherine.

(*f*) *Grey-brown Cracking Clays*

The grey-brown cracking clays were described (Stewart 1956) as grey soils of heavy texture following earlier authors (Prescott 1931; Prescott and Skewes 1941; Stephens 1953). These soils differ from the previous group in that they are clay texture throughout, they crack deeply when dry, they have well-developed structure, and may have gilgai microrelief. The only family — Cununurra — is taken from Stewart (1956), who adopted this name from Burvill (unpublished data).

(i) *Cununurra family* (38 records) has dark greyish brown to grey surface soils that merge into slightly lighter-coloured greyish brown or olive brown clay subsoils. More than one-third of the profiles had mottling starting in the surface soils. The mottles of dark yellowish brown, yellowish red, or black were few, distinct, and fine. Soil structure was usually strong-grade $\frac{1}{8}$ in. granular to $\frac{1}{2}$ in. subangular blocky, which rapidly becomes coarser and angular blocky with depth. The surface is usually not self-mulching. These clays are hard to very hard when dry, plastic when wet, medium acid to moderately alkaline at the surface, and neutral to moderately alkaline in the subsoil. Lime concretions and small black manganiferous nodules commonly occur. Large nodules and rock fragments tend to be concentrated on the soil surface.

Where gilgai relief occurs the soils on the puff tend to be brownish or yellowish in colour, and have more concretions and finer structure. The shelves have greyer coarser-structured soils and many depressions have "runaway cavities" (Litchfield 1952) which apparently connect with subterranean cracks and tunnels.

The only analytical information from this area is the family type profile of Stewart (1956). The exchange capacity (60 m-equiv. per 100 g clay) is much higher than for other soils in the area and montmorillonite was the dominant clay mineral with subdominant illite and kaolin.

(*g*) *Prairie–Rendzina Depression Complex*

These soils have not been previously described from the area. They are grey or dark grey, non-cracking, not mottled except in the subsoil, and may be calcareous. They occur on alluvial floors and around springs, mainly in the northern part of the area.

(i) *Witch Wai family* (6 records) is similar to prairie soils as described by Stephens (1953). It has surface horizons of black or very dark grey silty clay loam to light clay of moderate to strong, medium to coarse angular blocky structure, slightly hard to hard when dry, friable when moist. These merge gradually into slightly lighter, more yellowish or brownish subsoils that may be weakly mottled light to medium clays. Reaction ranges from slightly acid to neutral.

(ii) *Ingrid family* (11 records) is similar to Witch Wai family but is calcareous in at least some part of the profile, and highly calcareous subsoils may be much lighter in colour. Reaction ranges from neutral to strongly alkaline depending on the presence of carbonates.

(iii) *Phillips family* (9 records) is massive in structure and calcareous throughout. The surface soils are light grey to black calcareous silty clay loams which become lighter-coloured with depth. Carbonates are finely dispersed through the soil but may in part occur as nodules.

From the association of these soils with springs and alluvial floors it is concluded that calcareous seepage waters may have played an important part in their evolution. This effect is least marked in Witch Wai family and most marked in Phillips family.

(*h*) *Alluvial Regosols*

The soils have no profile differentiation other than a slight accumulation of organic matter and are equivalent to alluvial soils of Stephens (1956). Families have not been defined. The 25 profiles recorded mostly had little or no texture variation in the top 3 ft, being mainly sand, but some profiles were clays and some were gritty or gravelly. The colour was generally brown, dark brown, or yellowish brown, structure was massive, and consistence ranged from hard in clay soils to soft in sands.

These soils usually occur on alluvial benches or levees along stream channels.

IV. Soil Geography

Table 8 shows the estimated area of soil families in relation to land systems. These estimates should be treated only as a guide to the relative distribution of the different soils as they are based on field impressions mainly, although in some cases it was possible to establish correlations between field observations and air-photo patterns, allowing extension over the whole area mapped. Such correlations are most reliable when soil boundaries coincide with geomorphic boundaries, which normally are readily observable on air photos.

The soils show clear-cut, but not always exclusive, relationships with the various erosional and depositional surfaces described by Wright in Part VI, and with the parent material of the soil.

The Bradshaw surface is characterized by sandy brown earths (Florina family) with small areas of red earths containing concretions (Xanthippe and Vivienne families), and with outcrop or skeletal soils on escarpments and adjacent stripped slopes.

The Maranboy surface, which in many parts is more closely dissected than the Bradshaw surface, is also characterized by sandy brown earths (Florina) but with a greater proportion of outcrop and skeletal soils.

The gentler lower slopes of the dissected margins of the Bradshaw and Maranboy surfaces may have a range of soils depending on the nature of their parent material. Mottled and pallid zones of sandier materials give rise to sandy brown earths (Florina), while more clayey materials in the lower parts of deep weathered profiles carry mainly yellow earths (Elliott), with some red earths with concretions (Xanthippe). Below the level of the weathering front, calcareous rocks, mainly limestone, have red earths (Tippera), and in Chinaman land system a particular bed of siltstone has cracking clays (Cununurra).

Much of the Tipperary surface is mantled with colluvium–alluvium. Where the source rocks for these deposits were sandy, including the Maranboy weathering zone, there have been relatively deep accumulations of transported material. It appears that in the upper parts of the Tipperary surface, where the transported material locally overlies the truncated Maranboy weathering zone on slowly permeable rocks, the relatively poorly drained Florina soils have formed, but where subsurface drainage is better, generally downslope with deeper fill, a range of coarser-textured red earths (Blain, Cockatoo, Venn) and some sandy yellow earths (Elizabeth and Cullen) have developed. The yellow earths appear to be formed on material derived from pallid-zone rock, which would provide less iron as a source of colour. Small areas of sandy red earth soils with concretions tend to occur near the source rocks (Coralie, Vivienne, Elaine). In drainage floors in these areas the soils may range from well-drained red earths (Tippera) to poorly drained mottled greyish brown earths. Where the source rocks were apparently finer-textured, the depth of transported material appears to be shallow and the effect of the underlying unweathered calcareous sediments on the soil is greater. The soils are mainly red earths (Tippera) with some yellow earths (Elliott) and small areas of grey-brown cracking clays (Cununurra).

TABLE 8

ESTIMATED AREAS (SQ MILES) OF SOIL FAMILIES IN VARIOUS LAND SYSTEMS

Geomorphic Situation	Land System	Outcrop or Skeletal Soils	Red Earths								Red Earths on Alluvium				Yellow Earths			Sandy Brown Earths	Mottled Greyish Brown Earths	Grey-brown Cracking Clays	Prairie–Rendzina Complex	Alluvial Regosols	Total
			Tippera	Xanthippe	Blain	Elaine	Venn	Vivienne	Cockatoo	Coralie	Katherine	Daly	Edith	Manbulloo	Elliott	Elizabeth	Cullen	Florina	Marrakai	Cununurra			
Plateaux formed by dissection of Bradshaw surface	Mullaman	175		20				20	5						5			220	5				450
Land systems formed by dissection of Maranboy surface	Yujullowan	210					10								10		5	160	5			5	400
	Yungman	120	20		100	5	10	20	20	10					5			90					400
	Maranboy	5	20												25			25	5				80
Undulating terrain eroded between Maranboy and Tipperary surfaces	Beemla	15	15		5										10	5		50					100
	Jindara	95	270	65	30		70		30						50			300	20	10	10		950
	Woggaman	130	5							5					25		10	280	45				500
	Wallingin	25			5		25								20	60	60	50				5	250
	Chinaman	5													5			20		10			40
Land systems forming part of Tipperary surface	Claravale	95	15		150		70		30						25		55	310					750
	Wriggley	30	170	45	40		5						5		60			10	25	10			400
	Blain	5	90		360		125		45						25								650
	Douglas		25												25					20		10	80
Land systems eroded below Tipperary surface	Tagoman	155	200		15										30			50	5		45		500
	Budbudjong	35	45												5					5			90
	Kimbyan	170	500		30	10		10							80					50	50		900
Depositional surfaces	Karaman						45		5	10					5	5		5	5				80
	Green Ant	5										5			5			15	10	25	15		80
	Wongalla		20												40	5			5	80			150
	Banyan	25			80		35				5	15	15	5	5				20	140		5	350
Total area		1300	1215	130	815	15	395	50	135	25	5	20	20	5	460	75	130	1585	150	350	120	25	

On landscapes eroded below the Tipperary surface the parent materials are calcareous rocks and sandy surface soils do not occur. The most common soil is the red earth (Tippera) with smaller areas of yellow earth (Elliott) and minor cracking clay (Cununurra), but rock outcrop and/or boulders are common.

The alluvial plains vary considerably in age and in associated soils. Alluvial plains equivalent in age to the Tipperary surface (Karaman land system and parts of Green Ant and Banyan land systems) have strongly weathered, generally sandy-surfaced, earth-type soils ranging from red to mottled greyish brown in colour. The alluvial plains of Wongalla land system, which in part are equivalent in age to landscapes eroded below the Tipperary surface, also have some strongly weathered earth-type soils but with loamy surface horizons (Tippera, Elliott, and Marrakai) and appreciable areas of grey-brown cracking clays (Cununurra).

Younger alluvial surfaces along the major stream channels have levees with red earths on alluvium which are less weathered than other earth soils probably because they are younger, and back plains of brownish grey cracking clay (Cununurra). The prairie–rendzina complex appears to be associated with alluvia of similar age but calcareous ground water appears to have played an important role in their evolution. The youngest alluvial surfaces, mainly occurring as benches along major stream channels, have youthful, undifferentiated alluvial regosol soils.

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PART VIII. VEGETATION AND PASTURES OF THE TIPPERARY AREA

By N. H. SPECK*

I. INTRODUCTION

The area falls within the 30–50-in. isohyet and has been described as tropical savannah climate (Slatyer 1960). The year is divided into two seasons, a warm dry winter period, May to September, and a hot summer period, October to April. Most of the rainfall is received during the summer period. The long winter droughts have been the main influence in the selection of the vegetation.

(a) *Plant Types*

The plant species are adapted to withstand the long annual drought period except for those in restricted environments of abundant and continuous water supply. According to their means of survival through droughts the species can be divided into three groups (Perry 1960).

(i) *Perennial Drought-resisting Species.*—The vegetative parts of species in this group remain green and alive but growth is suspended during the long dry periods. Growth resumes in the rainy season. The great majority of trees and shrubs, including *Acacia* and most *Eucalyptus* spp., are in this group. Grasses in this group are mainly the tussock-forming grasses collectively known as spinifex. Spinifex, although widespread in the area, is restricted to one species, *Plectrachne pungens*, and is a "soft" spinifex.

(ii) *Perennial Drought-evading Species.*—This category includes those perennial plants which during the unfavourable season lose their leaves (trees and shrubs), or die back (grasses) and resume growth from perennating buds with the return of the favourable season. Thus these plants evade rather than resist the dry season. Deciduous trees (including some *Eucalyptus* spp., either partially or wholly) and shrubs fall into this group, but the most important plants in this area are those perennial grasses in which the above-ground parts die back each season. They make rapid growth during the wet season but during the long dry season they remain as standing hay, providing a fodder of dry, mature pasturage of low nutritive value. Typical species include *Sorghum plumosum*, *Themeda australis*, *Chrysopogon* spp., *Sehima nervosum*, and many others.

