The Lands and Pastoral Resources of the North Kimberley Area, W.A.

Comprising papers by N. H. Speck, Janice Bradley, M. Lazarides, R. A. Patterson, R. O. Slatyer, G. A. Stewart, and C. R. Twidale

Land Research Series No. 4

Commonwealth Scientific and Industrial Research Organization, Australia

Melbourne 1960

Printed by C.S.I.R.O., Melbourne

CONTENTS

Maps

SUMMARY AND GENERAL RECOMMENDATIONS

(1) A rapid reconnaissance survey of the North Kimberley area, Western Australia (34,000 sq. miles), was conducted in 1954 by the C.S.I.R.O. Land Research and Regional Survey Section (now the Division of Land Research and Regional Survey).

(2) Because of the very rugged nature of much of the area it has remained undeveloped and relatively unexplored in spite of its high rainfall.

(3) The climate is monsoonal, the rainfall of 25 to 50 in. being almost entirely confined to the summer six months.

(4) The vegetation is mainly woodlands, or open forests dominated by the genus *Eucalyptus*.

(5) Skeletal soils are the most extensive but there are also large areas of deep sandy soils. There is also a range of other soils, mostly associated with volcanic rocks.

(6) Nine land systems (types of country) have been described and mapped and their cattle-carrying capacity has been assessed.

(7) This investigation supports the findings of earlier explorations that parts of the area are suitable for cattle-raising. They have remained undeveloped because of their inaccessibility.

(8) On general northern Australian standards the pastures are only moderate to very poor, their estimated carrying capacity ranging from 10 beasts to nil per sq. mile. Development will be practicable only if areas of poorer pastures are utilized in conjunction with areas of moderate pastures.

(9) In the area suitable for development for cattle, excluding the existing Gibb River and Karunjie stations, the total estimated carrying capacity is approximately 57,000 head. If stock numbers of 7000 to 8000 head per lease are required, then there is scope for only seven leases.

(10) In general the area is well watered but additional water points will be required in some parts.

(11) The steep scarps and rugged terrain make access to some areas difficult and care should be taken in designing the leases to ensure that parts are not cut off by scarps.

(12) By forming natural barriers the scarps, etc., will reduce the amount of fencing needed for adequate stock control.

(13) There are no known economic methods of raising the nutritive level of the native pastures. Pasture improvement by the introduction of buffel grass and Townsville lucerne may be possible in some areas.

(14) Small-scale agriculture, either irrigated or dry-land, would be warranted at the present time only for fodder to maintain horses in good working condition.

(15) The provision of a suitable outlet for cattle is essential for development of the area.

PART I. INTRODUCTION TO THE LANDS AND PASTORAL RESOURCES OF THE NORTH KIMBERLEY AREA, W.A.

By G. A. Stewart*

The North Kimberleys are one of the least known portions of the Australian continent. The annual rainfall ranges from 25 to 50 in. and the country is fairly well watered by such rivers as the Drysdale, King Edward, Mitchell, Prince Regent, Charnley, and Isdell. In spite of this the area is only partly explored and is largely unoccupied. Apart from Kalumburu Mission† and an adjacent pastoral lease near the north coast, and Kunmunya Mission‡ and Munja Aboriginal Reserve on the west coast, the only country occupied is along the southern margin, which is the northern fringe of pastoral development, e.g. Karunjie, Gibb River, and Mt. House stations. The major obstacle to exploration and development has been the difficulty of access from the south and east and the large areas of very rugged terrain.

The first general exploration was made by Surveyors Brockman and Crossland in 1901. Their report indicated at least five million acres of good pasture country and following this most of the land was taken up under pastoral lease by 1904. The leases were soon abandoned, principally because of their inaccessibility. In 1921 Surveyor Easton (1922) accompanied by the Government Botanist, C. A. Gardner, explored parts of the North Kimberleys and confirmed the earlier report. Other than the recently granted pastoral lease near Kalumburu Mission there was no subsequent effort at land development.

I. Origin of Survey

In June 1953 the Prime Minister received a request from the Premier of Western Australia for Commonwealth assistance in a project to provide access roads and to carry out surveys, mapping, and land classification in the North Kimberleys in order that the area might be opened up for pastoral development. As a result of inter-departmental and State and Commonwealth consultations, the following arrangements were made:

(1) The Surveyor General's Office, Western Australia, was to organize a land survey party to work in the field from April to October 1954. It included the following sections: a pack horse reconnaissance section to confirm, on the ground, routes of access for road construction; a transport section; a survey section to carry out ground surveys; and a road construction section.

(2) The Division of Land Research and Regional Survey of C.S.I.R.O., which had previously made resources surveys in adjacent areas to the east, was to make a preliminary land classification by aerial photo interpretation, and to make available

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

† Previously called Drysdale Mission (Easton 1922).

‡ Previously called Port George IV Mission (Easton 1922). The Surveyor General, W.A., advises that the mission does not now exist.

an ecologist and a specialist on native pastures for field investigations so that the field data collected could be used to correct and amplify the preliminary assessment.

(3) The Bureau of Agricultural Economics was to make available an officer to study the economic aspects of cattle production in the area.

The activities of the first group have been recorded by Morgan (1955). The work of C.S.I.R.O. was first recorded in unpublished interim reports dealing with the eastern half of the area (May 26, 1955) and the western half of the area (July 18, 1955).

This report contains all the information included in the interim reports but presentation has been modified and some additional data are provided.

As a result of the activities of the various groups mentioned above, parts of the area have been made available for pastoral leasing by the Lands and Surveys Department, Western Australia.

II. Survey Procedure

In December 1953 a very rapid aerial photo interpretation was carried out by the author and Miss J. Bradley of this Division and D. M. Traves and J. Rattigan, geologists of the Commonwealth Bureau of Mineral Resources. The author and Traves and Rattigan had previously carried out geological and other surveys in adjoining areas to the east and south and this knowledge was of great value in the aerial photo interpretation.

In January and February 1954, Miss Bradley and the author made a more detailed preliminary aerial photo interpretation and prepared tentative descriptions of the 14 mapped units. Possible routes for access roads were indicated and the route followed by Easton in 1921 was plotted on to the aerial photographs. The preliminary report and maps were distributed to other participating departments in March 1954.

Between August 25 and September 15, 1954, field traverses were carried out by N. H. Speck (ecologist) and M. Lazarides (pasture botanist) of the Division of Land Research and Regional Survey, accompanied by R. A. Patterson of the Bureau of Agricultural Economics. Except for some short detours, the traverses were confined to the new tracks opened up by the Western Australia Surveyor General's party. The traverse routes were plotted on the aerial photos and, by means of continuous notes on the vegetation, soil, topography, and geology, the land characteristics were related to the aerial photo patterns. Detailed observations of soil profiles and vegetation communities were made at selected typical sites. The final photo interpretation and mapping were done by Speck and Lazarides. Their field data were correlated with those from the adjacent Ord–Victoria area as a basis for the final assessment of stock-carrying capacities.

III. Acknowledgments

This project has been one of cooperation between various departments, both State and Commonwealth. The Surveyor General's Office, Western Australia, which was the major force in the project, gave considerable assistance in the provision and transport of petrol and food supplies in the field. C. A. Gardner, Government Botanist of Western Australia, visited Canberra in February 1954. Because of his personal knowledge of the area he was of considerable assistance in the preliminary air photo interpretation. Also he added to the botanical field work by his field knowledge and the identification of specimens. The Department of Army provided four-wheel drive vehicles for the use of our officers in the field, and the Surveyor General's Office arranged the transport of these vehicles to Wyndham. The Bureau of Mineral Resources kindly permitted D. M. Traves and J. Rattigan to assist in the first aerial photo interpretation.

IV. References

Easton, W. R. (1922).—Report on the North Kimberley district of Western Australia. W. Aust. Dep. North-west Publ. No. 3. (Govt. Printer: Perth.)

Morgan, J. F. (1955).—Report on central North Kimberley region. North Kimberley Survey and Mapping Expedition 1954. (Govt. Printer: Perth.)

PART II. CLIMATE OF THE NORTH KIMBERLEY AREA, W.A.

By R. O. Slatyer*

I. Introduction

The climate of the area has been described by Koppen (1936) as tropical savannah with a distinct dry season in winter. Nearly all the rainfall is received in the five-month period November to March, although some rain is also received fairly regularly in late October and early April. The remainder of the year is almost rainless, particularly the months of August and September.

Maximum daily temperatures seldom fall below 85° F and even in winter, night temperatures remain sufficiently high to preclude frost occurrence in all but the most inland areas and parts of the highlands, where occasional frosts occur.

II. General Climatic Characteristics

(a) *Rainfall*

Total annual rainfall decreases in a south-easterly direction from about 50 in. on the coast to 25 in. at the most inland localities (Fig. 1). Data are available for only three stations within the area but they enable a general picture of changes in rainfall characteristics to be obtained (Table 1 and Fig. 2).

The number of months in which an appreciable amount of rain is received falls sharply from Kunmunya to Gibb River. Intensity of rainfall and number of wet days per year likewise decrease with decreasing annual rainfall.

(b) *Temperature and Humidity*

Within the surveyed area the only temperature and humidity recording station (now abandoned) was at Kunmunya (formerly Kwinana or Port George IV Mission), but the Bureau of Meteorology (1939) has published maps showing that temperature and humidity conditions at Derby (Fig. 3) are similar to the general conditions which obtain in the remainder of the area. Conditions on the coast near Kalumburu (formerly called Drysdale) are less extreme than those at Derby, and near Gibb River they are more extreme, but the differences are of a rather small order and do not change the general picture.

From Figure 3, where data from Kunmunya and Derby are given, it can be seen that maximum temperatures at both stations are high throughout the year, remaining at over 85°F even in the coolest months. Minimum temperatures likewise seldom fall below 55°F although in the inland areas lower recordings could be expected. In general the temperatures are lower at Kunmunya by several degrees, and reflect a generally milder, less arid climate. The annual range in mean monthly maximum temperature is very narrow at Kunmunya (86–93°F), although even at Derby (85–97°F) it is not wide when compared with stations at high latitudes. The

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

range in minimum temperatures is considerably greater at both stations. An interesting feature of the annual rainfall regime at Kunmunya is the marked depression in maximum temperatures in the months December to March which accompanies the heavy wet-season rains and results in a double peak in the curve. The depression in the curve at Derby is only slight and a second peak does not occur.

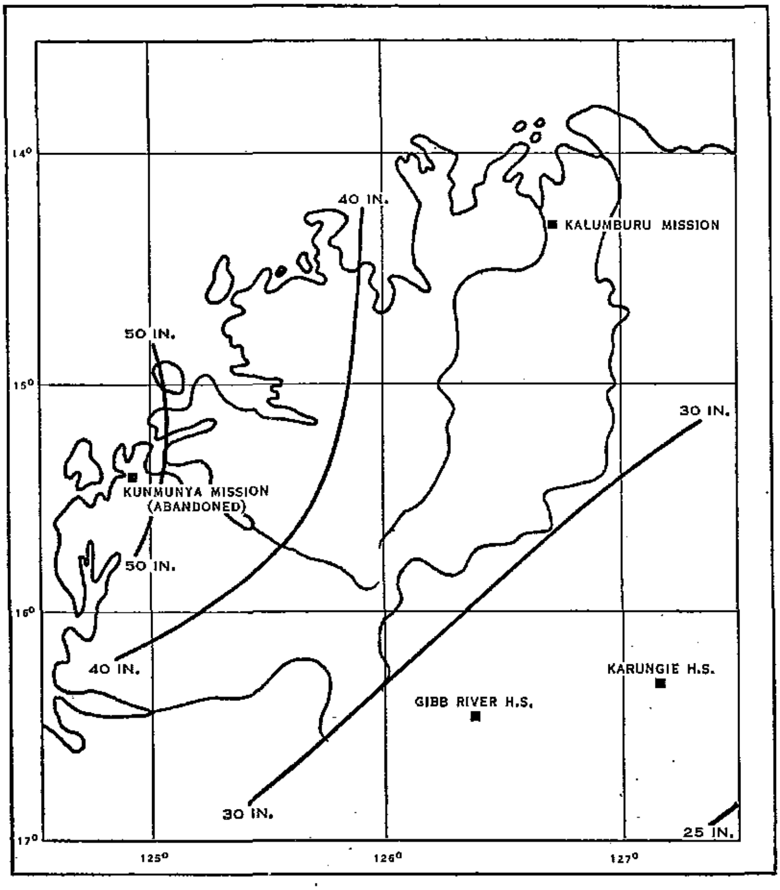


Fig. 1.—Annual rainfall isohyets showing the decreasing rainfall towards the south-east.