(iii) *Ephemeral Drought-evading Species.*—Plants in this group grow rapidly during the wet season but die before the dry season and persist as seeds until the next wet season. Annual sorghums are the only important representatives of the group in this area. Other representatives grow in the inter-tussock spaces of the perennial grasses and are widespread but not abundant. For most of the year these species are dry, unpalatable, and of extremely low nutritive value.

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(*b*) *Vegetation Classification*

For descriptive purposes the vegetation of the area has been arranged into broad structural forms and subforms, defined as follows:

(1) Forest — communities comprising dense trees.

(2) Open forest — communities with crowns of trees touching but not continuous, and with many open spaces in the canopy. Tree boles generally longer than crown depth.

(3) Woodland — tree layer more open. Trees with boles generally shorter than crown depth.

(4) Shrubland—communities dominated by shrubs.

(5) Grassland—communities dominated by grasses; trees and shrubs very sparse or absent.

Tall, low, and mixed open forests and savannah woodland are extensive, whilst forest, including lancewood and cypress pine forests, fringing forests, and rain forest, show a more localized distribution, as do shrublands, grasslands, and deciduous woodlands.

Although rain-forest elements, deciduous trees and shrubs, and other tropical species characterize a number of minor communities, and although some tropical species, including cycads and palms, are commonly conspicuous in the subordinate layers of the open forests and woodlands, *Eucalyptus* spp. characterize the tree layers of all the major communities and the vegetation therefore is predominantly sclerophyllous.

As each of these structural forms and subforms has a distinct assemblage of characteristic species they also readily form the basis for floristic grouping into alliances and suballiances.

The vegetation descriptions and postulated ecological relationships are based upon field observations at sample sites carefully selected by air-photo interpretation and in the field to include all environments.

Throughout this report the letter *E.* has been used for *Eucalyptus.*

(*c*) *Plants and Environment*

(i) *Regional Climate.*—Mean annual rainfall appears to be the main climatic factor affecting regional differences of vegetation in the area. The increase in rainfall from 30 in. in the south to 45 in. in the north is expressed in increasing height and density of vegetation northwards but not in any major floristic changes. Although the main tree species (e.g. *E. tetrodonta*, *E. miniata*, *E. tectifica*) have an environmental tolerance that enables them to extend throughout the area, they are lower and more scattered in the south and some are approaching their environmental limits. Others (*E. terminalis*, *E. umbrawarrensis*, *E. pruinosa*), which are widely distributed further to the south, occur only in the south of this area. Palms and cycads are common in the northern, higher-rainfall parts, but are absent in the south.

(ii) *Site.*—Although climate is considered to be the primary factor in the selection of species and life form for the area as a whole and is the major factor in controlling structure and density, in detail, site characteristics determine the floristics and dis-

TABLE 9

NUMBER OF OBSERVED ASSOCIATIONS OF VEGETATION COMMUNITIES WITH SOIL FAMILIES

Soil Family	Rain Forest	Fringing Forest	Lancewood Forest	Cypress Pine Forest	Tall Open Forest	Mixed Open Forest	Low Open Forest	Savannah Woodland	Deciduous Woodland	Shrub-land	Grass-land	Total
Tippera		2			9	17	1	86			2	117
Xanthippe		1	1		5	1	2	11			1	22
Blain				2	7	37		22				68
Elaine					1	3		2				6
Venn					7	18		4				29
Vivienne					6							6
Cockatoo				1	9	2	3	4				19
Coralie			2		3	2	1	2				10
Edith								3				3
Katherine								1				1
Daly		1						6				7
Manbulloo								6				6
Elliott		2			14	4	4	62		3	2	91
Elizabeth		2			6	2		7				17
Cullen					4		3	2		1		10
Florina			2		62	6	24	25		5		124
Skeletal and lateritic outcrop			1		12		9	8		3		33
Limestone outcrop									4			4
Marrakai		1						21	3	11	9	45
Cununurra		5						10	2	1	7	25
Prairie–rendzina complex	1							13	7	1	3	25
Total	1	14	6	3	145	92	47	295	16	25	24	

TABLE 10

NUMBER OF OBSERVED ASSOCIATIONS OF TREE SPECIES WITH SOIL FAMILIES

Tree Species	Tippera	Xanthippe	Blain	Elaine	Venn	Vivienne	Cockatoo	Coralie	Edith	Katherine	Daly	Manbulloo	Elliott	Elizabeth	Cullen	Florina	Skeletal and Lateritic Outcrop	Limestone Outcrop	Marrakai	Cununurra	Prairie–Rendzina Complex	Total
Eucalyptus miniata	30	10	16	2	14	3	9	5			1		11	4	4	32	12	1	2	1		157
E. tetrodonta	46	8	22	1	13	4	7	4					23	5	2	23	18	1				177
E. bleeseri	1	1	3	2	2			1					5	3	2	25	15					60
E. dichromophloia	8	3	7		3		1						7	1	1	5	9					45
E. alba	1												2		3		5		3			14
E. ferruginea			1	1	1								4	1	3	4	4					19
E. phoenicea													1			2	3					6
E. umbrawarrensis							1						1				8					10
E. tectifica	44	6	15	1	6		1	3		1	3	1	42	7	2	12	35	2	2	4		187
E. foelscheana	62	5	17	1	8		1		1	2	7	1	27		1	6	6	2	4	2	2	155
E. confertiflora	12	3	8		7		1		2		1	1	15	1	9	5	13	1	7			86
Erythrophleum chlorostachys	15	2	18	2	9		4	1	1	1	2	2	14	3	7	13	17	1	11			123
Eucalyptus patellaris	12		2		1				1		3	1	6	1			1	1	5	1	3	38
E. oligantha	6												3									9
E. terminalis	3		3	1	1		1									1	1	3	2			16
E. grandifolia	7						1	1					17	3	2	3	3	1	2	1		41
E. pruinosa													1						2			3
E. argillacea	3	1													1	1						6
E. apodophylla															1				1			2
E. bigalerita	4	1	1										6			1	1		1			15
E. latifolia	3							1					8	1	2	2	1		3			21
E. polycarpa	3	2			3						1		5			3			10	1		28
E. papuana	6	4	3		5		3		4	1	8	3	14		2				8	4	9	78
E. microtheca	1		1						2		1		7		1				1	12	2	28
Tristania suaveolens																				1	12	13
Terminalia platyptera																					3	3
Melaleuca sp.																			2		3	5
Total*	267	46	117	14	73	7	30	16	11	5	27	9	219	30	43	140	152	13	66	27	34	

* Figures are not the true numbers of soil observations, because where several species occur at the one site, each is recorded separately.

tribution of communities. In Part VI it is seen that the area contains a wide range of erosional and depositional sites formed from a variety of weathered and relatively fresh parent materials. These sites vary in microclimate, drainage status, and soil mantle, thus offering a variety of habitats to plants. In Part VII close relationships are outlined between geomorphic sites and soils; in turn the vegetation pattern clearly reflects similar relationships.

The relationship of the vegetation forms and subforms with soil families is shown in Table 9. Tall and low open forests (with spinifex–tall grass ground storey) characterize the lateritic soils and deep sands (skeletal and lateritic outcrop, Florina and Cockatoo families). Mixed open forests (with mixed tropical grass ground storey) characterize the sandy loams (Blain, Elaine, Venn, and Vivienne families). Savannah woodlands (with tropical tall grass ground storey) characterize the finer-textured soils and cracking clays (Marrakai and Cununurra families, prairie–rendzina complex). Savannah woodlands (with ground storeys that are a complex of tropical tall grass and frontage grass) occur on the other alluvial soils (Edith, Katherine, Daly, and Manbulloo families).

Because the environmental tolerances of individual species are commonly wider than the communities formed by the various combinations of such species, the relationships pointed out in the preceding paragraph are not so obvious in Tables 10 and 11, which show the relation of individual tree and grass species to the various soils. Nevertheless, significant correlations may be discerned.

Of the first eight tree species, *E. miniata* and *E. tetrodonta* exhibit very wide tolerances, and although they characterize extensive areas of lateritic soils and deep sands (tall and low open forests) they also occur on clay loams and sandy loams, but on these soils they form communities of a different structure (mixed open forests and savannah woodlands). *E. bleeseri* favours the skeletal lateritic and Florina soils as does *E. dichromophloia* in the higher-rainfall parts, but the latter extends to Blain and Elliott families in lower-rainfall areas, presumably because the more favourable moisture characteristics of these soils compensate for decreased annual rainfall.

The next three species (*E. tectifica*, *E. foelscheana*, and *E. confertiflora*) show a strong relationship with Tippera and Elliott soils which characterize the extensive savannah woodlands. Table 10 indicates that *E. tectifica* is also commonly found on lateritic soils, mainly on lower slopes below breakaways, and field evidence suggests that there is a correlation with underlying pallid-zone rock. As well as being an important constituent of the savannah woodlands on Tippera and Elliott soils, *E. confertiflora* commonly characterizes the communities on rocky or lateritic outcrops.

Erythrophleum chlorostachys is extremely widespread and occurs on most soils, either as a minor or characteristic species in the community. Numerous additional relationships are obvious from Table 10.

In Table 11, which shows grass species arranged in pasture groups, annual sorghum is seen to be a prominent constituent of three of the four groups. The three species of the spinifex–tall grass group are characteristic of the lateritic soils and deep sands and, although the table indicates their occurrence on a range of other soils, these latter habitats are restricted in extent. The main distribution of the tropical tall grasses shows a strong association with Tippera and Elliott soils, but they also

TABLE 11

NUMBER OF OBSERVED ASSOCIATIONS OF GRASS SPECIES WITH SOIL FAMILIES

	Tippera	Xanthippe	Blain	Elaine	Venn	Vivienne	Cockatoo	Coralie	Edith	Katherine	Daly	Manbulloo	Elliott	Elizabeth	Cullen	Florina	Skeletal and Lateritic Outcrop	Limestone Outcrop	Marrakai	Cununurra	Prairie–Rendzina Complex	Total
Spinifex–tall grass																						
Plectrachne pungens	7	5	8	1	6	1	2	2	1				16	5	10	33	27					124
Annual sorghum	5	1	7	1	2		5	2					6	1	9	16	10					65
Heteropogon triticeus	6	1			1		2			1			6		1	4	12					34
Tropical tall grass																						
Sorghum plumosum	59	10	21	3	5		3	2	3	3			52	7	2	14	24	3	13	9	8	241
Themeda australis	52	8	7	1	4		3	2	4	2	1	1	43	2	3	5	20		15	8	6	187
Sehima nervosum	62	5	19		4	1	3	2	1	2	1		23			1	5	3	8	6	3	149
Chrysopogon sp.	34	5	16		11		4	2	5		2		36	7	3	9	19	2	9	5	1	170
Annual sorghum	2	1	2	1	3	1	1	3	1		1	1	6	2	2	2	10			2		41
Heteropogon triticeus	23	5	4		2		1	1					15	3	4	3	10	2	3		1	77
Mixed tropical grass																						
Annual sorghum	1		9	1	7	1	4				1		6		4	7	6	2	3	2	2	56
Aristida sp.	3		6		1		2				1	1	5	1	1	4	4		1			30
Aristida browniana	3		5				2	1				3	5	3	2	3	5	2	1			35
Panicum delicatum	2	1	1		1								1			1			1			8
Frontage grasses																						
Coelorachis rottboellioides	1			1				1	2				7			1	1		4	1	3	22
Arundinella nepalensis		1				1					1		1			1	1		6	1	3	16
Heteropogon contortus	7	1	3		2				1		2	1	8		1		4	1	6	3	2	43
Bothriochloa spp.													1			1			6	3	1	12
Dichanthium spp.									1		1		1		1				1	3		8
Total*	267	44	108	9	49	5	32	18	19	8	11	7	238	31	43	105	158	16	77	43	30	

* These figures are not the true numbers of soil observations, because where several species occur at one site, each is recorded separately.

have minor occurrences on a wide range of other soils. The mixed tropical grasses mainly occur on the sandy loams (Blain, Elaine, Venn, and Vivienne families). Within frontage country, the frontage grasses are important only upon the range of fine-textured soils characteristic of depressions, back plains, and certain tributary drainage floors.

(iii) *Other Environmental Influences*.—Besides the basic determinants of regional climate and site which have already been discussed, other factors that have exerted an influence on the vegetation are fire, termites, the natural herbivorous fauna, and man.

(1) *Fire*.—It is highly probable that fire exercised a selective influence on the evolution of the vegetation (Perry 1960) and that the present vegetation is in equilibrium with fire. The aborigines made a regular practice of starting fires, and natural fires started by lightning from storms at the commencement of the wet season were probably not uncommon. Under present pastoral practice much of the country is burned annually or biennially either by accident or by design.

Recent investigations have shown that productivity is not increased by any burning programme and that pastures should probably not be burned at all. However, because of the danger of wild fires, it is advisable to have controlled burns toward the end of the dry season at not less than 2-year intervals (Norman 1963).

(2) *Termites*.—Termites are abundant throughout the area. They are responsible for the destruction of large amounts of organic matter and the bringing to the surface of clay subsoil used in mound-building. In many places these mounds, ranging from a few feet to 18 ft in height, are a prominent feature of the landscape. The influence of termites has not been measured.

(3) *Animals*.—Kangaroos and wallabies comprise the main elements of the native herbivorous fauna, which is relatively sparse compared with many other parts of Australia. Grazing pressures exerted by these animals in the past were negligible except in the frontage areas during drought periods. Buffaloes were present in the higher-rainfall parts but these also would have exerted no appreciable grazing pressure.

(4) *Man*.—The aboriginal inhabitants were not numerous. They lived a nomadic life of hunting, fishing, and collecting. They neither herded animals nor practised any form of agriculture. Their main influence on the vegetation was in whatever effect they had on the marsupial numbers, and through fires, either accidental or used deliberately for hunting.

With the advent of European settlement, beef cattle were introduced into the area in the period 1870–80, but they have been maintained under open-range conditions at low stocking rates and the effect on vegetation has been relatively small. Wild pigs descended from introduced domestic pigs are increasing; although the hummocky surfaces created by their wet-season rooting are a menace to stockmen, the effect on pastures is negligible.

(*d*) *Relation of Formations to Land Systems*

Each unit of a land system is commonly characterized by a distinctive vegetation community. From the estimated proportions of these units the associated

TABLE 12

ESTIMATED PERCENTAGES OF LAND SYSTEMS OCCUPIED BY THE VEGETATION COMMUNITIES

Geomorphic Situation	Land System	Area (sq miles)	Rain Forest	Fringing Forest	Lancewood Forest	Cypress Pine Forest	Tall Open Forest	Mixed Open Forest	Low Open Forest	Savannah Woodland	Deciduous Woodland	Shrubland	Grassland
Plateaux formed by dissection of the Bradshaw surface	Mullaman	450		<5	<5	<5	75	4	4	14			
Land systems formed by dissection of the Maranboy surface	Yujullowan	400		5	<5		85	10					
	Yungman	400			<5	10	50	35		5			
	Maranboy	80					38	29		33			
Undulating terrain eroded between Maranboy and Tipperary surfaces	Beemla	100					50	15		35			
	Jindara	950		5			30	15		50			
	Woggaman	500		3			32		37	20		8	
	Wallingin	250		5			40			55			
	Chinaman	40							10	45		25	20
Land systems forming part of Tipperary surface	Claravale	750					55	25		15		5	
	Wriggley	400		5			5	10		80			
	Blain	650		5			5	95					
	Douglas	80								70		25	5
Land systems eroded below Tipperary surface	Tagoman	500						5		95			
	Budbudjong	90								75	20		5
	Kimbyan	900		5				10		75	5		5
Depositional surfaces	Karaman	80								90			10
	Green Ant	80	5	5				20	10	35			25
	Wongalla	150		5						50	5		40
	Banyan	350		10						80			10
Unclassified	Volcanics	150											
Total area		7350	<1	3	<1	<1	27	24	3	37	1	2	3

vegetation communities are shown in Table 12 as percentages of each land system. The various communities are also expressed as a percentage of the total survey area. As the land systems are arranged in a geomorphic classification, the table also shows the relationships between the communities and broad geomorphic environments.

Except for small pockets of cypress pine forest, uniform tall open forest characterizes the high plateau-remnants of the Bradshaw surface (Mullaman land system) and it is only upon restricted lower slopes that other formations occur. Tall open forests also dominate the low plateaux and undulating terrain produced by dissection of the Maranboy surface (Yujullowan, Yungman, and Maranboy land systems), occupy large parts of undulating lateritic terrain eroded between the Maranboy and Tipperary surfaces (Beemla, Jindara, Woggaman, Wallingin, and Chinaman land systems), and characterize the higher parts of the Tipperary surface (Claravale land system) underlain by the truncated Maranboy weathering zone.

Mixed open forests occur mainly on the sandy or loamy alluvial–colluvial mantles which are widespread on the Tipperary surface (Blain and Claravale land systems), and occur to a lesser extent in the lower parts of plateaux and undulating terrain produced by dissection of the Maranboy surface or eroded between it and the Tipperary surface. However, savannah woodland characterizes these mantles where they are finer-textured (Wriggley and Douglas land systems) and also dominates land systems eroded below the Tipperary surface (Tagoman, Budbudjong, and Kimbyan land systems) and the alluvial land systems (Karoman, Green Ant, Wongalla, and Banyan), which are commonly more open and grade into grassland locally.

(*e*) *Relation between the Upper and Lower Storeys*

Except in special cases a feature of the vegetation is the apparent lack of interdependence between the tree and grass layers (Perry 1955, 1960). Work done by Arndt and Norman (1959) gives no indication that the yield of native pasture is increased by removal of the trees. Similarly, the destruction of the perennial ground cover by heavy grazing over a period of eight years does not appear to have had any effect upon the tree layer. It is only in the forest communities, where the density is high and the canopy continuous or almost so, that there is an appreciable effect of the tree layer upon the subordinate layers. In the more open communities (open forests and woodlands) each species appears to have its own environmental tolerances. The main tree and grass species of these communities have been arranged in Table 13 so that the associations between them may be seen. The various combinations of each layer cannot be shown in this table. Reading the figures from left to right gives the number of observations of the grass species with the various tree species, with the total number of observations for each grass species in the right-hand column. Reading the figures from top to bottom gives the number of times each tree species was observed with the various grass layers. For example 70% of the observations on *Plectrachne pungens* occur with the four main species (*E. miniata*, *E. tetrodonta*, *E. bleeseri*, *E. dichromophloia*) of the tall open forest. Another 13% occurs with the next four species (low open forest).

TABLE 13

NUMBER OF OBSERVED ASSOCIATIONS OF MAIN TREE AND GRASS SPECIES

	E. miniata	*E. tetrodonta*	*E. bleeseri*	*E. dichromophloia*	*E. alba*	*E. ferruginea*	*E. phoenicea*	*E. umbrawarrensis*	*E. tectifica*	*E. foelscheana*	*E. confertiflora*	*Erythrophleum chlorostachys*	*E. patellaris*	*E. oligantha*	*E. terminalis*	*E. grandifolia*	*E. pruinosa*	*E. argillacea*	*E. apodophylla*	*E. bigalerita*	*E. latifolia*	*E. polycarpa*	*E. papuana*	*E. microtheca*	*E. setosa*	*Melaleuca viridifolia*	*Tristania suaveolens*	*Terminalia platyptera*	Grassland	Total
Plectrachne pungens	45	43	40	14	3	16	2	5	10		4	11	8		2	2				1	1	2			1	2			2	209
Annual sorghum	48	30	13	3	4	10			23	8	16	26	2		6	7					3	8	7	1			1	1	6	223
Heteropogon triticeus	24	33	5	2	2				18	20	10	11	1			6					3	2	4							141
Sorghum plumosum	20	43	5	8	3	4		5	60	45	21	24	10	4	4	8				2	8	9	9	4		2		3	20	321
Themeda australis	9	14		4	3	1		2	71	56	21	15	16		2		1	1		8	8	6	25	14					6	296
Sehima nervosum	16	32		5					36	40	9	11	15	2	4	2				2		3	8	8			11	1	1	206
Chrysopogon spp.	11	24	14	16	4	6		5	40	27	24	25	9	6	6	6		2		6	5	2	21	15		1			8	283
Aristida spp.	17	12	6	4	1	7		1	10	5	8	19	1		3	4		1			2	9	5						1	116
Panicum delicatum	1								4	2	4	5		1		2						1	4							24
Eragrostis spp.	2					1			2	2	2	4			1	1			1	1		2								19
Eriachne spp.		1	1	1	1	2		1	1		3				2	1										1				15
Coelorachis rottboellioides	5	4								4	3	3										4	7				4	1		35
Arundinella nepalensis	1	1							1	1	1	2				2						2	9	1		1			5	27
Heteropogon contortus	2	1		1	1	1			4	8	11	4	4	1	1	2		1		3	1	3	18	4				2	1	74
Bothriochloa spp.					1						1										1	5	5	2		1	2		2	20
Dichanthium fecundum									2			1	1							1		1	4	2					6	18
Total	201	238	84	58	23	48	2	19	282	218	138	161	62	14	31	56	1	5	1	24	32	59	126	51	1	8	18	8	58	

II. Tree Communities

(a) *Forests*

Forests are relatively unimportant and occupy approximately only 5% of the area.