The 9 a.m. relative humidity picture is similar at both stations and shows a rather even curve throughout the year, although the earlier onset of rainfall at Kunmunya is reflected in higher humidities towards the end of the year, compared to Derby.

The absence of more temperature stations within the area precludes a discussion of frost occurrence, but Foley (1945) considers that frosts are rare, the northern areas being virtually frost-free and the southern portions having occasional frosts in some years in midwinter, probably only in topographically suited localities.

III. Climate in Relation to Plant Growth

(a) *Dry-land Agriculture*

To assess the relationship of climate to possible dry-land agricultural development in this area, the procedure of Christian and Stewart (1953) has been used. This method allows the time of commencement and length of the agricultural growing period to be estimated, as well as the occurrence of "false starts" to, and of breaks within, the growing period.

Table 1

ANNUAL RAINFALL CHARACTERISTICS AT KUNMUNYA, KALUMBURU, AND GIBB RIVER*

	Kunmunya	Kalumburu	Gibb River
Years of record	33	40	31
Mean annual rainfall (in.)	50·56	37·17	29·07
Number of rainy days	80	77	60
Rain per wet day (in.)	0·63	0·48	0·48

* Data from Commonwealth Meteorological Branch, Melbourne.

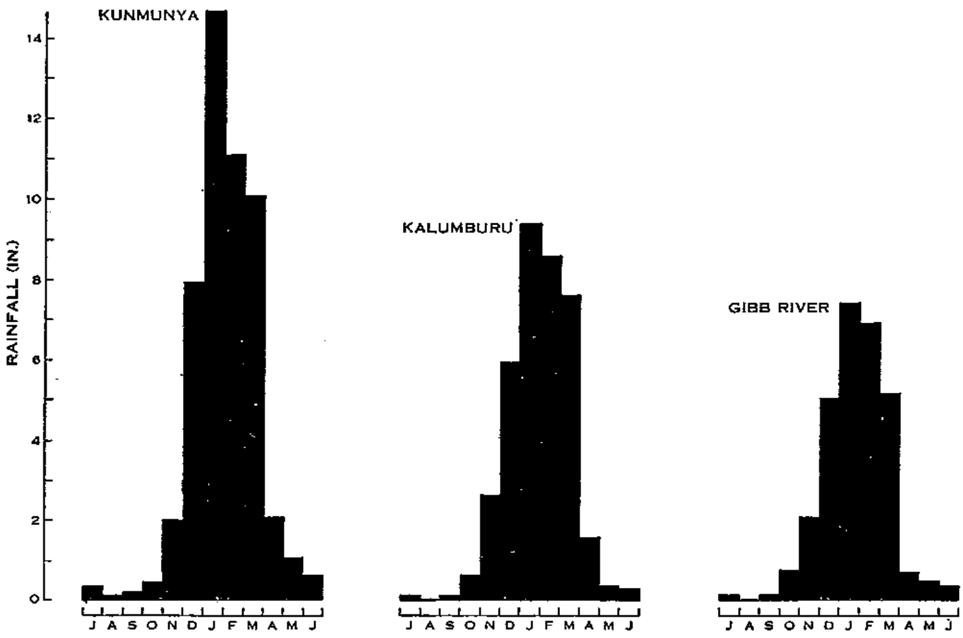


Fig. 2.—Distribution of rainfall throughout the year for the three recording stations within the area.

By this method the mean date of commencement of the agricultural growing period is estimated to be December 14 at Kalumburu and January 11 at Gibb River.

The length of the period is likewise appreciably shorter at Gibb River (14·3 wk) than at Kalumburu (18·3 wk).

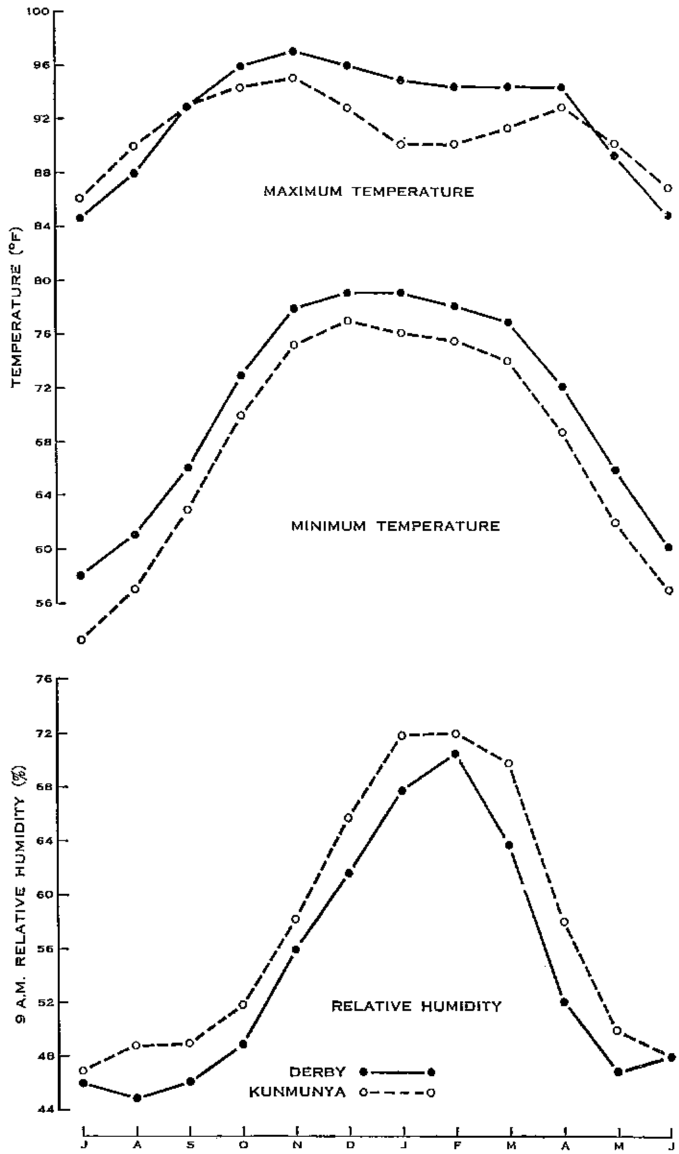


Fig. 3.—Maximum and minimum temperatures and relative humidity data for Derby (adjacent coastal station outside the area) and Kunmunya.

Variability in the time of commencement of the growing period is of much the same degree at each station, being approximately 2·7 wk about the mean date of commencement. This is a moderate figure for variability, and is similar to that experienced at Katherine, N.T. False starts occur in 45 per cent. of the years at Gibb River. At Kalumburu false starts occur only one year out of four, and at Kunmunya one year in six. At all stations they occur most commonly at the beginning of December.

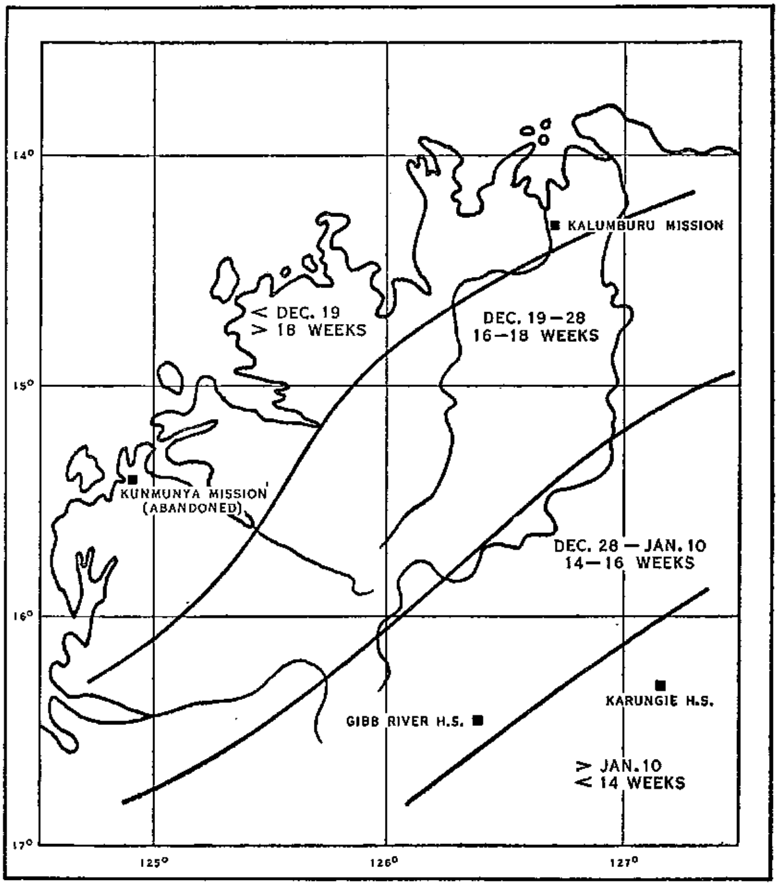


Fig. 4.—Regional subdivisions of the area based on calculated length of growing period for agricultural purposes.

The length of the agricultural growing period is also subject to variability of a moderate order. In Table 2, where details concerning the growing period are given, figures are included which show the percentage of years at each station in which the growing season exceeded 12 and 16 wk.

In Figure 4 regional subdivisions based on the growing period have been drawn. These subdivisions are based on the data for the three stations discussed, and also on data from stations beyond the area to the south and east.

(b) *Natural Pastures*

The period each season during which useful growth can be expected by natural pastures has been assessed by a method developed by Slatyer and Christian (1954) which is based largely on the earlier work of Christian and Stewart (1953). This method has particular application to the responses of perennial pastures on heavy soil, but the results can be interpreted in regard to other pasture groups on a range of soil types. When applied to Kunmunya, Kalumburu, and Gibb River, this procedure indicates that the period of useful pasture growth commences in early December and has an average length at the three stations of 22·0, 21·7, and 19·5 wk respectively (Table 3). The time of commencement of the period is very similar at all stations. This is because light falls of rain which would have caused "false starts" if the agricultural growing period were being considered, are adequate to initiate pasture growth. Although such falls are of less intensity inland than on the coast, they occur throughout the area at much the same time, and this is reflected in earlier times of commencement of the period of useful pasture growth.

TABLE 2

ESTIMATED AGRICULTURAL GROWING PERIOD AT KUNMUNYA, KALUMBURU, AND GIBB RIVER

	Kunmunya	Kalumburu	Gibb River
Mean time of commencement	Dec. 14	Dec. 14	Jan. 11
Mean variability in time of commencement (wk)	±2·7	±2·7	±2·6
Mean length of estimated growing period (wk)	20·5	18·3	14·3
Percentage of years in which length of growing period equals or exceeds 12 wk	100	100	73
16 wk	92	73	46

TABLE 3

PERIOD OF USEFUL PASTURE GROWTH AT KUNMUNYA, KALUMBURU, AND GIBB RIVER

	Kunmunya	Kalumburu	Gibb River
Mean time of commencement	Dec. 6	Dec. 6	Dec. 8
Mean variability in time of commencement (wk)	±2·7	±2·7	±2·4
Mean length of period of useful pasture growth (wk)	22·0	21·7	19·5
Percentage of years in which the period equals or exceeds 12 wk	100	100	96
16 wk	96	100	92

Because less rain is needed to sustain pasture growth there is much less variation in the length of the period of useful pasture growth at the different stations than there is with the agricultural growing period. On all stations the average length of the period is over 19 wk, and in nearly all the years examined periods of 16 wk or longer were recorded at each station.