(i) *Rain Forest*.—This several-layered, evergreen forest is dominated by mesomorphic trees, 80–100 ft high. They form a closed community with interlacing canopy. Palms and lianes are a prominent feature. The mesomorphic subordinate strata comprise smaller trees, shrubs, ferns, and herbs. Many species were not identified but prominent species include *Nauclea orientalis*, *Ixora* sp., *Ficus racemosa*, *F. coronulata*, and *Tristania* spp. These tropical rain forests are ecologically interesting but economically unimportant because of their limited extent. They are restricted to one land system (Table 12) and occur only in certain calcareous spring-fed areas (rainfall 40–50 in.), commonly less than ½ sq mile in extent, and occupy considerably less than 1% of the area.

Monsoon forest (characterized by deciduous elements in the main tree layer) was described by Christian and Stewart (1953) for the Katherine–Darwin area but occurs here only as limited extensions of the fringing forest communities and has therefore not been separately recorded in the land system descriptions.

(ii) *Fringing Forest*.—These communities vary in structure, density, and floristic composition according to the length of period in which water is available and they exhibit a range from little more than a single line of trees to a dense several-layered forest. In the driest situations, along the ephemeral tributary channels *E. camaldulensis* characterizes a very open fringing community. Other trees (*Grevillea* spp., *Acacia holosericea*, *Tristania* spp., and *E. microtheca*) are sparingly represented. *Heteropogon contortus* and other frontage grasses form a moderately dense ground storey. With increasing availability of water *Melaleuca*, *Tristania*, and *Ficus* spp. also occur.

Along the perennial streams the several-layered fringing forest is characterized by *E. camaldulensis*, *Casuarina cunninghamii*, *Nauclea orientalis*, *Terminalia* spp., *Ficus* spp., and *Melaleuca* spp., the latter extending as a definite fringe at low-water level. *Ficus* spp., *Acacia* spp., *Barringtonia* sp., *Atalaya hemiglauca*, and *Pandanus* sp. are conspicuous in the subordinate layers. *Bambusa* spp. are also common in the higher-rainfall parts. Grasses are generally sparse or absent except where the community is more open. In some places *Imperata* sp., *Coelorachis rottboellioides*, and *Arundinella* sp. form dense stands at the water's edge.

The main channels are commonly incised 60–70 ft and these fringing forests have a very important stabilizing effect on the channel banks, as they grow to the water's edge and are generally capable of protecting the banks from erosion even in the severest floods. Because of this, care should be exercised in cutting timber from these forests.

(iii) *Lancewood Forest*.—These forests, characterized by *Acacia shirleyi*, consist of a single tree layer 25–35 ft high. The trees are small in diameter (6–12 in.) and are so close together that visibility is reduced in many places to a few yards. Although *Acacia shirleyi* forms almost pure stands, a few other tree species (*E. dichromophloia*, *E. confertiflora*, *Callitris columellaris*) are sparsely present.

Shrubs (*Erythrophleum chlorostachys*, *Calytrix* sp.) are few. The ground is commonly covered with litter, and grasses (*Cymbopogon bombycinus*, *Arundinella nepalensis*, *Plectrachne pungens*, and *Panicum* sp.) are sparse. Lancewood forests were observed only to the south of the 40-in. isohyet and occur in scattered stands ranging in size from a few square yards to an acre or two in extent. They are characteristic of the lateritic breakaways and outcrop areas of Yujullowan and, to a lesser extent, Mullaman land systems. They also occur locally in similar habitats in several other land systems.

(iv) *Cypress Pine Forest*.—As individual, isolated trees or as scattered small clumps *Callitris columellaris* commonly occurs as a minor element in association with *E. tetrodonta* and *E. miniata*. However, in places where the remnants of the Bradshaw surface (Mullaman land system) are more extensive and on parts of Blain land system within the 35–45-in. isohyet, there are numerous remnants of *Callitris* forest. These range from a few chains to half a mile or so in diameter. The distribution and the observed burning pattern of these communities indicate that they were once much more extensive in these particular habitats and are now disappearing. This disappearance has been assisted by the demand for the excellent timber they provide, which has encouraged active milling. The stands are quite dense and the method of branching reduces visibility to a few yards. The practice of leaving the waste when trees are cut results in total destruction of the stand, including the young trees, when the first fire occurs. The trees are not large, and seldom attain more than 12–24 in. diameter and 35–40 ft in height. Other trees (*E. dichromophloia*, *Owenia vernicosa*, *Erythrophleum chlorostachys*) are sparsely present. Shrubs (*Calytrix microphylla*, *Terminalia* spp.) are few and the grass layer (*Chrysopogon* spp.) is very thin except where burning has taken place.

(*b*) *Open Forest*

(i) *Tall Open Forest*.—Tall, straight trees of forest form (length of bole greater than depth of crown) characterize these communities. The crowns tend to be flat-topped, touching, but not interlacing, forming a canopy with many open spaces. The density is such that visibility is limited to a few hundred feet and even less where the shrub layers are well developed. There is characteristically a single tree layer 50–70 ft high, rarely to 80 ft and in some habitats as low as 35–40 ft high. *E. miniata*, *E. tetrodonta*, *E. bleeseri*, and *E. dichromophloia* in various combinations constitute the main tree layer. Smaller trees (*Erythrophleum chlorostachys*, *Grevillea* spp., *Acacia* spp., *E. tectifica*, *E. confertiflora*, and *E. ferruginea*) have a scattered distribution and form a poorly defined subordinate layer. The shrub layers are variable but commonly only moderately dense. The tall shrub layer (10–15 ft) is characterized by *Planchonia careya*, *Buchanania obovata*, *Petalostigma quadriloculare*, *Grevillea mimosoides*, *Grevillea* spp., and *Persoonia falcata*. In the higher-rainfall parts, the palm *Livistona humilis* is very conspicuous in this layer. Low shrubs (4–8 ft) are not numerous and consist mainly of smaller plants of the same species. The ground storey is open and characterized by various combinations of *Plectrachne pungens* and annual sorghums (spinifex–tall grass pastures), with *Heteropogon triticeus* and *Sorghum plumosum* as less important constituents. This formation occupies a little less than 30% of the area.

(ii) *Mixed Open Forest.*—These communities resemble the tall open forests in that the upper layer is composed of trees that are tall, straight, and of forest form. The layer comprises many of the same species (*E. tetrodonta*, *E. miniata*, *E. dichromophloia*) with some additional species (*E. papuana*, *Erythrophleum chlorostachys*, *E. tectifica*). It differs in that many of the trees of savannah woodland (*E. tectifica*, *E. foelscheana*, *E. confertiflora*, and *Erythrophleum chlorostachys*) occur as a subordinate tree layer. Visibility is commonly restricted to a few hundred yards.

The shrub layer is open and in some places sparse or absent, but floristically resembles the shrub layer of tall open forest. The ground storey (mixed tall grass) is very variable but is characterized by annuals (annual sorghums, *Aristida* spp., *Panicum delicatum*, *Eragrostis*, and *Eriachne* spp.) and scattered perennials (*Sorghum plumosum*, *Themeda australis*, *Chrysopogon* spp., *Sehima nervosum*, and *Plectrachne pungens*).

In the lower-rainfall parts the tree canopy is more open, and tropical tall grass more commonly occurs as a ground storey.

(iii) *Low Open Forest.*—There is no sharp line of demarcation between tall and low open forests. The trees of this formation are not so tall and straight and are commonly more openly spaced. The tall shrub layer ranges from sparse or absent to extremely dense and thicket-like. Visibility varies from several hundred yards where the shrub layer is thin to only a few yards where the undergrowth is dense. The tree layer is typically 20–35 ft high but in places is depauperate and grades into shrubland. These forests occur mainly either in the lower-rainfall parts of the area or in widely distributed drier sites such as stony outcrop areas or on shallow soils. Some trees that characterize this formation (*E. phoenicea*, *E. umbrawarrensis*) have a wider distribution outside the area. Some others (*Erythrophleum chlorostachys*, *E. ferruginea*, and *E. confertiflora*) are widespread as minor elements in the vegetation and dominate only in these special sites. Still others that are common throughout the area (*E. tetrodonta*, *E. tectifica*) occur in these communities in stunted form. The floristics of the shrub layers and ground storey (spinifex–tall grass) closely resemble those of the tall open forest.

Low open forests, though widely scattered in these distinctive habitats, occupy an extremely small part of the total area.

(*c*) *Woodland*

(i) *Savannah Woodland.*—These communities were described by Christian and Stewart (1953) as low open forests. Although in many places these communities have the density of forest they are characteristically more open. The trees rarely have straight trunks and are branched low down (woodland form). Shrubs are sparse and the grassy ground storey is tall and dense. The tree layer is commonly 25–35 ft high, rarely to 45 ft, but on some shallow soils over limestone may occur as low as 10–20 ft. These latter communities, which consist of trees appearing to be regularly distributed and having a stunted, pruned appearance, were described by Christian and Stewart (1953) as "orchard" communities.

The characteristic species (*E. tectifica*, *E. foelscheana*, *E. confertiflora*) in various combinations constitute the main communities, with *E. grandifolia*, *E. patellaris*, and *E. oligantha* as widely distributed minor elements. *E. papuana*, *E. polycarpa*, and *E. microtheca* characterize another group of grassy woodlands closely associated with frontage country. *E. bigalerita*, *E. alba*, and *E. latifolia* are typical of many valley floors and alluvial flats with *E. apodophylla* as an uncommon element. In the extreme south of the area *E. terminalis* and *E. pruinosa* occur as northerly margins of a wider distribution.

Sorghum plumosum, *Themeda australis*, *Chrysopogon* spp. with *Sehima nervosum*, occurring as separate "pure" stands or in various combinations, typify the ground storey (tropical tall grass).

Savannah woodlands are characteristic of the widespread red and yellow earths as well as the prairie and meadow soils and the cracking clays, and occupy a little less than 40% of the area.

(ii) *Deciduous Woodland*.—The communities characterized by *Eucalyptus* spp. which lose all or some of their leaves during the unfavourable season are not included in this category. Two distinct communities are described here as deciduous woodland.

(1) Associated with some areas of cracking clay soils is a vegetation consisting of a dense cover of medium-height to tall perennial grasses, *Sorghum plumosum*, *Chrysopogon* spp., *Aristida latifolia*, and *Brachyachne convergens*, with a scattered tree cover. These trees (*Bauhinia cunninghamii*, *Acacia bidwillii*, *Terminalia platyptera*, *Tristania suaveolens*, and locally *E. terminalis*) occur as scattered clumps or individuals and are mainly deciduous. This community has been described by Christian and Stewart (1953) as deciduous parkland.

(2) Occurring on the rocky limestone outcrop hills is another distinctive community which is characterized by deciduous elements but also contains many evergreen species. The trees are generally small (20–40 ft) and occur in pockets and crevices between and around the rocks; there is some interlacing of crowns although there are many open spaces in the canopy because of the rocky nature of the habitat. The density in places approaches forest. The tree layer is floristically rich and includes *Erythrophleum chlorostachys*, *Bauhinia cunninghamii*, *Gyrocarpus americanus*, *Brachychiton diversifolium*, *Terminalia platyphylla*, *Ficus opposita*, *Canarium australianum*, *Buchanania obovata*, *Atalaya hemiglauca*, *Acacia* sp., and scattered, stunted *Eucalyptus* spp. (*E. confertiflora*, *E. ferruginea*). *Cycas* sp. and *Dolichandrone filiformis* are prominent in the subordinate layers. Tropical tall grass (annual sorghums, *Heteropogon contortus*, *Themeda australis*, and *Sehima nervosum*) forms a patchy ground storey.

(*d*) *Shrubland*

Communities characterized by shrubs are mostly restricted to small, local habitats except in two land systems (Table 12). They commonly comprise dense stands of tall shrubs 10–15 ft high, consisting of *Melaleuca viridifolia*, *Terminalia platyptera*, *Erythrophleum chlorostachys*, and *Acacia* spp. in various combinations. Scattered, stunted *Eucalyptus* spp. (*E. confertiflora*, *E. ferruginea*, *E. setosa*) are present in places and rise little above the general shrub level. Smaller shrubs (*Calytrix microphylla*, *Petalostigma quadriloculare*, *Terminalia volucris*, and *Gardenia* sp.) form a patchy subordinate layer. The ground storey is typically sparse and variable, but is most commonly characterized by annual *Sorghum* spp., *Plectrachne pungens*, and *Chrysopogon* spp. (spinifex–tall grass).

(e) *Treeless Communities (Grassland)*

Vegetation communities characterized by grass only or grasses with sparse trees and shrubs occupy only an estimated 2% of the area and are mainly restricted to fine-textured soils (cracking clays, prairie soils, and mottled greyish brown earths) associated with depressions, back plains of the frontage country, or other cracking clay areas (Table 12). These grasslands are mainly characterized by dense stands of *Sorghum plumosum* 4–6 ft high. Marginal areas or slightly higher parts are commonly dominated by *Themeda australis*, while seepage areas in places carry dense tall stands (8–10 ft) of annual sorghums or patches of *Coelorachis rottboellioides* or *Arundinella nepalensis*. Less commonly, *Dichanthium fecundum*, *Bothriochloa intermedia*, *Heteropogon contortus*, *Chrysopogon* spp., *Aristida* spp., and *Sehima nervosum* form local restricted areas of grassland.

III. Grass Communities (Native Pastures)

(a) *Introduction*

Natural pastures in this area, as in other higher-rainfall parts of Australia, generally comprise only the ground storeys of the communities. Although shrubs are moderately abundant, top feed or browse in the form of palatable species is unimportant. The native pastures of this area have developed under an average rainfall of 30–45 in. and are mainly gramineous. That they are well adapted to the environment is indicated by the work of Arndt and Norman (1959) on the major pasture type. "The general impression gained of Tippera clay loam native pasture is that of a vigorous perennial community, strongly resistant in the undisturbed condition to invasion by other species; apparently little affected by fire and in fact probably conditioned by it; susceptible to heavy uncontrolled grazing which under free range it does not receive by virtue of its inherent unattractiveness to stock; markedly modified but not destroyed by extreme drought; and capable of rapid recovery following a run of normal seasons". The vigour of these pastures has been further demonstrated by the same workers. "Although native pasture . . . is clearly adapted to low natural levels of nitrogen and phosphate, it shows a remarkable capacity for response to nitrogen and phosphate fertilizers when applied together" (Arndt and Norman 1959).

(b) *Description of Grass Communities*

The major components of the ground storey communities (pastures) for each site have been given in the land system descriptions. Because of the great number of combinations in which these components occur in each kind of pasture, and because of the dynamic nature of their distribution in time and space, no attempt has been made to describe the numerous individual combinations (pasture types). These pasture types fall naturally into four main groups and these are described below.

(i) *Spinifex–Tall Grass Community*.—This extensive community (almost 30% of the area) is characteristic of those land systems produced by dissection of the Bradshaw and Maranboy surfaces (Table 14) where it dominates the lateritic, gravelly, and sandy soils (Florina and related families) which are typical of these surfaces and occurs locally in a number of other land systems. The bulk of the pasture consists of perennial drought-resistant spinifex (*Plectrachne pungens*). This occurs either as pure stands or with annual sorghums, which vary in density from site to site and from season to season. Other perennial grasses (*Heteropogon triticeus* in higher-rainfall parts, *Sorghum plumosum*, and others) are relatively sparse and mainly occur

TABLE 14

ESTIMATED PERCENTAGE OF LAND SYSTEMS OCCUPIED BY GRASS COMMUNITIES

Geomorphic Situation	Land System	Spinifex–Tall Grass (%)	Tropical Tall Grass (%)	Mixed Tropical Grass (%)	Frontage Grass (%)
Plateaux formed by dissection of Bradshaw surface	Mullaman	74	19	4	3
Land systems formed by dissection of Maranboy surface	Yujullowan	85	10		5
	Yungman	60	40		
	Maranboy	38	62		
Undulating terrain eroded between Maranboy and Tipperary surfaces	Beemla	50	40	5	5
	Jindara	15	80		5
	Woggaman	73	20	4	3
	Wallingin	40	55		5
	Chinaman	50	30	20	
Land systems forming part of Tipperary surface	Claravale	65	10	25	
	Wriggley		90		10
	Blain	5	40	55	
	Douglas		100		
Land systems eroded below Tipperary surface	Tagoman	10	60	20	10
	Budbudjong		100		
	Kimbyan		95		5
Depositional surfaces	Karoman		100		
	Green Ant		40	5	50
	Wongalla		70	15	15
	Banyan		65	6	30
Percentage of total		28	56	8	8

in special habitats and only locally as dominants. Over most of the plateau surfaces which form a large part of the range of this pasture the vegetation appears remarkably stable and uniform. Structurally the ground storey comprises straggly, xerophytic tussocks interspersed with bare ground, and sparse annuals, including forbs or scattered perennial drought-evading grasses. It typically occurs as a ground storey of open forests or shrubland and, rarely, as a grassland.

As a pasture this widespread community is of low value and in general has a low stocking rate.

(ii) *Tropical Tall Grass Community*.—This is the most important and most extensive pasture of the area, and is the one investigated by Arndt and Norman (1959). It occurs to some extent in every land system (Table 14) but is most important in those land systems characterized by Tippera, Elliott, and related soil families, and on the cracking clays (Table 11). It is characterized by four perennial drought-evading grasses (*Sorghum plumosum*, *Themeda australis*, *Chrysopogon* spp., and *Sehima nervosum*) which normally constitute the bulk of the sward. These species occur in numerous combinations and proportions. Other perennial grasses (*Heteropogon triticeus*, *H. contortus*, *Aristida* spp., *Brachyachne convergens*) and annual grasses provide a small percentage. Legumes and other forbs make only a small contribution and there is little top feed or browse in the form of edible shrubs.

This pasture typically occurs as an understorey of savannah woodland characterized by various combinations of *Eucalyptus* spp. (*E. tectifica*, *E. foelscheana*, *E. confertiflora*, *E. tetrodonta*) but also occurs with a number of other tree communities (Table 13). A number of variations in this pasture can be recognized. Various species assume local dominance and the characteristic species occur in a number of combinations and proportions which vary in both time and space. These are related to soil and minor topographic differences and to differences in seasons or series of seasons and in grazing pressure. Satisfactory correlations of species and micro-habitat have not been possible. *Sorghum plumosum* is the most widespread and common species on the cracking clays, depressions, lower slopes, and favoured sites on Tippera clay loams and Elliott soils. *Themeda australis* is closely associated but occupies the slightly more elevated sites, and is extremely widespread and abundant. These two species are much more vulnerable to drought than the drought-resistant *Chrysopogon* spp. and *Sehima nervosum*. However, all species are represented at most sites and this would facilitate the changing dominance that may be observed from season to season, but little is known of the controlling factors.

The undisturbed pasture has a structure of coarse distinct tufts of perennial grasses interspersed with bare ground or light cover of annuals, including legumes and other forbs. At maturity the height of the leaf canopy averages 3–4 ft, though flowering culms may extend up to 8 ft. On the cracking clays the pastures may be considerably denser and several feet taller.

The pastoral value of this pasture depends to a certain extent on floristic composition. *Sorghum plumosum* is palatable to cattle during the wet season and appears to form a major part of their diet during the dry season (Arndt and Norman 1959), and has the advantage of having its reproductive tillers remain green throughout much of the dry season. *Themeda australis* appears to be palatable during the wet season but is neglected in favour of *Sorghum plumosum* during the dry. The other characteristic species are less palatable.

(iii) *Mixed Tropical Grass Community*.—The ground storeys of this pasture vary considerably from site to site. They are characterized by annual drought-evading grasses (annual sorghums, *Panicum delicatum*, *Eragrostis* spp., and others) throughout which are scattered tufts of perennial drought-evading grasses (*Themeda australis*, *Chrysopogon* spp., *Sehima nervosum*, and *Sorghum plumosum*) and occasional spinifex tussocks. The grass cover (2–4 ft high) is commonly continuous but light, and readily flattens with trampling following the onset of the dry season. The pasture occurs as ground storeys of the mixed open forests which characterize the alluvial–colluvial mantles of the Tipperary surface and similar sites throughout the area (Table 12). Although shrubs are moderately abundant, top feed in the form of edible shrubs is unimportant.

Where the habitat occurs in the lower-rainfall parts, the canopy of the tree storey is more open and there are more and denser perennial grasses.

The pastoral value of this community is very low. It would have a moderate grazing potential during the wet season but would comprise a dry fodder of extremely low nutrient status for most of the year.

(iv) *Frontage* Grass Community*.—This pasture is commonly restricted to flats, depressions, floors, and similar habitats throughout the area but is most widespread in the alluvial land systems associated with the main stream lines. It is characterized by tall (6–10 ft), coarse, perennial drought-evading grasses (*Coelorachis rottboellioides*, *Arundinella nepalensis*, *Heteropogon contortus*, *Dichanthium* spp., *Bothriochloa* spp., and others). These occur either as ground storeys of open savannah woodlands or as local patches of grasslands. It is generally unattractive to stock.

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*Frontage is a well-established local term relating to country fronting onto the rivers of the area, generally alluvial in nature.

PART IX. PASTURE LANDS OF THE TIPPERARY AREA

By N. H. SPECK*

I. INTRODUCTION

(a) General

Since 1870–80 the area has been utilized for beef cattle raising on native pastures at a low rate of stocking. Ten cattle stations occur either wholly or partly within the area with an approximate stocking rate of 4 cattle per sq mile. The original land resources survey in 1946 (Christian and Stewart 1953) suggested that parts of the country should be investigated for arable agriculture. Recent research (CSIRO Division of Land Research and Regional Survey 1959) has also shown that some of the soils and the climate are suitable for this. However, the utilization of native pastures is likely to be an important feature of any development scheme because of the non-arable nature of the greater part of the area and the probability that grazing of small areas of improved pastures will be integrated with grazing of native pastures.