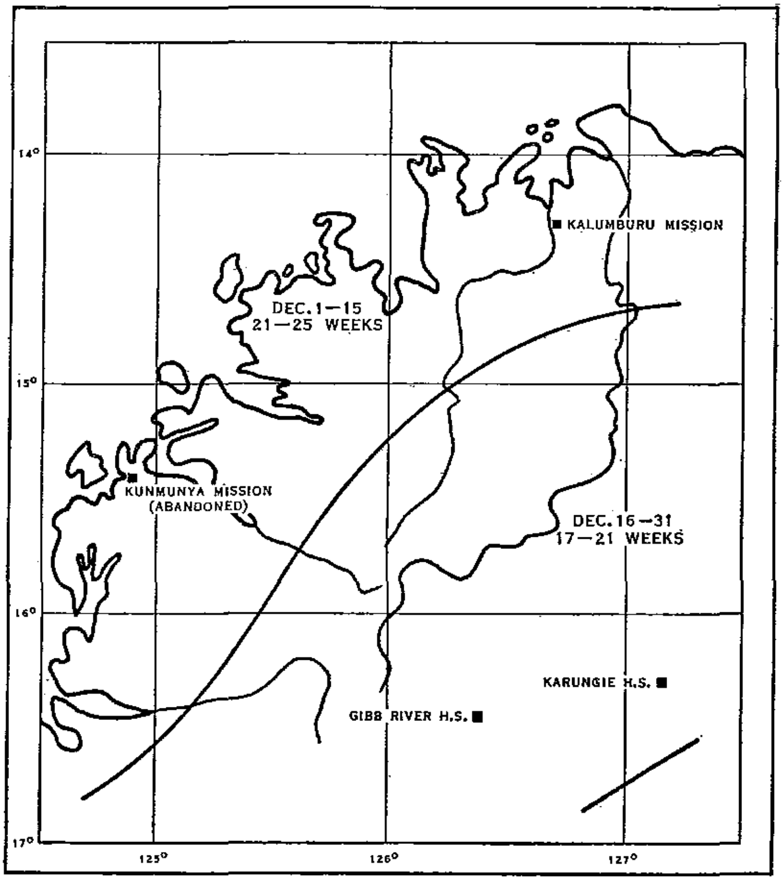


Fig. 5.—Calculated time of commencement and length of useful pasture growing period for various parts of the area.

The period of useful pasture growth may be made up not only of one unbroken period, but of two or three short periods between which rain is inadequate for growth. This is because a period of dry weather which would kill crop plants merely renders perennial pasture plants dormant, and growth is resumed when further rain falls. At Kalumburu there is usually only one period of growth, a break occurring in about one-third of the years. The usual length of the break is 3–4 wk, and more than one break per season is of rare occurrence. At Gibb River a break occurs in more than half of the years, although more than one break per season is unusual. Here again the average length of the break is 3–4 wk. Breaks in the growing period at Kunmunya are rare, and seldom exceed 2 wk.

In Figure 5 the time of commencement and length of the period of useful pasture growth are shown on a regional basis. This figure is made up, as is Figure 4, from data from stations beyond the area, as well as Kalumburu and Gibb River.

IV. Discussion

On the basis of climate alone, it appears that the northern and north-western parts of this area would be suitable for permanent agriculture. In the central and southern parts, although the growing period would be too short for crops, the production of short-season fodder crops would be practicable. Unfortunately, however, the limited extent of suitable soils severely limits the possibilities of agricultural development (see Part IX).

On the basis of the figures quoted earlier for the length of the period of useful pasture growth, it would appear that from the point of view of moisture supply the area as a whole would be very reliable stock country, with droughts most unusual. Although the figures quoted refer particularly to pasture growth by perennial species on heavy soils, because of the rainfall reliability they should apply with only slight modifications to areas of light soils. In general the pastures are dominated by tall coarse perennial grasses which lose their nutritive value in the dry season (see Part VII).

V. References

Bureau of Meteorology (1939).—"Climatological Atlas of Australia." (Govt. Printer: Melbourne.)

Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine-Darwin region, 1946. C.S.I.R.O. Aust. Land Res. Ser. No. 1: 27–31.

Foley, J. H. (1945).—Frost in the Australian region. Bur. Met. Aust. Bull. No. 32.

Koppen, W. (1936).—Das Geographische System der Klimate. In "Handbuch der Klimatologie", vol. 1, pt C. (Borntraegter: Berlin.)

Slatyer, R. O., and Christian, C. S. (1954).—Climate of the Barkly region. C.S.I.R.O. Aust. Land Res. Ser. No. 3: 17–33.

PART III. GEOLOGY OF THE NORTH KIMBERLEY AREA, W.A.

By N. H. SPECK*

I. INTRODUCTION

The compilation of this report on the geology of the North Kimberley area, together with the included map (geology of the North Kimberley area) and geological cross-sections (Fig. 6), is based upon photo interpretation and limited field traverses.

D. M. Traves, who had previously carried out geological surveys in the adjacent Ord–Victoria area, provided notes on the probable stratigraphy of the area and advice during the photo interpretation. Observation in the field was limited to approximately 500 miles of traverse as indicated on the map. Several times during these traverses the author conferred with J. E. Harmes (geologist, Broken Hill Proprietary Co. Ltd.), who was in the area at the same time.

Because of the comparatively simple stratigraphic nature of the country, with prominent and often continuous scarps extending for great distances, it was possible to extend the photo interpretation to cover the whole of the North Kimberley area. The mapping was correlated with the geology of the adjoining Lennard River sheets (Guppy *et al.* 1958).

II. STRATIGRAPHY

Unlike the adjacent Ord–Victoria area, in which rocks of almost all systems are represented (Traves 1955), the North Kimberleys consist almost entirely of rocks that are considered to be of Upper Proterozoic age.

Stratigraphic units will be discussed under the headings of (*a*) Lower Proterozoic, (*b*) Upper Proterozoic, (*c*) Rocks of Uncertain Age, and (*d*) Quaternary.

(*a*) *Lower Proterozoic*

Lower Proterozoic rocks of the Lamboo complex occur along the south-western margin of the area. They have been described (Matheson and Guppy, unpublished data, 1949) as "undifferentiated massive granite, granite gneiss and undigested remnants of both the McClintock Greenstones and Halls Creek Group". Both Traves (1955) and Guppy *et al.* (1958) consider them to be younger than the Halls Creek metamorphics and older than the Upper Proterozoic described below, and they conclude that their age is Lower Proterozoic.

These rocks were not examined in the field. Their location and relationship to younger rocks are shown on the geological map and sections. Land systems have not been described or mapped for the area of these rocks and the north-eastern edge of the Lamboo complex forms the south-western margin of the land system map.

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

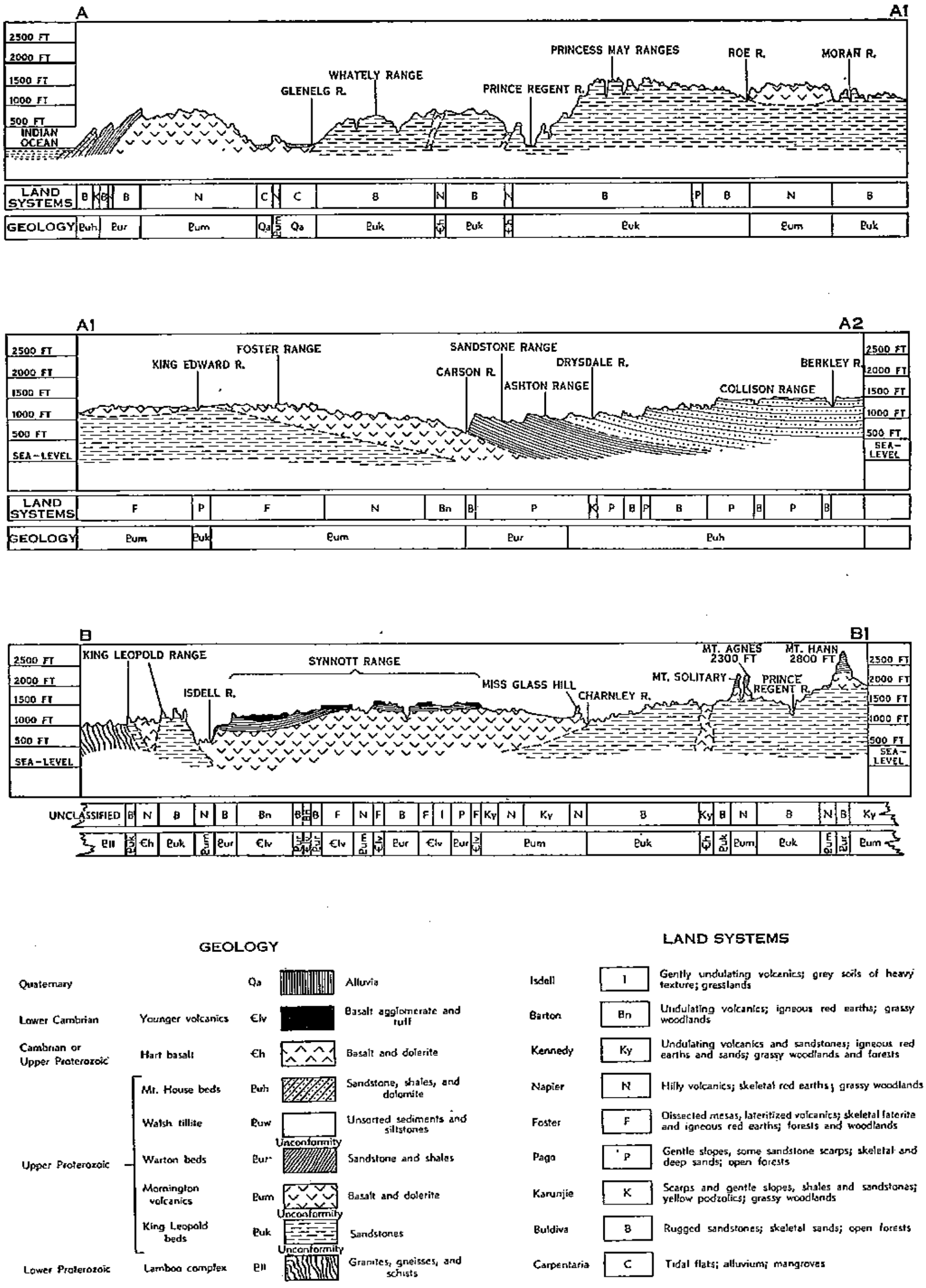


Fig. 6.—Geological sections corresponding to *A–A*1–*A*2 and *B–B*1 on geology map. Relationships between geology, topography, and land systems are shown.

(b) Upper Proterozoic

These rocks have previously been referred to as "Nullagine" but Traves (1955) rejects this name as not applicable. They extend from the south-west corner of the area right across the North Kimberleys into the Ord–Victoria area.

Guppy *et al.* (1958), working to the south of the North Kimberleys, have divided the rocks into six units: King Leopold beds, Mornington volcanics, Hart basalt, Warton beds, Walsh tillite, and Mt. House beds. All of these, with the exception of Walsh tillite and Hart basalt, were observed during field reconnaissance and the boundaries have been traced on aerial photographs.

(i) *King Leopold Beds.*—This formation is described by Guppy *et al.* (1958) as follows: "The King Leopold Beds crop out typically in the King Leopold and Precipice Ranges; and outcrops extend east into areas not systematically mapped during this survey. The sediments, mainly quartzite, with shaly beds and a basal conglomerate, unconformably overlie the Lamboo Complex and are unconformably overlain by the Mornington Volcanics. The name is derived from the King Leopold Ranges (Long. 125° 25′ E., Lat. 17° 2′ S.)."

Traves (1955) describes this basal formation of the Upper Proterozoic sediments on the Kimberley Plateau as consisting of medium to coarse, strongly jointed, friable to silicified sandstone, with basal beds that are in places conglomeratic.

These massive sandstones occupy, except where overlain by Mornington volcanics, almost the entire western half of the North Kimberleys. No outcrops of these rocks occur in the eastern half of the area except in the extreme south-east.

(ii) *Mornington Volcanics.*—These were described (Guppy *et al.* 1958) as an andesitic suite of volcanics that unconformably overlie the King Leopold beds, and they are conformably overlain by the Warton beds. The King Leopold beds were uplifted and eroded to an irregular land surface before the outpouring of the Mornington volcanics buried that surface to greatly varying depths. They outcrop to the west of the lower scarp of the Warton beds and form a continuous north–south band across the area. These rocks also cover extensive areas in the vicinity of Mitchell, Moran, and Charnley Rivers, and near Kunmunya Mission and Munja Aboriginal Reserve. In the west and south-west the Mornington volcanics are in places overlain by Warton beds which are in turn overlain by younger volcanics (Fig. 6). Numerous smaller areas of Mornington volcanics are found in the hollows and depressions of the King Leopold beds. They are absent from the eastern part of the area except the extreme south-east where there is a thin band of volcanics, which are probably Mornington, exposed between the King Leopold beds and the Warton beds. In places these volcanics occur as dissected mesas, the tops of which are heavily lateritized.