(b) Climate

Climatically the year is divided into two parts, a warm dry winter period and a hot wet summer period. Practically all the rainfall occurs within the hot summer period, December to March (Slatyer 1960). Rainfall, which varies over the area from 30 to 45 in., is the dominating climatic factor in plant growth. Although the conditions for pasture growth vary over the area from north-west to south-east, in all but the driest parts a 16-wk period of useful pasture growth is assured, while in the north-west this extends to 24 wk (Part IV).

(c) Growth Cycle and Nutritive Value of the Tropical Tall Grass Pasture

The growth cycle of this pasture over a full year reflects the highly seasonal climatic regime. Dry matter increase occurs almost wholly within the wet season. Norman (1963*b*) studied the seasonal fluctuations in yield and showed that after effective rainfall (2 in. or more in a fortnight) dry matter production was very rapid, but ceased within 4 weeks of the cessation of rain, and then yield decreased.

At the end of the wet season, translocation of nitrogen and phosphorus from the leaves of grasses to below-ground storage sites is rapid, resulting in a marked loss in pasture quality. Nitrogen yield in mid wet season is of the order of 7 lb/ac, but drops to about 3 lb/ac by mid dry season. Phosphorus yield changes similarly from 0·5 lb/ac to about 0·25 lb/ac.

Cattle on tropical tall grass pasture gain 100 to 300 lb per head from the beginning of the wet season until 1 or 2 months after the rains cease, a period of approximately 6 months, but lose approximately 20% of their body weight between May and November (Norman and Arndt 1959). During this period the crude protein

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content of the pasture falls from 3% in May to 1·5% in October–November (Arndt and Norman 1959). Recent work (Norman 1963*c*) indicates that the dry standing native pasture is an adequate source of energy, which can be effectively utilized during the dry season if cattle are given small amounts of high-protein supplement. His work also shows that during the period of early storms the pasture is not an adequate source of energy, and high-protein supplements do not prevent liveweight loss. These findings indicate that as wet-season grazing, or as dry-season grazing with protein supplementation, tropical tall grass pasture might make a useful and inexpensive contribution to more intensive systems of cattle husbandry.

(*d*) *Grazing Management of Tropical Tall Grass Pasture*

A stocking rate trial conducted over 4 years (Arndt and Norman 1959) indicated that, with respect to botanical composition, stocking at rates up to 10 ac/beast is possible on tropical tall grass pasture. However, evidence from observation and other experiments suggests that if grazed heavily at the vulnerable period of early wet season, the perennial grasses are rapidly replaced by annuals.

Little work has been done on grazing management. However, the evidence which is available (Norman 1960) suggests that rotational grazing is of little benefit with respect to either botanical composition of the pasture or cattle liveweight gain. Attempts to set back the maturation of the grasses by mid wet season burning or early heavy grazing, and thus to prolong the period of liveweight gain into the dry season, have not been successful. It is thought that continuous grazing at conservative stocking rates, particularly in the first few weeks of growth, is the best form of pasture management.

(*e*) *Burning*

Fires are one of the major features of the environment of the native pastures of the area. They can occur through lightning from dry storms at the end of the dry season (September–November), and were used by the aboriginal population for hunting. During the 80 years of pastoral occupation fire has been used as an aid to cattle management, and the influx of tourists has increased the frequency of accidental fires.

A recent experiment on the effects of time and frequency of burning on tropical tall grass pasture on Tippera clay loam has shown that the highest dry matter yield and the highest nitrogen yield are to be gained from unburned pasture (Norman 1963*a*). Although these results indicate that for best production tropical tall grass pasture should not be burned at all, this is not practical, because, with the lack of fences and firebreaks and with the general attitude of the population toward grass fires, a large proportion of the pastures will inevitably be burned at some time or other. Hence, controlled burning is recommended as a preventative measure against wild fire, at not less than two-year intervals. On evidence from Katherine and from African savannahs it appears that late in the dry season is the best time to burn (Norman 1963*a*).

(*f*) *Other Pasture Types*

Experimental work on native pastures at Katherine Research Station has been restricted to tropical tall grass pastures and little information exists about other types.

The frontage grass pasture is similar in that it is comprised of perennial drought-evading tussock grasses but they are taller, coarser, and less attractive to stock.

It is known that, in general, the tall annual grasses mature earlier and have a lower nutritive status than the perennial grasses of the tropical tall grass pasture. Because of the earlier maturation of the annual grasses, mixed annual–perennial stands can be burned while the soil contains enough moisture for the perennial constituents to make appreciable regrowth.

No evidence exists that spinifex is grazed by cattle.

TABLE 15

PASTURE LANDS AND THEIR CONSTITUENT LAND SYSTEMS AND PASTURE TYPES

Pasture Land	Area (sq miles)	Land Systems	Estimated Proportion of Pasture Types			
			Spinifex–Tall Grass (%)	Tropical Tall Grass (%)	Mixed Tropical Grass (%)	Frontage Grass (%)
Plateaux spinifex country	850	Mullaman	75	20	5	5
		Yujullowan	85	10	0	5
Undulating spinifex country	1790	Woggaman	75	20	5	5
		Claravale	65	10	25	0
		Beemla	50	40	5	5
		Chinaman	50	30	20	0
		Yungman	60	40	0	0
Tropical tall grass–spinifex country	350	Maranboy	40	60	0	0
		Wallingin	40	55	0	5
Tropical tall grass country	2950	Wriggley	0	90	0	10
		Douglas	0	100	0	0
		Kimbyan	0	95	0	5
		Tagoman	10	60	20	10
		Budbudjong	0	100	0	0
		Jindara	15	80	0	5
		Karaman	0	100	0	0
Mixed tropical grass country	650	Blain	5	40	55	0
Frontage country	580	Green Ant	0	65	5	25
		Wongalla	0	70	15	15
		Banyan	0	65	5	30

II. DESCRIPTION OF PASTURE LANDS

The pastures described earlier in this report cannot be mapped at the scale of the survey, but each land system contains a definite pattern of them. The land systems can be grouped, according to their pattern of pastures, into six pasture lands (Table 15).

(*a*) *Plateaux Spinifex Country* (*850 sq miles*)

These lands carry mainly spinifex–tall grass pastures, with local areas of poor tropical tall grass, under comparatively uniform tall open forest. The country consists of the extensive, high, mainly sandy plateaux of Mullaman land system and the more broken, low, mainly stony plateaux of Yujullowan land system. It is characterized by steep escarpments and deeply entrenched valleys. The soils are shallow, sandy and gravelly, or skeletal.

The stock-carrying capacity is low because of the poor pastures and difficult terrain.

(*b*) *Undulating Spinifex Country* (*1790 sq miles*)

In this country the pastures are mainly (50–75%) spinifex–tall grass under tall and low open forests. In Beemla and Yungman land systems the proportion of tropical tall grass pasture is 40% but it is commonly sparser than similar pasture under savannah woodland. The topography is undulating with mainly shallow, sandy brown earths (Florina and related families), extensive skeletal soils and outcrop, and lesser areas of sandy red earths (Blain).

The country has a low stock-carrying capacity, because of the poor pastures on stony or infertile soils.

(*c*) *Tropical Tall Grass–Spinifex Country* (*350 sq miles*)

In this pasture land, tropical tall grass constitutes the main (>50%) pastures and spinifex–tall grass and mixed tropical grass occupy lesser areas (30–40%).

The country consists of plains and undulating terrain with extensive sandy valley fills. The soils are loamy red and yellow earths (Tippera and Elliott families) on the extensive plains, sandy brown earths (Florina and related soils) on the rises, and sandy red earth (Blain soils) in the valleys.

At present the country is stocked at a moderate rate but the tropical tall grass pastures may have a greater potential in association with improved pastures.

(*d*) *Tropical Tall Grass Country* (*2950 sq miles*)

This is the largest pasture land and is characterized by mainly (>60%) tropical tall grass pastures (various combinations of *Sorghum plumosum*, *Themeda australis*, *Sehima nervosum*, and *Chrysopogon* spp.) under savannah woodlands.

The country consists of plains and undulating terrain forming part of the Tipperary surface or eroded below it, and underlain mainly by relatively unweathered rock. The soils are mainly fine-textured and are characterized by loamy red earth (Tippera family) with moderate areas of yellow earth (Elliott family) and many small areas of cracking clays. There are local areas of sandy alluvium and much sandstone and limestone outcrop.

The country has a moderate stocking rate but has a potential for more intensive beef production in association with small areas of improved pasture or fodder crops.

(*e*) *Mixed Tropical Grass Country* (*650 sq miles*)

This pasture land is characterized by mixed tropical grass (mostly annuals, including annual sorghum, but with scattered perennial grasses) under mixed open forest and lesser areas of tropical tall grass pastures. Tropical tall grass pasture is more common in the lower-rainfall parts.

This pasture land consists of one land system (Blain) which comprises gently sloping plains with deep sandy soils (Blain and Venn families).

Because of the poor pastures and scarcity of surface waters, present stocking rate is low. Much of the country is arable and appears suitable for improved pastures.

(*f*) *Frontage Country* (*580 sq miles*)

Although frontage pastures, characterized by tall, coarse, perennial grasses, are a conspicuous feature of this pasture land they occur only in special and restricted habitats such as depressions, channels, and drainage floors, and as fringing communities. Tropical tall grass pasture occupies extensive areas on the adjacent levees and back plains.

The country includes the mainly stable tributary flood-plains (Green Ant and Wongalla land systems) and also the major flood-plains (Banyan land system). It is associated with the main rivers of the area but is particularly extensive in the northern parts. The soils are varied and consist of recent alluvium, red earths, meadow and prairie soils, and cracking clays.

The country is well watered and has a moderate stocking rate. Some areas are boggy during rainy periods.

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PART X. AGRICULTURAL CHARACTERISTICS OF THE LANDS OF THE TIPPERARY AREA

By G. A. Stewart*

I. Past and Present Agriculture

The only agriculture practised in the area is on a few small farms along the levee of the Katherine River. Peanuts for the confectionery trade were the major crop during their developmental stage in the 1930s. Some peanuts are still grown and some farmers grow fruit and vegetables for the local and Darwin markets, but many of the originally cleared areas are not cultivated regularly.

II. Climatic Aspects

Using daily rainfall data over a number of years for stations within or close to the area, it has been estimated that the average length of the agricultural growing season ranges from about 15 wk along the dry, inland margin to about 23 wk in the higher-rainfall zones toward the coast (Part IV). Most of the area has an average growing season greater than 20 wk. In all but the extreme inland parts, a growing season of at least 16 wk can be expected in 3 out of 4 yr, and in the higher-rainfall zone toward the coast, a growing season of 20 wk or longer can be expected with this frequency. Thus, in so far as its control of the overall length of the growing season is concerned, the climate may be considered adequate over most of the area for a range of crops with reliance upon summer rainfall without supplementary irrigation. It must be emphasized, however, that within the growing seasons there may be dry periods long enough to impose some degree of water stress upon crops. The incidence of these dry periods decreases considerably toward the coast, and at Daly River is only about one-quarter of that at Katherine. This suggests that certain crops sensitive to water stresses may be better adapted to higher-rainfall parts of the area; however, the higher and more intense rainfalls may create land management problems.

III. Post-war Agricultural Investigations

In 1946, Christian and Stewart (1953) considered that the Tipperary land system offered the best prospects for improved dry-land agriculture in the Katherine–Darwin area.

The CSIRO Katherine Research Station was established in 1946. Initial plant introductions and agronomic experiments were carried out on red earths on alluvium at the station headquarters. Since 1948 most of the experimental work has been concentrated on soils of the Tippera family, with some experimental work on soils of Elliott family (CSIRO Division of Land Research and Regional Survey 1959). Since 1957 experiments have also been undertaken on soils of Blain and

*Division of Land Research and Regional Survey, CSIRO, Canberra, A.C.T.

Florina families (Arndt, Phillips, and Norman 1963). A complete bibliography of publications arising from the above investigations at Katherine Research Station is presented in Appendix I.

At Kimberley Research Station some investigations of crops and pastures under dry-land conditions have been carried out on soils of Cununurra and Cockatoo families. Also, the Northern Territory Administration has carried out considerable experimental work on soils of the Marrakai family at the Upper Adelaide River Experiment Station, as well as testing on a large scale the findings of the Katherine Research Station on soils of the Tippera, Elliott, and Florina families at the Katherine Experiment Farm (Anon. 1959, 1960, 1961).

Thus some investigations have been done on all the more extensive soils of the area, and certain inferences can be made on the agricultural characteristics of the less extensive soils that have not been tested in field experiments.

IV. Crop–Soil Relationships

Local farming experience and limited investigations indicate that the red earths on alluvium of the levees of the major streams are suited to a wide range of dry-land crops and also, from limited data at Katherine Research Station, their crop yields are approximately 25% higher than those obtained on other soils. Although texturally they range from deep sands to loams over clay, no marked crop differences have been observed, probably because their high content of fine sand and the greater activity of their clay fraction (as indicated by exchange capacity) give much better moisture retention characteristics than the strongly weathered earth soils. Because of their limited area and patchy occurrence, little experimental work is in progress or planned on these soils.

Tippera and Elliott soils (Arndt, Phillips, and Norman 1963) show similar crop responses and it is considered that Xanthippe soils would behave similarly, but Xanthippe soils and Elliott soils with high amounts of concretions would be more droughty than the soils without concretions. The following crops have been shown to be adapted to these soils:

Cash crops: peanuts, grain sorghum

Forage crops: bulrush millet, fodder sorghums, sudan grass, cowpea, guar

Improved pasture legume: Townsville lucerne

Improved pasture grass: buffel and birdwood grasses

Cotton has been extensively tested but its yields are low and variable.

The agronomic practices which have proved successful on those soils cannot be applied successfully to Blain–Venn soils. Five years of cropping on Blain soils led to soil erosion and rapid loss of nitrogen from the surface soil. Because of their low moisture storage in the upper sandy horizons, only deep-rooted crops (bulrush millet and cotton) have appeared promising, cotton yields over 6 years being 849 lb seed cotton/ac compared with 590 lb on Tippera soils. Townsville lucerne is less adapted to these soils, particularly in competition with birdwood grass, but the perennial legume siratro is showing promise. It appears that these soils would be best adapted to improved pastures, with cotton or bulrush millet on a wide rotation.

At Kimberley Research Station, bulrush millet has shown itself to be well adapted to Cockatoo soils and Townsville lucerne has been successfully established. A wider range of crops and pastures is now being tested. It is believed that deep-rooting crops will be best adapted and this can also be expected on the other red and yellow earths with sandy surface soils—Elaine, Vivienne, Coralie, Elizabeth, and Cullen families.

The sandy brown earths (Florina family) have shown themselves to be poorly suited to all cash and fodder crops and improved grasses. The only pasture legume tested, Townsville lucerne, has established well but its productivity is much lower than on Tippera soil. Unless better-adapted legumes are found, the productivity of Townsville lucerne is such that it would only warrant cheap establishment of pastures without tree clearance (Norman 1961).

The mottled greyish brown earths (Marrakai family) occur only in small scattered areas and could not be used for rice growing as they are at the Upper Adelaide River Experiment Station of the Northern Territory Administration (Anon. 1959, 1960, 1961). However, work at that centre has shown that the pasture legumes Townsville lucerne and phasey bean are well adapted and siratro is giving promising results. Other cash and forage crops do not appear well adapted.

Trials on Cununurra soils at Kimberley Research Station under dry-land conditions have not given promising results with any cash or forage crops or improved pastures.

There is no record of agricultural experience or experiment on the prairie–rendzina complex. It is expected that those soils would have above average fertility and good moisture retention characteristics, but the highly calcareous horizons in Ingrid and Phillips families may be droughty.

V. Possibilities for Irrigated Agriculture

A very small amount of irrigation has been carried out on some of the farms along the Katherine River by pumping from the river, a lift of some 60 ft, utilizing the red earths on alluvium of the river levees.

Broadly, the loamy red and yellow earths, the red earths on alluvium, the cracking clays, and the prairie–rendzina complex should all be reasonable soils for flood or furrow irrigation. For crops sensitive to waterlogging the yellow earths and cracking clays may not be suitable. Also, some areas of cracking clays and prairie–rendzina complex appear to be liable to flooding. The sandy red and yellow earths and sandy brown earths are so rapidly permeable that spray irrigation would be necessary on most of them. The mottled greyish brown earths, which are of only minor extent, are poorly drained and experience at the Upper Adelaide River Experiment Station has shown them to be suitable for paddy rice and for pasture plants that are not sensitive to waterlogging.

Because of the isolated nature of the area, and consequent high marketing costs, crops grown under irrigation need to give a high return per unit area and have a high value per unit weight. Cotton appears most likely to meet these requirements, and irrigation experiments with this crop have been commenced by both CSIRO and the Agriculture Branch of the Northern Territory Administration.

TABLE 16

SELECTED STREAM DISCHARGE DATA FOR THE KATHERINE AND DALY RIVERS

Stream	Gauge Location	Catchment Area (sq miles)	Period of Record	Monthly and Average Monthly Discharge ('000 ac ft)												Annual and Average Annual Discharge ('000 ac ft)
				Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	
Katherine River	Railway Bridge Katherine	3100	1961–62	2·04	2·00	2·44	10·3	290	302	36·9	3·25	1·98	1·84	1·83	1·78	657
			1952–63	2·38	3·55	4·41	48·4	143	245	295	88·9	16·7	5·22	3·76	2·95	860
Daly River	Dorisvale Crossing	13,000	1961–62	5·36	5·50	6·97	28·3	466	630	75·2	12·3	7·38	6·87	7·05	7·05	1258
Daly River	Gourley*	18,000	1961–62	21·2	21·3	22·1	46·8	564	971	181	32·8	27·3	22·8	22·3	22·0	1955

* Gourley is approximately 10 miles from the western edge of the survey area.

From information collected during this survey there does not appear to be any large area of land with a suitable combination of topography and soils near major streams for large-scale gravity irrigation as is general in southern Australia.

Over the last 12 years the Water Resources Branch of the Northern Territory Administration (Anon. 1963) has established many gauging stations. Some selected discharge data for stations in or near the survey area are given in Table 16. As the station on the Katherine River at Katherine has a record of 11 years, its average discharge is given, as well as a near-average year (1961–62). For the other stations, only the discharge for 1961–62 is given. Periods of high flow are restricted to the period January to April. However, the streams listed are unique in the Northern Territory in having significant spring-fed flow throughout the dry season. This flow offers considerable scope for irrigation by pumping on the small areas of suitable land along the rivers. For example, even in October, when irrigation requirements are at a maximum (of the order of 10–12 in. per month), approximately 20,000 ac could be supplied with irrigation water.

Also, the Water Resources Branch (Anon. 1963) is initiating a study of ground water conditions in the Daly River Basin. This should make possible the definition of the supply and suitability of ground water for both stock and quality use and irrigation.

VI. Distribution of Potentially Arable Soils

A simplified soil map showing the most extensive soils is presented as an inset on the land system map. The groupings used, which were selected on the basis of similarity of agricultural characteristics, are different from those used in the description of the soils. The relationship of these groupings to soil families is shown below:

Loamy red and yellow earths	Tippera, Xanthippe, and Elliott
Sandy red and yellow earths	Blain, Elaine, Venn, Vivienne, Cockatoo, Coralie, Elizabeth, and Cullen
Sandy brown earths	Florina
Grey-brown cracking clays	Cununurra
Skeletal	Skeletal soils and outcrop

The red earths on alluvium (Katherine, Manbulloo, Daly, and Edith), the mottled greyish brown earths (Marrakai), the prairie–rendzina complex (Witch Wai, Ingrid, and Phillips), and the alluvial regosols are minor components of land systems.

In view of crop–soil relationships discussed in the previous section, only the first two groups—loamy red and yellow earths and sandy red and yellow earths—are considered as potentially arable soils. Their estimated areas are shown in Table 17. These estimates should not be interpreted literally but used only as a guide to the likelihood of occurrences of unit areas of 200 ac or more of arable land. In total, it appears that there are approximately 900 sq miles of loamy red and yellow earths, approximately 800 sq miles of sandy red and yellow earths, and approximately 100 sq miles of various soils including red earths on alluvium, sandy red earths, and loamy red and yellow earths.

VII. Economic Factors and Possibilities of Agricultural Development

In 1959 the Commonwealth Minister for Territories appointed a committee (the Forster Committee) to inquire into the prospects of agriculture in the Northern Territory. They have reported and made recommendations (Commonwealth of Australia, Department of Territories 1960) on all aspects associated with agricultural development, including land resources, land clearing, present agricultural knowledge, budgets for various types of farming enterprises, water supplies, transport, land tenure, credit and finance, government services, pilot farms, and requirements for land development. Because of the lack of commercial farming in the area they recommended the establishment of pilot farms to test experimental findings under commercial conditions. Two types of pilot farms were considered for the Tipperary area.

Table 17

ESTIMATED AREAS OF POTENTIALLY ARABLE LAND IN THE VARIOUS LAND SYSTEMS

Land System	Major Soils (see inset on Land System Map)	Estimated Area of Potentially Arable Soils (sq miles)	
		Loamy Red and Yellow Earths	Sandy Red and Yellow Earths
Mullaman Yujullowan	Skeletal soils and sandy brown earths	—	—
Beemla Woggaman Chinaman	Mainly sandy brown earths	—	—
Yungman Claravale Wallingin	Sandy brown earths, sandy red earths, and skeletal soils	— — —	100 150 75
Blain Karaman	Mainly sandy red earths	— —	450 40
Tagoman Budbudjong	Loamy red and yellow earths and skeletal soils	50 15	— —
Maranboy Jindara	Loamy red and yellow earths and sandy brown earths	30 200	— —
Wriggley Douglas Kimbyan	Mainly loamy red and yellow earths	250 40 300	— — —
Green Ant Wongalla Banyan	Grey-brown cracking clays with many other soils	Probably approx. 100 sq miles of soils that would mainly behave like loamy red and yellow earths	
Total		985	815

It was concluded that an arable farming system based on peanuts could not be recommended at this time because the estimated cost of production was high in relation to likely market returns from peanuts for oil production, and the more lucrative confectionery market is fully supplied from Queensland production.