(iii) *Warton Beds.*—This unit, named from the Warton Range, 30 miles east of Mt. Clifton (Long. 126° 27′ E., Lat. 17° 24′ S.), outcrops over a large area of the Kimberley Plateau. Guppy *et al.* (1958) described the rocks as white to light brown, well-bedded, medium-grained to fine conglomeratic quartzite, red micaceous sandstone, and shale.

There is a shale unit of several hundred feet towards the centre of the sequence. This appears in the lower part of a conspicuous scarp that can be identified readily on the air photos (Plate 1, Fig. 1). Also the basal beds of Warton sediments overlying the volcanics almost invariably form a prominent scarp. These two scarps have been traced almost continuously from north to south of the area.

Guppy *et al.* (1958) suggest that the unit is apparently conformable with the underlying Mornington volcanics but that it is overlain unconformably by both Walsh tillite and Mt. House beds.

As well as outcropping as a continuous north–south band in the eastern half of the area, the unit appears as outliers overlying parts of the volcanics in the west.

(iv) *Walsh Tillite.*—The Walsh tillite is named from outcrops in the head-waters of Walsh Creek (Long. 125° 35′ E., Lat. 17° 12′ S.). Its only occurrences within the area are on the Traine River (a tributary of the Hann River) and in another small area a few miles further west. The formation unconformably overlies the Warton beds and is conformably overlain by the Mt. House beds.

The formation was not seen during the reconnaissance but is described by Guppy *et al.* (1958) as follows: "In the type area at Walsh Creek the formation consists of a completely unsorted sediment ranging in grain-size from silt to boulders up to 7 feet across; the bedding is absent or very crudely developed. The matrix consists of grey-green and red siltstone and unsorted sandstone. Erratics are predominantly quartzite of types occurring in Warton Beds, together with a few igneous rocks. Boulders are commonly faceted and striated.

"The thickness of the formation varies. A study of the outcrop pattern on aerial photographs indicates that it occurs as lenses rather than a continuous deposit over a large area. No evidence of the age of the Tillite has been discovered, and it is tentatively placed in the Upper Proterozoic."

(v) *Mt. House Beds.*—The Mt. House beds is the name given by Guppy *et al.* (1958) to the interbedded siltstone and quartzite with bands of limestone and dolomite which crop out in the vicinity of Mt. House.

Traves (1955) in describing the section south of Mt. Cockburn in the East Kimberleys states that the Mt. House beds commence with 1000 ft of medium-bedded sandstone which probably contains some dolomite and shale beds. This is overlain by 1000 ft of shale with their beds of dolomite and siltstone in their turn overlain by well-bedded and massive sandstone.

In the North Kimberleys the beds vary greatly in thickness, and are apparently thickest in the area of the Collison Range in the north-east and between Bluff Face Range and Elgee Cliffs in the south-east. Typically they form a series of scarps and dip slopes (Section *A*–*A*2, Fig. 6). The lower beds dip more steeply than the upper ones, which are more or less horizontal. There is at least one very extensive shale member in the sequence. The distribution of this shale member in the east and south-east of the area may be seen in the land system map, where it is mapped as Karunjie land system.

The distribution of the Mt. House beds is limited to the east of the area with the exception of a small outlier on the west coast, where it overlies the Warton beds and dips steeply seawards.

Traves (1955) states that the age of the Mt. House beds cannot yet be determined definitely, but as the Antrim Plateau volcanics overlie them with an erosional unconformity, and they overlie the Halls Creek metamorphics with an angular unconformity, it is suggested that they were deposited entirely in the Upper Proterozoic time, although deposition of the upper portion on the Mt. House beds may have extended into the Lower Cambrian epoch.

(c) *Rocks of Uncertain Age*

(i) *Hart Basalt*.—Guppy *et al.* (1958) describe this unit as follows: "The Hart Basalt derives its name from Mount Hart (Long. 125° 04′ E., Lat. 16° 55′ S.), and the basalt crops out at Mount Hart as well as in the valleys in the King Leopold and Lady Forrest Ranges.

"The formation consists of basalt and dolerite which fill old valleys in the eroded older Precambrian rocks. It unconformably overlies the Lamboo Complex and King Leopold Beds.

"The age is uncertain; it may be Lower Cambrian, similar in age to the volcanics in East Kimberley, or it may be late Proterozoic and even associated with the same phase of volcanic activity which formed the Mornington Volcanics."

The type locality is within the south-western margin of the survey area. From examination of aerial photographs of the type area and the adjoining country to the north-west the Hart basalt appears to be either fills of deep, steep-sided valleys, eroded in the King Leopold beds, or hypabyssal intrusions within that formation. These criteria were used in all the mapping from aerial photographs as otherwise there was no means of separating the Mornington volcanics from the Hart basalt. Using these criteria it was found that in some places the Hart basalt is continuous with the Mornington volcanics with no apparent unconformity. If this is so then it would support the theory that the Mornington and Hart belong to the same phase of volcanic activity. Also, the Warton and Mt. House beds are completely free from volcanic rocks of this type.

From examination of aerial photographs the Upper Proterozoic gabbro and dolerite of Traves (1955) near Bedford Downs appear to be very similar to the Hart basalt of this area.

(ii) *Younger Volcanics*.—In the Synnott Range, overlying the Warton beds and in places the Mornington volcanics, are considerable areas of younger volcanics (Section *B*–*B*1, Fig. 6). There are also small isolated areas of volcanics above the Warton and Mt. House beds in the vicinity of Karunjie homestead and Chapman River.

The age of these younger volcanics is not known. They are obviously of younger age than the Mornington volcanics and the Warton beds but there is insufficient evidence to correlate them with the Antrim Plateau volcanics which are widespread through the East Kimberleys, therefore they are referred to in this report as Younger volcanics.

(d) *Quaternary*

Areas of coastal and estuarine alluvium have been delineated on the geological map of the area. These are relatively small in area and unimportant. They consist of saline mud flats liable to tidal flooding, and deposition is still active.

III. Mineral Resources

At the present time no minerals are being exploited in this area.

The iron ore deposits of Yampi Sound and Cockatoo Island, some 30 miles to the west of the south-western corner of the survey area, occur in the Upper Proterozoic sediments but no similar prospects are known in this area.

Along the northern coastline, at Cape Bougainville and also near Cape Londonderry, there are extensive areas of lateritized volcanic rocks (mapped as Foster land system) that should be examined as possible sources of bauxite. There are also considerable areas further inland but access to them is not always easy.

IV. Underground Water

Underground water for the development of the cattle industry will be required in the areas of volcanic rocks. From the aerial photographs it is evident that in many places the volcanics consist of numbers of flows of variable hardness and probably of variable porosity and underground water should generally be obtainable wherever required.

V. References

Guppy, D. J., Lindner, A. W., Rattigan, J. H., and Casey, J. N. (1958).—The geology of the Fitzroy Basin, Western Australia. Bur. Min. Resour. Bull. No. 36.

Traves, D. M. (1955).—The geology of the Ord-Victoria region, northern Australia. Bur. Min. Resour. Bull. No. 27.

PART IV. GEOMORPHOLOGY OF THE NORTH KIMBERLEY AREA, W.A.

By G. A. Stewart, C. R. Twidale, and Janice Bradley*

I. Introduction

No specialist geomorphological field studies have been carried out in this area and this report is based on aerial photo interpretations and the correlation of all available information on the area.

The sources of information are: early explorers' records; field observations by N. H. Speck and M. Lazarides; field observations in the adjoining Ord–Victoria area and Fitzroy valley by G. A. Stewart; the report on the geomorphology of the Ord–Victoria area (Paterson, in preparation) prepared as a result of the resources survey of that area; and various broad geological and geomorphological reports, apparently based largely on studies in neighbouring areas, explorers' records and specimens, rather sketchy topographic data, and laymen's descriptions of the country.

This report presents maps and accounts of the general physiography of the area, the geomorphological units into which the aréa can be resolved, and the geomorphogeny of the area.

II. General Physiography

The North Kimberley area includes almost all of the country commonly referred to as the Kimberley Plateau. It consists mostly of a series of sandstone, shales, and volcanic rocks of Upper Proterozoic and possibly Lower Cambrian age. The rocks have been gently folded over a major regional anticline along a north–south axis through the centre of the region. Upon this structure several minor synclines are superimposed. Dips are gentle everywhere except along the south-western and south-eastern margins near the neighbouring Lower Proterozoic rocks.

Faulting with little displacement is common in the King Leopold sandstones and it is likely that it is associated with folding.

As will be seen in the following descriptions of the geomorphological units, structure has played an important part in determining the relief of the area both in general and in detail, for the relief is essentially consequent.

It can be seen from Figure 7, a topographic map following Hills (1946, p. 89), that the area forms a dome, the centre of the dome rising above 1750 ft. The highest feature, Mt. Hann (*circa* 2800 ft), is an isolated, cliff-faced mountain rising 800 ft above the surrounding country (Easton 1922). Mt. Agnes (*circa* 2300 ft) and Mt. Elizabeth (*circa* 2200 ft) are the only other points known to be above 2000 ft.

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

The western part of the area is chiefly rugged sandstone tablelands with some valleys of more gentle relief on igneous rocks. The central part has considerable areas of low relief, on both sandstone and igneous rocks, whilst the eastern part is mostly rugged sandstone country with a number of well-defined linear escarpments.

The main drainage is radial from the high part of the dome. The Durack River drains north-eastwards to Cambridge Gulf. The Drysdale and King Edward flow northwards towards the sea, the Prince Regent and Charnley westwards to the sea. The Isdell flows southwards from the high central core, then flows on a north-west course parallel to the King Leopold Ranges. The southern portion of the area is drained by southward-flowing tributaries of the Fitzroy River.

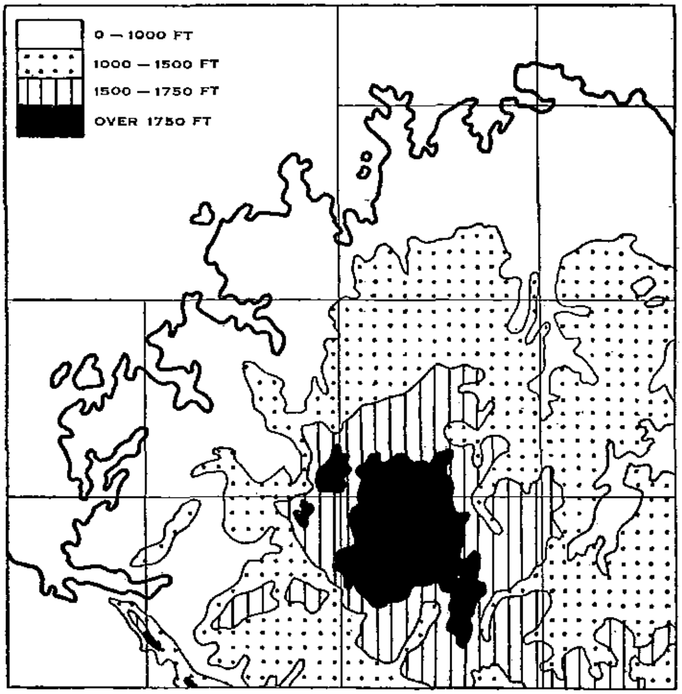


Fig. 7.—Topographic map of the area following Hills (1946).

The streams appear to be largely structurally controlled, i.e. they follow zones of weakness such as faults, joints, or comparatively soft strata. The Prince Regent River is an extreme example in that almost its entire course is along a south-east–north-west joint. In several places streamlines follow relatively soft volcanic rocks at the foot of steep sandstone scarps.

In general the intensity of drainage is moderate but the sandstone country of low relief has low drainage intensity.

The coastline has been described by Easton (1922). It consists mostly of spectacular precipitous cliffs, generally more than 200 ft and in some places rising to 800 ft. There are very many offshore islands, mostly very steep and flat-topped, and the coastline has many deep indentations. The coastal configuration is strongly controlled by jointing in the King Leopold sandstones and the lower strata of the Warton beds as in the adjoining part of the Ord–Victoria area (Paterson, in preparation). Depositional features are of very minor extent. It is clearly a submerged coastline in a young stage of development (Johnson 1919, pp. 201–3).