It was recommended that pilot farms should be established in the Tipperary land system to assess the commercial feasibility of cattle-fattening on improved pastures in the wet season. No pilot farms have been established to date.

Since that time considerable progress has been made in dry-season cattle feeding. As mentioned in Part IX, Norman (1963) has shown that the dry standing native pasture is a moderate source of energy which can be effectively utilized during the dry season if cattle are given small amounts of high-protein supplement. The energy value of the native pasture is destroyed by early storms in October–November.

Norman and Stewart (1964) have shown that good liveweight gains in the dry season can be achieved by grazing dry standing hay of Townsville lucerne and bulrush millet, both of which maintain much higher protein contents than dry standing native pasture. A farming system based on these two crops would take maximum advantage of the climatic pattern of the area. The wet season provides the means of growing introduced annuals with the special characteristic of maintaining adequate protein content as dry standing feed; the reliably dry and warm winter permits this feed to be utilized at will without fear of loss from frost or rain.

An assessment of the economics of such a farming system is now being made by an interdepartmental committee, with a view to the establishment of pilot farms.

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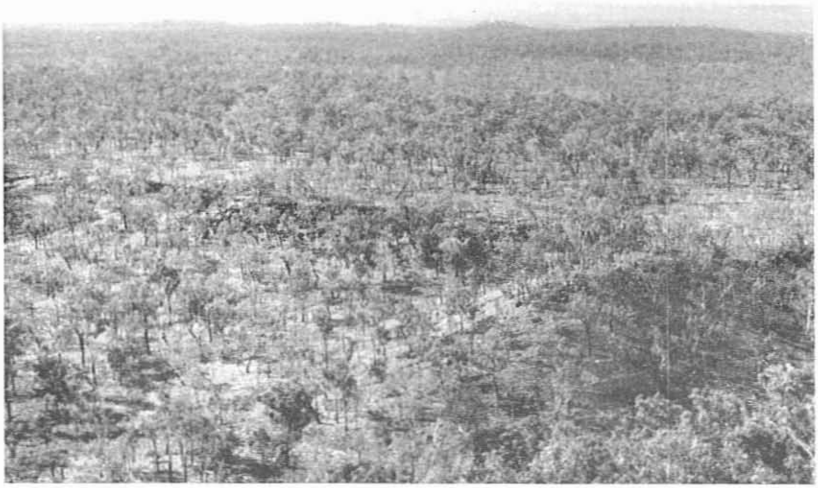

Fig. 1.—The basic mapping unit is the land system (an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation); e.g. in Jindara land system (No. 6), comprising undulating terrain underlain by deeply weathered and relatively unweathered sandstone, siltstone, and limestone, and carrying savannah woodland, the recurrence of the land units indicated by numbers (described in the text) is very evident.

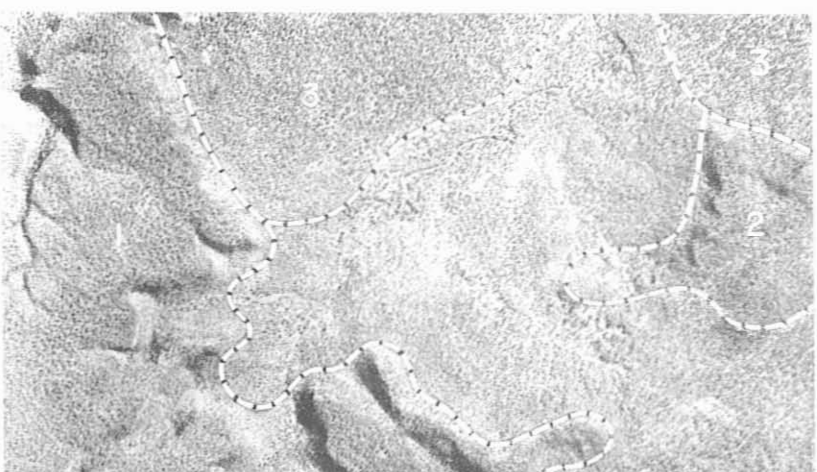

Fig. 2.—The method of survey is based on the fact that the pattern of topography, soils, and vegetation of each land system is expressed by a distinctive pattern on a trial photograph. This aerial photograph shows: (1) Extensive stable high plateau with uniform vegetation pattern of Mullaman land system; (2) stony low plateau and rocky hill slopes of Yujullowan land system; (3) gently undulating terrain of Claravale land system; (4) undulating terrain with minor lateritic plateau remnants and restricted alluvial plains (Woggaman land system).

Fig. 1.—An understanding of the evolution of the physical landscape is provided by the recognition of a number of erosional and depositional surfaces. In this photograph, the oldest landscape element, the deeply weathered Bradshaw surface, forms plateau remnants (Mullaman land system) on the skyline. A second erosion surface, the Maranboy surface, has been dissected into lower stony plateaux and hills (Yujullowan land system). Undulating terrain (Jindara land system) eroded between the Maranboy and Tipperary surfaces occurs in the lowest parts of this landscape.

Fig. 2.—A third stage of erosion produced an extensive younger erosion surface, the Tipperary surface, commonly separated from the Maranboy surface by low escarpments. This surface comprises plains and very gently undulating terrain, with extensive alluvial–colluvial mantles. This photograph shows the sandy plains of the Tipperary surface (Blain land system) downslope from a dissected remnant of the Maranboy surface (Yujullowan land system).

Fig. 1.—Fire has always been a feature of the area and has exercised a selective influence on the vegetation. Burning is almost the only form of pasture management practised by cattlemen, the pastures being burned as soon as possible after the wet season. Recent work at Katherine has shown that burning decreases productivity, but as controlled burning is necessary to prevent destructive wild fires it is recommended that burning be carried out as late as possible in the dry season and at two-year intervals.

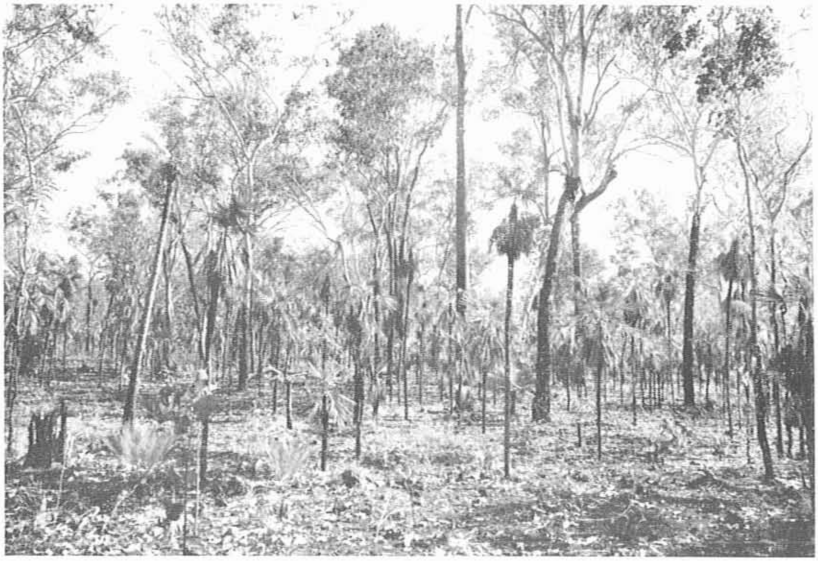

Fig. 2.—The land systems can be grouped according to their pattern of pastures into six pasture lands. Plateaux spinifex country (Mullaman and Yujullowan land systems) is characterized by spinifex–tall grass pastures and tall open forest. Stocking capacity is limited by steep escarpments and rocky terrain.

Fig. 1.—Undulating spinifex country is mainly on deeply weathered rocks, with stony slopes and extensive sandy and shallow gravelly soils. It is characterized by spinifex–tall grass pastures with small areas of better perennial grasses. Stock-carrying capacity is low.

Fig. 2.—Tropical tall grass country comprises seven land systems with predominantly tropical tall grass pastures. It is flat or undulating with mainly reddish clay loam soils. Stock-carrying capacity is moderate during the wet season but stock lose weight during the dry season.

Fig. 1.—Mixed tropical grass country (Blain land system) is characterized by annual grasses with scattered perennials and smaller areas of tropical tall grass. It comprises plains of alluvium–colluvium with reddish sandy or loamy soils.

Fig. 2.—Agriculture is confined to a few small farms along the levees of the major streams. In their development phase peanuts for the confectionery trade were their major crop, but many of the original areas cleared are not now regularly cropped. In the post-war years considerable research has been undertaken on cash crops (peanuts, sorghum, cotton), fodder crops (bulrush millet, fodder sorghums, cowpeas), and improved pastures (buffel grass, birdwood grass, and Townsville lucerne).

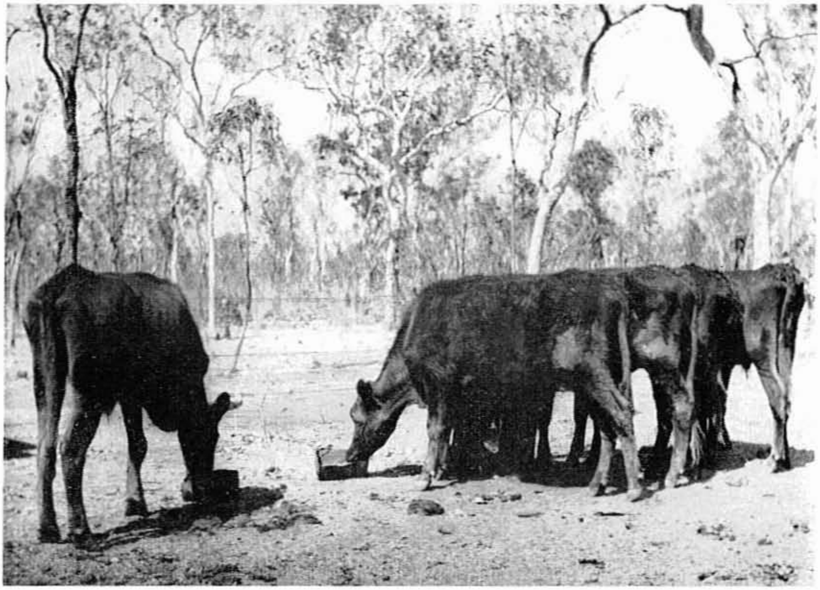

Fig. 1.—Cattle are in very poor condition in the late dry season because of the low protein content of the dry standing native pastures. This has been the major factor limiting development of the cattle industry in the area to large open-range stations at very low stocking rates (4 cattle/sq mile).

Fig. 2.—Improved pastures dominated by Townsville lucerne (here shown with buffel grass) maintain a high protein content when dry and cattle continue to gain weight throughout the dry season on these pastures.