In the following descriptions of the geomorphological units their relationships to the land systems are indicated. The land systems, which are described in Part VIII, are the units used to describe and map the various complex types of country identifiable in this type of reconnaissance survey.

III. Geomorphological Units

The area is the major part of the Kimberley region of Paterson (in preparation). It has been resolved into six geomorphological units:

Immaturely dissected lateritic plateaux on volcanic rocks

Maturely dissected plateaux on volcanic rocks

Erosional plains on volcanic rocks

Dissected sandstone plateaux

Cuestas and structural plateaux

Depositional plains

(a) *Immaturely Dissected Lateritic Plateaux on Volcanic Rocks*

This unit includes the Foster land system, which consists of lateritic-capped mesas and buttes and gently undulating lateritic plains fringed by scarps. It is found on both Mornington and Younger volcanics. The relief of the mesas and buttes varies from 600 ft (east of Admiralty Gulf) to approximately 100 ft and the scarps bordering the lateritic plain are generally of the order of 100 ft. The altitude of the cappings and plains ranges from 150 ft (Cape Londonderry) and 600 ft (Admiralty Gulf) at the coast to 1300 ft in the Foster Range and 1600 ft in the Synnott Range. The mesas and buttes and scarps are equivalent to the dissected elevated lateritic plain of the Ord–Victoria area (Paterson, in preparation) and the undulating lateritic plains are closely related to the elevated lateritic plain (red earth and lateritic podzolic surface horizon) of that area.

The lateritic plains and cappings are remnants of an old land surface which has been described over wide areas in northern and western Australia by Whitehouse (1940), Christian and Stewart (1953), Noakes and Traves (1954), Paterson (in preparation), and Twidale (in preparation). No evidence has been found to fix the age of the surface(s) accurately and estimates all fall between early to mid Tertiary (Twidale) and mid to late Tertiary (Paterson). In this report it is referred to as the Tertiary surface. The land surface was elevated by warping and/or uplift in late Tertiary or Pleistocene and then actively dissected. The remnants remaining owe their preservation to one or more of the following factors: they had lateritic caps which offered resistance to erosion; they were not adjacent to actively incising streams; they were protected from such streams by resistant rock barriers.

(b) *Maturely Dissected Plateaux on Volcanic Rocks*

This unit includes the Napier land system found on Mornington volcanics, Hart volcanics, and Younger volcanics. It consists mostly of rounded hills with hogbacks, cuestas, and structural benches where there are strata of varying resistance to erosion. Also, it includes a number of small lateritic-capped mesas too small to map in the previous unit. The relief range varies from 100 to 500 ft and the altitude from sea-level to 2300 ft on the slopes of Mt. Hann.

The drainage texture is of moderate intensity and the pattern varies from dendritic in areas of massive uniform rocks to angular and trellised types in areas of tilted rocks of variable hardness.

In this unit dissection of the volcanic rocks has reached maturity, i.e. the Tertiary land surface has been virtually completely removed and the relief is maximal. The valleys are generally very narrow with only minor alluviation along the lower parts of the major watercourses.

(c) *Erosional Plains on Volcanic Rocks*

This unit includes the Barton, Kennedy, and Isdell land systems, formed on Mornington, Hart, and Younger volcanics. The topography is generally undulating with some low hills. The relief is from 20 to 150 ft and altitude ranges from just above sea-level to 2000 ft. The drainage is subrectangular in pattern and of low intensity. The streams have mostly reached grade and are flanked by narrow strips of alluvium. The most extensive of these plains are along the lower Drysdale River and north of the Gibb River homestead, and there are many small isolated areas, some of which are upland plains.

The plains represent a further stage of erosion than the previous unit in that they are areas of volcanic rocks that have been reduced to low relief following the complete removal of the Tertiary land surface, and they have a higher proportion of deeper and more mature soils.

(d) *Dissected Sandstone Plateaux*

This is a complex formed on strongly jointed, gently folded sandstones of the King Leopold beds with three sub-units that are more or less equivalent to the three previously described units formed on volcanic rocks. They are included in this complex because of the difficulty of separating them consistently. The sub-units are described below.

(1) The maturely dissected sandstone plateaux, which are by far the most extensive sub-unit, consist of the rugged steeply sloping sandstone outcrops of the Buldiva land system. Erosion along the strongly developed joint planes has resulted in an angular drainage pattern of very close texture with many precipitous gorges. The topography also exhibits strong structural control. Erosion along strongly marked joint planes and weaker bedding planes has produced angular blocks and stacks.

The altitude ranges from sea-level to 2000 ft and the relief varies from 50 to 800 ft.

This sub-unit has reached a stage of development similar to that of the maturely dissected plateaux on the volcanic rocks, i.e. dissection has reached maturity and the relief is maximal.

(2) The gently undulating undissected plateaux (part of Pago land system) appear to be remnants of the Tertiary land surface. In places they adjoin the immaturely dissected lateritic plateaux but they are not fringed by scarps. Apparently the sandstones did not contain sufficient weatherable material to allow the formation of resistant laterite and other horizons. Their relief is low, being generally less than 30 ft, and their altitude ranges from 150 ft on the north coast to 1100 ft on the Synnott Range. Generally they occur on drainage divides and the drainage pattern is dendritic of low intensity.

(3) The erosional plains formed on sandstones (also included in Pago land system) occur at altitudes ranging from sea-level to that of the undissected plateaux. Where these sub-units merge it was not possible to distinguish the boundary consistently because of lack of scarps and the similarity of land characteristics. These erosional plains on sandstone are similar in their genesis to the erosional plains on volcanic rocks.

(e) *Cuestas and Structural Plateaux*

This unit consists of cuestas and structural plateaux with minor areas of hogback ridges in the south-east and west. It is formed on the gently dipping sandstones and shales of varying hardness of the Mt. House and Warton beds and occupies all of the eastern part of the area as well as small areas in the west. It adjoins Paterson's (in preparation) ridges, hogbacks, cuestas, and structural plateaux but it has less diverse topographic form than that complex unit.

Gentle dip slopes on sandstone with deep sandy soils together with narrow, unmappable scarps are mapped in Pago land system. Sandstone outcrop areas of the structural plateaux, cuesta strike slopes and less mature dip slopes, and the hogbacks are included in Buldiva land system. Valleys and dip slopes formed on the shales, which are relatively soft, have been mapped with adjacent narrow sandstone scarps in the Karunjie land system.

The relief varies from less than 50 ft to 500 ft and the altitude from sea-level to 1500 ft.

The strike slopes of the cuestas are formed by sandstone scarps up to 500 ft high and sandstone scarps form the margins of the structural plateaux. The hogbacks are formed where these beds of variable hardness have moderate dips along the margins of the Kimberley region, i.e. in the south-east and western parts of the survey area. The drainage patterns are angular and of moderate to low intensity.

There is no evidence of remnants of the mid-Tertiary land surface in this unit but the upper structural surface east of Karunjie homestead may have been part of that surface.

(f) *Depositional Plains*

The only mapped depositional plains are along the coastline. They are saline mud flats (Carpentaria land system) built of Recent sediments in estuarine situations. They are equivalent to Paterson's (in preparation) estuarine deltaic plains.

They are quite flat and suffer periodical tidal flooding and their drainage is of contrasting intensity, being quite absent over large areas and in profusion in others. They are very young plains and deposition is still active.

IV. Geomorphogeny

There is no evidence of deposition since early Cambrian time although Palaeozoic deposition was considerable in adjoining parts of the Ord–Victoria basin to the east and along the Fitzroy River to the south. The geomorphogeny can be traced back only as far as the Tertiary—the assumed age of the lateritic land surface of the immaturely dissected lateritic plateaux. This is the "Australian" surface of King (1949) and the Miocene surface of David (1950). Because of the small scattered occurrences of the lateritic surface it is not possible to reconstruct its original form, but it seems likely that parts of the King Leopold Range, the Mt. Hann section, and the hilly eastern parts of the area may have had residuals standing above the general level of the plain.

Probably in the late Tertiary or early Pleistocene, the area suffered uplift and/or warping and a period of active dissection ensued. In a number of places dissection below this Tertiary surface is of the order of 600 ft and deep gorges are not uncommon. Structural control of topography and drainage is strongly evident in almost all of the dissected areas.

Paterson (in preparation) has postulated the presence of a number of "cyclic land surfaces" in the adjacent Ord–Victoria area. There does not appear to be any evidence in this area to support that proposition.

After dissection had almost reached maturity, a submergence occurred which resulted in the drowning of the valleys and the formation of the highly indented coastline with many offshore islands. Although the area has been considerably dissected there are only relatively small areas of depositional material, which would indicate a rather recent submergence. The deposition plains are very young and deposition is still active. There is no evidence in this area of the emergence in Recent time postulated further to the north-east (Christian and Stewart 1953) to explain the development of mature soils and weak stream incision on older alluvial deposits where deposition is no longer active.

V. References

Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine-Darwin region, 1946. C.S.I.R.O. Aust. Land Res. Ser. No. 1.

David, T. W. E. (1950).—"Geology of the Commonwealth of Australia." Vol. II. (Edward Arnold and Co.: London.)

Easton, W. R. (1922).—Report on the North Kimberley district of Western Australia. W. Aust. Dep. North-west Publ. No. 3. (Govt. Printer: Perth.)

Hills, E. S. (1946).—Some aspects of the tectonics of Australia. *J. Proc. Roy. Soc. N.S.W.* **79**: 67–91.

Johnson, D. W. (1919).—"Shoreline Processes and Shoreline Development." (Wiley: New York.)

King, L. C. (1949).—The cyclic land surfaces of Australia. *Proc. Roy. Soc. Vict.* **62**: 79–95.

Noakes, L. C., and Traves, D. M. (1954).—Outline of the geology of the Barkly region. C.S.I.R.O. Aust. Land Res. Ser. No. 2: 34–41.

PATERSON, S. J. (in preparation).—Report on a geomorphological reconnaissance of the Ord–Victoria area. C.S.I.R.O. Aust. Land Res. Ser.

TWIDALE, C. R. (in preparation).—Geomorphology of the Leichhardt–Gilbert area of north-west Queensland. C.S.I.R.O. Aust. Land Res. Ser.

WHITEHOUSE, F. W. (1940).—Studies in the late geological history of Queensland. Univ. Qld. Pap. Dep. Geol. **2** (1).

PART V. SOILS OF THE NORTH KIMBERLEY AREA, W.A.

By N. H. Speck*

I. Introduction

The soils of the area are diverse in genesis and morphology but leaching has been sufficient to deplete the bases and give an acid reaction in all the major soils. Many of the parent materials are "acidic", e.g. sandstone and shales, and even the basalt is of the basic intermediate type and produces a soil that is acidic throughout its profile.

The monsoonal climate has been a dominating influence in determining the nature of the soils of the area. The 25–50 in. annual rainfall concentrated into a short wet season, alternating with a long and marked dry season, has been responsible for active erosion on the areas of high relief and strong leaching of the permeable soils.

The soils with massive laterite, although widely dispersed throughout the central and northern parts, occupy only a small part of the total area. However, very few soils do not contain ferruginous concretions somewhere in the profile.

The fertility assessment is based only on pedological interpretation as no samples were collected for chemical analyses.

Soils were examined by boring holes with a 4-in. post-hole auger and by examination of any other exposures of soil profiles. In the following descriptions the depth in inches and the nature of the horizons are given for profiles that are examples of the various soil groups recognized. Each description is accompanied by short notes on the occurrence, extent, and agricultural characteristics, and an assessment of the fertility of the soil group. In Table 4 the factors affecting the agricultural value of the soils are summarized.

II. Grouping of the Soils

As far as possible the soils of the area have been correlated with those of the adjoining Ord–Victoria area (Stewart, in preparation), but this was not always possible because of insufficient information from limited sampling due to the reconnaissance nature of the survey.

The following soil groups were recognized:

(*a*) Hard yellow sands
(*b*) Deep yellow sands
(*c*) Deep light grey sands
(*d*) Red medium sands
(*e*) Fine-textured yellow podzolics
(*f*) Coarse-textured yellow podzolics
(*g*) Lateritic podzolics
(*h*) Igneous red earths
(*i*) Red levee soils
(*j*) Sandy levee soils
(*k*) Grey soils of heavy texture
(*l*) Skeletal soils.

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

Table 4

SUMMARY OF FACTORS AFFECTING AGRICULTURAL VALUE OF SOILS

Soil	Chemical Fertility	Major Physical Characteristics	Mode of Occurrence
Hard yellow sands	Low	Mostly shallow, coarse-textured, well-drained	Mostly as scattered small areas among skeletal soils in the south-eastern part of the region
Deep yellow sands	Low	Deep, coarse-textured, well-drained	Very extensive in Pago land system, mixed with deep light grey sands and skeletal soils
Deep light grey sands	Low	Deep, coarse-textured, poorly-drained	Minor linear depressions in Pago and Buldiva land systems
Red medium sands	Low	Deep, coarse-textured, well-drained	Small scattered areas in Pago land system
Fine-textured yellow podzolics	Moderate	Deep, medium- to fine-textured, moderately drained	Irregular patches in Barton, Kennedy, Napier, Foster, and Karunjie land systems
Coarse-textured yellow podzolics	Low	Deep, coarse-textured, moderately drained	Small irregular areas associated with flats in Kennedy, Pago, and Karunjie land systems
Lateritic podzolics	Low	Shallow, coarse-textured gravelly surface, overlying concretions or laterite	Small patches in plateaux and flats of Pago, in flats in Barton and Kennedy, and some gentle slopes in Foster land system
Igneous red earths	Moderate	Deep, medium- to fine-textured, well-drained, may be self-sealing in surface	Mostly as irregular small patches in Napier, Kennedy, and Barton land systems, some larger areas along the lower Carson and Drysdale Rivers
Red levee soils	Moderate	Deep, medium-textured, well-drained but may be flooded occasionally	Very small linear bands along stream-lines
Sandy levee soils	Variable	Very variable, mainly coarse-textured, well-drained but may be flooded occasionally	Limited to narrow linear bands along stream-lines, mostly in southern parts of area
Grey soils of heavy texture	Fair	Fine-textured, cracks deeply when dry but poorly drained when wet, some areas subject to flooding	Some large areas in Isdell land system but only small areas, probably liable to flooding, in Napier, Barton, and Kennedy land systems
Skeletal soils	Variable	Too stony, shallow, and steep for agriculture	Forms the major soils of Buldiva and Napier and Foster land systems and although patchy in distribution covers considerable areas in Barton, Kennedy, and Karunjie land systems

III. Description and Agricultural Characteristics of the Major Soils

(a) *Hard Yellow Sands*

The hard yellow sands are formed on the sandier parts of the shale areas and have a range of textures from sand to clayey sand. They are hard when dry.

Vegetation	Grassy woodlands, *Eucalyptus argillacea* (form C)–*E. grandifolia* association.
0–3 in.	Yellow-grey sand, hard when dry.
3–32 in.	Yellow, slightly clayey sand which deepens in colour and increases slightly in clay content with depth.
32 in.	Sandstone.

Agricultural Characteristics.—These medium- to coarse-textured soils are well drained, lightly timbered, and have moderate grass cover. Fertility assessment is low. Because of their low fertility and scattered distribution amongst skeletal soils they are not likely to be developed for agriculture.

(b) *Deep Yellow Sands*

These are the major soils of the Pago land system, which occupies about 25 per cent. of the total area, and is formed upon the Upper Proterozoic sandstones (King Leopold, Warton, and Mt. House beds). They are similar to the deep yellow sands of the Ord–Victoria area (Stewart, in preparation).

Vegetation	Open forests, *Eucalyptus tetrodonta*–*E. miniata*, *E. phoenicea*–*E. ferruginea* sub-alliances.
0–4 in.	Yellowish grey sand.
4–43 in.	Yellow sand.

Agricultural Characteristics.—Although topographically suitable, these soils are highly leached, of low fertility, and of coarse texture. Their ease of cultivation and ability to respond to small falls of rain could be advantageous in agriculture.

(c) *Deep Light Grey Sands*

These sands are formed in the depressions and seepage areas of sandstone country and are generally but not always associated with stream-lines. They occur in the Pago and Buldiva land systems (Upper Proterozoic sandstones, King Leopold, Warton, and Mt. House beds). They are similar to the deep light grey sands of the Ord–Victoria area (Stewart, in preparation). Two profiles are described.

Profile (a)

Vegetation	Woodlands, *Eucalyptus polycarpa* association.
0 in.	Film of loose pinkish sand particles.
0–2 in.	Dark grey sand with organic material.
2–36 in.	Light grey-white sand, very slightly pinkish.
36–45 in.	Light grey-white sand with orange and red inclusions or staining.
pH	5·5 throughout.

Profile (b)

Vegetation	Woodlands, *Eucalyptus apodophylla*–*E. alba* association.
0–3 in.	Dark grey sand.
3–36 in.	Lighter grey sand, slightly yellowish and becoming slightly clayey with depth.
pH	6·0–6·5.

Agricultural Characteristics.—These small areas are highly leached, poorly drained, coarse-textured, and heavily timbered, and do not appear to be suitable for agriculture.

(d) *Red Medium Sands*

These red sandy soils are formed on undulating topography on the Upper Proterozoic sandstones of the Pago and Buldiva land systems. They occur as small patches mixed with the rocky outcrops and adjacent skeletal sands. They are very closely related to the Cockatoo family (Stewart, in preparation).

Vegetation	Forests, *Eucalyptus tetrodonta–E. miniata* sub-alliance.
0 in.	Surface film of pinkish sand.
0–4 in.	Red-brown loamy sand.
4–45 in.	Gradually changes to red medium sand.
pH	6 throughout.

Agricultural Characteristics.—These soils are well drained and of varying depth. Natural vegetation is open forest. Fertility assessment is low. Topographically they are generally suitable for agriculture but because of patchiness of distribution and isolation they are not likely to be developed for agriculture.

(e) *Fine-textured Yellow Podzolics*

On the flatter parts and slight depressions of the Mornington volcanics and shales of the Warton and Mt. House beds, fine-textured yellow podzolic soils are formed. They are distributed throughout the Napier, Barton, Foster, Karunjie, and Kennedy land systems. They show considerable variation in texture and in their extreme form show evidence of cracking. These soils are comparable to the Elliott family of the Ord–Victoria area (Stewart, in preparation). Two profiles are given.

Profile (a)

Vegetation	Grassy woodland, *Eucalyptus tectifica–E. grandifolia* alliance.
0 in.	Surface shows slight cracking.
0–1 in.	Yellowish grey-brown silty loam.
1–4 in.	Yellow-brown sandy clay loam.
4–20 in.	Yellow sandy clay.
20–45 in.	Yellow clay.
pH	6 throughout.

Profile (b)

Vegetation	Woodlands, *Eucalyptus latifolia* alliance.
0 in.	Surface covered with ferruginous concretions.
0–1 in.	Grey-brown sandy loam with ferruginous concretions. pH 6·5.
1–4 in.	Yellow-brown sandy loam with ferruginous concretions.
4–24 in.	Yellow sandy clay with abundant ferruginous concretions. pH 6·5.
24–45 in.	Reddish yellow sandy clay with abundant ferruginous concretions. pH 6·5.

Agricultural Characteristics.—These fine-textured soils are moderately well drained although there is evidence that some places would be flooded during the wet season. Topography is always flat or very gently sloping. The assessment of fertility is moderate. Topographically and physically these soils appear to be suitable for agriculture but their patchiness of distribution reduces their value.

(*f*) *Coarse-textured Yellow Podzolics*

These are similar to the previous soil group but they are formed on the coarse-textured materials of sandstones, shales, and volcanics of the Kennedy, Pago, and Karunjie land systems. These soils resemble the Cullen family of the Ord–Victoria area (Stewart, in preparation).

Vegetation	Woodlands and forests, various associations of *Eucalyptus latifolia*, *E. tetrodonta*, *E. miniata*, and *E. tectifica*.
0 in.	Surface covered with ferruginous concretions.
0–1 in.	Greyish yellow-brown loamy sand with ferruginous concretions.
1–4 in.	Yellow-brown loamy sand with ferruginous concretions.
4–24 in.	Yellow-brown clayey sand with abundant ferruginous concretions.

Agricultural Characteristics.—This group of soils is only moderately well drained. Fertility assessment is lower than for the previous soil group, and because of the patchy distribution they are unlikely to be important for agriculture.

(*g*) *Lateritic Podzolics*

These soils resemble the Koolpinyah family of the Ord–Victoria area (Stewart, in preparation), and are related to the yellow podzolics. They are found in topographically similar sites (flats and depressions) and often carry a similar vegetation. They differ from the above soils in that the upper horizons are generally lighter in texture and have a layer of compacted ferruginous concretions or massive laterite in the profile. Their distribution, like that of the yellow podzolics, is patchy but differs in that they are relatively more common in the northern parts of the area whereas the yellow podzolics are of more importance in the southern and south-eastern part of the area.

Vegetation	Woodlands, *Eucalyptus latifolia* alliance.
0 in.	Surface covered with ferruginous concretions.
0–6 in.	Grey sand with ferruginous concretions.
6–24 in.	Yellow sandy clay with many ferruginous concretions, very hard.
pH	6·5 throughout.

Agricultural Characteristics.—Fertility assessment is very low. The shallow sandy surface over laterite on clay with concretions makes these soils unattractive for agriculture.

(*h*) *Igneous Red Earths*

These soils resemble the igneous red earths of the Ord–Victoria area (Stewart, in preparation). They are found upon the Mornington volcanics and are distributed throughout the Napier, Barton, and Kennedy land systems. The best development of these soils is along the most northerly part of the Carson River and adjacent parts of the Drysdale River. Smaller areas of these soils occur at the Gibb River homestead and also at Karunjie. In the Kennedy land system these soils are generally slightly more sandy than the described profile.

Vegetation	Woodlands, *Eucalyptus tectifica* sub-alliance.
0 in.	Film of red sand.
0–1½ in.	Red-brown sandy loam. pH 6·0.
1½–6 in.	Red-brown sandy clay loam. pH 6·5.
6–32 in.	Red sandy clay, hard. pH 6·5.

Note.—Some profiles have variable amounts of ferruginous concretions.

Agricultural Characteristics.—The fertility of these well-drained soils is considered to be moderate, but they may have some of the undesirable physical properties of the related Tippera soils at Katherine Research Station, N.T., e.g. surface sealing and difficult seedling emergence.

These soils do not become boggy during the wet season and, where practicable. airstrips should be confined to this type of soil.

(*i*) *Red Levee Soils*

There are small isolated areas of these soils associated with the streams of the volcanic region. They vary considerably depending on the nature of the catchment. These soils have not been correlated with any of the described soil families. Two slightly different profiles are described below.

Profile (a)

Vegetation	Grassy woodlands, *Eucalyptus tectifica–E. grandifolia* and *E. papuana* alliance.
0 in.	Sparse ferruginous pebbles.
0–1 in.	Slightly hard silty clay loam.
1–4 in.	Red-brown loamy clay, slightly hard.
4–20 in.	Red loamy clay, slightly hard.
20–42 in.	Brown-red medium clay with grey and red mottling.
pH	6 throughout.

Profile (b)

Vegetation	Woodlands, *Eucalyptus papuana* alliance.
0–1 in.	Brown fine sandy loam.
1–27 in.	Red-brown fine sandy clay loam.
27–42 in.	Deep red sandy clay loam.
pH	6·0–6·5 throughout.

Agricultural Characteristics.—They appear to be well suited for agriculture but their general utilization is impracticable because of the small scattered areas. If intensive irrigation agriculture by pumping should be developed these soils would be suitable for such purposes.

(*j*) *Sandy Levee Soils*

The rather variable sandy levee soils are associated with rivers and creeks of sandstone and shale country, particularly in the south-eastern part of the area. A profile is described from the Karunjie land system.

Vegetation	Woodlands, *Eucalyptus papuana–E. camaldulensis* alliance.
0–6 in.	Grey to grey-brown sand to sandy loam.
6–24 in.	Grey-brown sand.
24–36 in.	Grey-brown sand to loamy sand.

Agricultural Characteristics.—These soils are similar in morphological characteristics to the levee soils of the Katherine–Darwin region, which are relatively fertile and have a wide variety of uses (Christian and Stewart 1953). However, in this area there are only small scattered patches amongst poorer soils and they are unlikely to be developed for agriculture.

(*k*) *Grey Soils of Heavy Texture*

Heavy-textured soils are extensive only in the Isdell land system. Small areas of a chain to several chains across occupy depressions in the Kennedy and Barton land systems but near the Carson River in the north and at Karunjie and Gibb River station they occupy areas of perhaps a quarter-mile or so across. They commonly have gilgai microrelief and they crack deeply during the dry season. They are formed on volcanic rocks or alluvia derived from volcanic rocks. Because the field data are limited these soils could not be correlated with the various families described by Stewart (in preparation) for the Ord–Victoria area.

Vegetation	Grassland or grassland with sparse deciduous trees.
0–1 in.	Grey clay with slight crumb structure. pH 6·0.
1–18 in.	Brownish grey clay, weak blocky structure, widely cracked.
18–36 in.	Similar to above with coarser structure. pH 7·0.

Agricultural Characteristics.—Fertility assessment is moderate, but heavy texture, scattered distribution, and liability to flooding of the more extensive areas do not favour agricultural development.

(*l*) *Skeletal Soils*

Skeletal soils have been formed upon a variety of parent materials and are the most extensive of the soil groups. They may be subdivided according to parent materials as follows:

(i) *Skeletal Red Earths.*—These are the major soils of the hilly volcanic country of the Napier land system. They also dominate two units of the Barton land system and are important, though to a lesser extent, in the Kennedy land system. They have a brown stony loam surface soil over thin red clay subsoils.

(ii) *Skeletal Shales and Sandstones.*—The scarps of the Karunjie land system are the main location of these soils. They consist mainly of fragments of shale and sandstones with finer-textured soil material filling the interstices.

(iii) *Skeletal Soils with Cherty Rock Fragments.*—Formed on slight rises, this group is limited to those areas of contact between the volcanic rocks and the underlying sandstone rocks. They consist of rock fragments and ferruginous concretions in which the interstices are occupied by yellow-brown clays. Depth varies from only 2 or 3 in. up to 18 in.

(iv) *Skeletal Laterite.*—This is the soil of higher portions of the Foster land system and consists of massive laterite or laterite fragments or particles with very little soil material.

(v) *Skeletal Sands.*—These are characteristic of much of the Buldiva land system and the rugged parts of the Pago land system. They consist of shallow sands adjacent to sandstone outcrops.

IV. References

Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. C.S.I.R.O. Aust. Land Res. Ser. No. 1.

Stewart, G. A. (in preparation).—Soils of the Ord–Victoria area. C.S.I.R.O. Aust. Land Res. Ser.

PART VI. VEGETATION OF THE NORTH KIMBERLEY AREA, W.A.

By N. H. SPECK*

I. INTRODUCTION

Although the area lies within the tropics and has a rainfall of 25–50 in., the climate is monsoonal and the long dry season exerts a dominating influence on the vegetation. There are no rain forests, usually considered characteristic of the tropics, and even the monsoon forests described for the Katherine–Darwin region by Christian and Stewart (1953) are absent.

The major vegetation communities closely resemble the grassy *Eucalyptus* woodlands and open forests widely distributed in northern and eastern Australia. In describing the vegetation of the Northern Province of Western Australia, which includes the survey area, Gardner (1942) emphasized the Indo-Malayan elements of the flora. In general these are relatively minor components and so do not give a distinctive physiognomy except where they are concentrated in special habitats such as stream-lines and scarps. These communities certainly have a distinctive appearance, e.g. the *Adansonia gregorii* (baobab or bottle tree)–*Eucalyptus grandifolia* community of the shale scarps or the *Terminalia* sp.–*Dichanthium fecundum* community of the northern grey soils of heavy texture.

Gardner's (1942) monsoon woodlands are dominated by *Eucalyptus* species but have a distinctive Indo-Malayan impress by reason of the number and density of Indo-Malayan arborescent plants. In this report the vegetation is treated in more detail, and communities which have Indo-Malayan elements as dominants or co-dominants (which are usually associated with special habitats) have been separated from communities dominated by *Eucalyptus* species with variable but generally minor components of Indo-Malayan elements. It has, therefore, not always been possible to correlate Gardner's formations with the communities described in this paper.

The vegetation may be classified into two major formations, firstly, the open forests of the sandstone areas with good development of shrubby undergrowth and ground storeys of soft spinifex (*Plectrachne pungens*) and annual *Sorghum* spp. and secondly, the grassy woodlands of the volcanic soils with sparse shrubs and good development of grass understoreys. Grasslands, which occupy only small areas, occur on the grey soils of heavy texture.

Edaphic factors, within certain limits of climate, are of considerable importance in determining the distribution of plant communities.

As in the Barkly region (Christian and Perry 1954), the importance of the water factor may be observed in the development of special communities in poorly drained and flooded sites and also in the more or less gradual change of species from the higher-rainfall areas of the north to the areas of lower rainfall towards the south.

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

Commencing about the 30-in. rainfall zone *E. phoenicea* dominates the open forests, which become lower and somewhat depauperate. Below the 27-in. rainfall zone, in the south-east of the area and in the adjacent Ord–Victoria area (Perry 1956), there is a more marked change where such communities as *E. brevifolia* and *E. pruinosa* associations appear.

II. Nomenclature and Classification

The vegetation "association" is used as the basic unit of classification. Related associations have been grouped into larger floristic units, "alliances and sub-alliances". The terms association and alliance are used in the sense of Beadle and Costin (1952) with the exception of the reference to "uniform structure". As indicated by Perry (1956) the dominants of associations in northern Australia frequently exhibit more than one life-form and hence associations and alliances should be retained as strictly floristic classifications, and reference to uniformity of structure should be deleted from the definition.

The associations are named from the dominants of the upper stratum. Perry (1956) states that, in the very open communities so typical of northern Australia, it is very doubtful if the trees of the sparse upper stratum exercise any dominance in the sense of conditioning the lower strata. Because of this Perry (1956) suggests the use of the term "characteristic" for these plants comprising the upper stratum. However, the term "dominant" will be retained in this paper but as used does not necessarily imply dominance in the sense of conditioning of the lower strata.

III. Description of the Vegetation

This tentative classification of the vegetation of the North Kimberleys is the result of approximately 500 miles of ground traverse through the central part of the area from south to north (see traverse route on land system map). By means of photo interpretation and correlation between vegetation and other land surface characteristics, the information gained during the traverse was extended to the rest of the North Kimberley area. While a more detailed survey or one that is extended to the climatic extremes will undoubtedly reveal more combinations of species and new communities, it is considered that the following classification will provide the framework for the major vegetation communities of the area.

Seventy-six associations have been recognized and their main features summarized in Tables 5–13. These have been grouped according to floristic relationships into six alliances, two mono-association units, and three communities (probably alliances) in which associations have not been defined because of insufficient records. The two major alliances, which have been divided into sub-alliances, cover approximately 90 per cent. of the North Kimberley area. The other alliances for the most part occupy the small areas of special habitats (e.g. the flats, depressions, and streamlines) within the area occupied by the major alliances.

Thirty-one arborescent species of *Eucalyptus* were collected, including two undescribed species. Species Speck No. 4991 was observed in association with *E. pruinosa* on fine-textured yellow podzolics 11 miles east of Gibb River homestead. It is a small tree to 20 ft in height and commonly assumes a leaning position. Young trees are clean-barked, but older trees have grey scaly bark on the trunks which on shedding discloses slightly orange-white bark beneath. The leaves and fruit (except that fruits are considerably larger) show affinities with *E. alba.*

Eucalyptus sp. Speck No. 4971 was observed in association with *E. foelscheana* on skeletal sands north of Karunjie, and with *E. dichromophloia* on rugged sandstone country. This species is a small (15–25 ft high) white-barked gum, with large leaves and large fruits, both very pruinose.

The nomenclature of genus *Eucalyptus* follows Blake (1953). Several forms resembling *E. houseana* and *E. bigalerita* were all determined by Blake as *E. alba.*

The structure of the various communities in Tables 5–13 is indicated by the use of the formula described by Christian and Perry (1953). In this system the tree storey is indicated by A, the shrub storey by B, and the ground storey by C, with numerical subscripts where there is more than one layer in a storey. The estimated average height of each layer in feet is shown as an index to the appropriate layer symbol. Density, subjectively estimated into five density classes ranging from very dense to very sparse, is indicated by the symbols xx, x, y, z, and zz (in decreasing order of density) placed after the symbols indicating the layers. The generic name *Eucalyptus* has been abbreviated to *E.* throughout this paper.

(*a*) E. tectifica–E. grandifolia *Alliance*

With the exception of small particular habitats this alliance occurs as grassy woodlands throughout the soils of the volcanic and shale areas. From the standpoint of land use it is the most important in the area and is second in extent only to the *E. tetrodonta–E. miniata* alliance. Its 23 associations have been grouped into two sub-alliances, the *E. tectifica* sub-alliance of the northern higher-rainfall areas on volcanic soils and the *E. grandifolia* sub-alliance of the lower-rainfall areas on soils of shale and volcanic origin.

The *E. tectifica–E. grandifolia* alliance corresponds approximately to the *E. tectifica* and *E. grandifolia* alliances of the Ord–Victoria area (Perry 1956), where they occur extensively on the Tippera, Elliot, and Cullen soils. These two communities are more strongly linked in the North Kimberleys. The *E. grandifolia* alliance of the Ord–Victoria area occurs on granites, alluvium, and sandstone, whereas it associates with *E. tectifica* on the basic-intermediate rocks in this area. It probably also corresponds to the low open forests of the Katherine–Darwin region (Christian and Stewart 1953). Perry (1956) stated that it is also represented in the Barkly region.

This alliance constitutes the major vegetation communities of the Barton, Napier, Isdell, and parts of the Kennedy, Foster, and Karunjie land systems.

(i) E. tectifica *Sub-alliance*.—The 10 associations of this sub-alliance have been classified as grassy woodlands except one minor community of low trees, which has the density of a forest (Table 5). Most of the associations are very similar in general structure and physiognomy although there is some floristic variation in the ground storeys. The changes from one association to another correspond to slight changes in habitat. The upper tree storey is open, usually one to several crown widths apart,

TABLE 5

SUMMARIZED DETAILS OF E. TECTIFICA SUB-ALLIANCE (E. TECTIFICA–E. GRANDIFOLIA ALLIANCE)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(1) *E. tectifica*	Woodland $A_2^{30}z\ A_1^{10-15}z\ C_2^4x$	Throughout the area but particularly northern and central	25–40	Volcanic rocks	Undulating, gentle to medium slopes and low rocky hills	Skeletal red earths, igneous red earths, and fine-textured yellow podzolics	Well-developed tall grass layer of *Sehima nervosum*, *Sorghum plumosum*, *Chrysopogon* spp., annual *Sorghum* spp., *Themeda australis*. *Aristida hygrometrica* becomes increasingly important towards the southern drier areas
(2) *E. tectifica–E. grandifolia*	Woodland $A_2^{30}z\ A_1^{10-15}z\ C_1^4y$	Throughout the area but particularly northern and central	25–40	Volcanic rocks	Medium to gentle slopes and small rocky stream-lines	Skeletal red earths, igneous red earths, and fine-textured yellow podzolics	As for (1), but includes *Iseilema* sp. and *Plectrachne pungens* in some areas
(3) *E. tectifica–E. foelscheana*	Woodland $A_1^{30}z\ B_1^{10}zz\ C_2^4x$	Throughout the area	25–40	Volcanic rocks	Levees and flats associated with stream-lines	Red levee soils and igneous red earths	Well-developed tall grass layer of *Sehima nervosum*, *Sorghum plumosum*, *Chrysopogon* spp., *Heteropogon contortus*, *Aristida hygrometrica*, and *Themeda australis*
(4) *E. foelscheana*	Woodland $A_2^{25}z\ A_1^{10}z\ B_1^{6-8}z\ C_2^4z$	Central	30–35	Volcanic rocks	Depressions and flats	Igneous red earths with sandy surface and some lateritic gravel	Fair development of *Plectrachne pungens* and *Aristida hygrometrica*
(5) *E. jensenii–E. tectifica*	Woodland $A_2^{45}z\ A_1^{10-15}z\ B_1^{6-8}z\ C_2^4z$	Central and southern	25–30	Volcanic rocks	Gentle slopes	Igneous red earths with sandy surface and lateritic gravel	Fair grass layer of *Plectrachne pungens*, *Aristida hygrometrica*, and *Heteropogon contortus*
(6) *E. jensenii*	Woodland $A_2^{45}z\ A_1^{10-15}z\ B_1^{6-8}z\ C_2^4z$	Central and southern	25–30	Volcanic rocks	Gentle slopes	Igneous red earths with sandy surface and lateritic gravel	Fair grass cover of *Plectrachne pungens* and annual *Sorghum* spp.

TABLE 5 (*Continued*)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(7) *E. tectifica–Terminalia* sp.	Forest $A_2^{15}z\ A_1^{10}y\ B_1^{6-8}z\ C_2^{4}zz$	Central and northern	30–35	Volcanic rocks	Low rocky ridges	Skeletal soils with cherty rock fragments and lateritic gravel	Poor development of *Plectrachne pungens*, *Eriachne obtusa*, *Aristida hygrometrica*, and annual *Sorghum* spp.
(8) *E. tectifica–E. confertiflora*	Woodland $A_2^{30}z\ A_1^{10-20}z\ C_2^{4}z\ C_1^{1}zz$	Throughout the area but particularly northern and central	25–40	Volcanic rocks	Steeper slopes	Skeletal red earths	Moderate development of tall grass layer of annual *Sorghum plumosum*, *Chrysopogon* spp., *Heteropogon contortus*, and *Themeda australis*
(9) *E. tectifica–E. jensenii–E. foelscheana*	Woodland $A_2^{45}z\ A_1^{10-15}z\ B_1^{6-8}z\ C_2^{3}z$	Southern	25–30	Volcanic rocks	Gentle slopes	Igneous red earths with sandy surface and lateritic gravel	Fair grass cover of *Plectrachne pungens*, *Aristida hygrometrica*, and annual *Sorghum* spp.
(10) *E. tectifica–E. grandifolia–E. foelscheana*	Woodland $A_1^{30}z\ A_1^{10-15}z\ C_2^{4}y\ C_1^{1}z$	Throughout the area but particularly northern and central	25–40	Volcanic rocks	Gentle slopes and levees	Skeletal red earths, igneous red earths, and fine-textured yellow podzolics	Well-developed *Chrysopogon* spp., *Sehima nervosum*, *Sorghum plumosum*, and *Themeda australis*

and approximately 25–35 ft high (Plate 4, Figs. 1 and 2). It may be slightly higher in more favoured habitats or lower in the drier parts of the area.

The low tree layer is very variable and consists usually of a small number of species of which a very high proportion are deciduous. The most important are: *Cochlospermum gregorii*, *Terminalia circumalata*, *Erythrophloeum laboucheri*, *Atalaya hemiglauca*, and more rarely *Livistona humilis*.

With the exception of the associations in which *E. jensenii* is a dominant or co-dominant and in very small special habitats the shrub layer is either very poorly developed or non-existent.

The ground storeys, consisting of tall perennial grasses, are very well developed, and apart from those found on the small areas of grey soils of heavy texture are the best pasture of the area. The dominant grasses in these communities are *Dichanthium* spp. and *Bothriochloa* spp. (blue grasses), *Sehima nervosum* (white grass), *Chrysopogon fallax* (beard grass), *Sorghum plumosum* (plume sorghum), *Heteropogon contortus* (bunch spear grass), and *Themeda australis* (kangaroo grass). The distribution of the ground storeys in relation to the tree storeys is shown in Table 5. Because the survey took place at the end of the dry period it was not possible to collect and identify the forbs which are probably abundant in some of these communities in the wet season. However, *Gomphrena canescens* was a very conspicuous part of the ground flora of several associations.

The most widespread communities of the alliance are *E. tectifica* and *E. tectifica–E. grandifolia* associations. They occur on the skeletal and igneous red earths and the fine-textured yellow podzolic soils of the volcanic areas, except the steeper, more rugged parts and the flats and levees. On the areas of more rugged topography, *E. grandifolia* is usually replaced by *E. confertiflora*. In this habitat the species in the low tree layer are more numerous and the ground storey is dominated by annual *Sorghum*. Where the alliance occurs on levees and gentler slopes *E. foelscheana* is commonly present and forms the *E. tectifica–E. grandifolia–E. foelscheana* association.

The *E. tectifica–Terminalia* sp. association is a minor one and occurs on stony ridges with cherty rock outcrops near the junction of the volcanic and sedimentary rocks.

The associations which include *E. jensenii* as a dominant occur on the sandy igneous red earths of the Kennedy land system within the 27–35 in. rainfall belt (Plate 5, Fig. 1). The low tree layer of these associations is more strongly developed and contains many of the species of the adjoining *E. tetrodonta–E. miniata* forests.

(ii) E. grandifolia *Sub-alliance.*—This is the lower-rainfall equivalent of the *E. tectifica* sub-alliance. The change is a gradual one. In the northern higher-rainfall areas within the *E. tectifica–E. grandifolia* alliance, *E. grandifolia* is a co-dominant; towards the southern lower-rainfall areas it gradually increases in importance. In the north it is common on the moderate slopes and skeletal soils. In the south it also occupies the gentler slopes, flats, and levees. It extends beyond the volcanic soils to the yellow podzolic and even the sandy soils of the shale areas and forms associations with *E. pruinosa* and two undescribed species of *Eucalyptus*. At this extreme of the alliance it associates with *Adansonia gregorii* on steep shale scarps of the Karunjie land system.

In the adjacent Ord–Victoria area (Perry 1956), *E. pruinosa* usually forms a mono-association alliance. In the North Kimberley area it appears only in the south, where it is apparently at one extreme of its range and forms associations with *E. tectifica* on igneous red earths and yellow podzolic soils and with *E. grandifolia* and an undescribed species on fine-textured yellow podzolic soils. *Eucalyptus* sp. Speck No. 4971–*E. foelscheana* association was observed on skeletal sands north of Karunjie.

There is a marked difference in the development of the lower layers of the associations of this sub-alliance (Table 6). Those on fine-textured yellow podzolics or igneous red earths resemble the *E. tectifica* sub-alliance with poor development of low tree and shrub layers but well-developed grass storeys. Those occurring on the sandier soils show much richer low tree and shrub layers with sparser grass storeys. The predominance of *Aristida hygrometrica* in the ground storeys of these low-rainfall associations is marked.

(*b*) E. tetrodonta–E. miniata *Alliance*

This alliance corresponds approximately with the *E. tetrodonta–E. miniata* alliance of the Ord–Victoria area (Perry 1956) where with its 17 associations it occupies a large proportion of the higher-rainfall parts. There is a marked difference in the North Kimberley area in the importance of *E. phoenicea* in the intermediate and lower-rainfall parts. It is widespread in the Katherine–Darwin region, where it is generally equivalent to the tall open forests of Christian and Stewart (1953) and includes their scrubby open forests. It includes both Gardner's (1923) sandstone savannah woodland and sclerophyllous woodland. It is widespread throughout northern Australia and extends from the lower part of the Cape York Peninsula in Queensland to the Kimberleys in Western Australia. It occurs on rock outcrops, skeletal soils, and deep sandy soils on quartzites, sandstones, and laterites under a mean annual rainfall greater than about 27 in.

In the North Kimberleys the alliance occupies approximately three-quarters of the total area. Fifteen associations have been recognized, the details of which have been summarized in Tables 7–9. For convenience and for reasons given above, the associations have been grouped according to floristic relationships into three sub-alliances. This grouping can be correlated with several factors of environment which will be discussed under each sub-alliance.

This alliance constitutes the major vegetation communities for the Buldiva and Pago land systems and the lateritized portion of the Foster land system.

(i) E. tetrodonta *Sub-alliance*.—This sub-alliance (Plate 2, Fig. 1) forms the major vegetation of the deep sandy soils of the Pago and Buldiva land systems and the greater part of lateritic soils of the Foster land system of the higher-rainfall areas. The trees are tall and straight. Individual trees were seen 70–80 ft in height, but typically the upper tree layer is 40–50 ft and in density constitutes an open forest. Many of the trees are "piped", which renders them useless for milling purposes.

There are nine upper tree storey dominants and their associations are indicated in Table 7. *E. tetrodonta* (messmate or stringybark) is the most common species, and

TABLE 6

SUMMARIZED DETAILS OF E. GRANDIFOLIA SUB-ALLIANCE (E. TECTIFICA–E. GRANDIFOLIA ALLIANCE)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(11) *E. grandifolia*	Woodland $A_2^{25}z\ A_1^{10}z\ B_1^{6-8}z\ C_2^{4}z\ C_1^{1}zz$	Southern and south-eastern	25–30	Shales and sandstones	Levees, river flats, and gentle slopes	Sandy levee soils and varied skeletal soils	Moderate development of *Plectrachne pungens*, *Eulalia fulva*, *Aristida hygrometrica*, and *Aristida* spp.
(12) *E. grandifolia–E. foelscheana*	Woodland $A_1^{25-35}z\ B_1^{4-8}zz\ C_2^{4}y\ C_1^{1}z$	South-eastern	25–28	Shales and sandstones	Levees and gentle slopes	Varied levee soils and deep sands	Moderate development of annual *Sorghum* spp., *Eriachne* spp., *Aristida hygrometrica*, *Plectrachne pungens*, and patches of *Themeda australis*
(13) *E. grandifolia–E. foelscheana–E. pruinosa*	Woodland $A_2^{20-25}z\ A_1^{10-15}z\ B_1^{4-6}zz\ C_2^{4}y\ C_1^{1}z$	South-eastern	25–28	Shales and sandstones	Flats and gentle slopes	Fine-textured yellow podzolics	Moderate development of *Plectrachne pungens*, *Aristida hygrometrica*, with patches of *Themeda australis*
(14) *E. pruinosa*	Woodland $A_2^{20-25}z\ A_1^{10-15}z\ B_1^{4-6}zz\ C_2^{4}y\ C_1^{1}z$	Southern areas only	25–30	Volcanic rocks	Flats and gentle slopes	Igneous red earths	Good development of *Chrysopogon* spp., *Sehima nervosum*, *Aristida latifolia*, annual *Sorghum* spp., *Aristida hygrometrica*, and *Plectrachne pungens*
(14*a*) *E. pruinosa*	Woodland $A_2^{20}z\ A_1^{10}z\ B_1^{4-6}zz\ C_2^{6}y\ C_1^{1}z$	Southern and south-eastern	25–30	Shales	Flats	Fine-textured yellow podzolics	Extremely tall development of annual *Sorghum* spp., *Aristida hygrometrica*, *Chrysopogon* spp., and *Plectrachne pungens*
(15) *E. pruinosa–E. grandifolia–E. tectifica*	Woodland $A_2^{20-25}z\ A_1^{10-15}z\ B_1^{4-6}zz\ C_2^{4}y\ C_1^{1}z$	Southern areas only	25–30	Volcanic rocks	Flats and gentle slopes	Igneous red earths, fine-textured yellow podzolics	*Plectrachne pungens*, annual *Sorghum* spp., *Aristida hygrometrica*, and *Themeda australis*
(16) *E. pruinosa–E. tectifica*	Woodland $A_2^{22}zz\ A_1^{10}zz\ B_1^{4}zz\ C_2^{4}y\ C_1^{1}z$	Southern and south-eastern	25–30	Shales	Flats and gentle slopes	Fine-textured yellow podzolics	Good development annual *Sorghum* spp., *Aristida hygrometrica*, *Plectrachne pungens* on higher ground

TABLE 6 (*Continued*)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(17) *E. pruinosa–* *E. grandifolia*	Woodland $A_1^{20}z\ B_1^{6-8}zz\ C_2^{4}y\ C_1^{1}z$	South-eastern	25–28	Shales	Flats and gentle slopes	Fine-textured yellow podzolics	Good development of *Aristida latifolia*, *Heteropogon contortus*, and *Sehima nervosum*, with patches of *Themeda australis*
(18) *E. pruinosa–* *E.* sp. Speck No. 4971	Woodland $A_1^{20-25}z\ C_2^{4}y\ C_1^{1}z$	Southern	25–30	Shales	Gentle slopes and flats	Fine-textured yellow podzolics	Good development of *Plectrachne pungens* and *Aristida hygrometrica*
(19) *E.* sp. Speck No. 4971– *E. grandifolia*	Woodland $A_2^{20}zz\ A_1^{10}z\ B_1^{4-6}zz\ C_2^{4}z\ C_1^{1}z$	South-eastern	25–28	Shales and sand-stones	Moderate to gentle slopes	Skeletal sands with sandstone outcrops	Good development of *Plectrachne pungens*, *Aristida hygrometrica*, annual *Sorghum* spp., and *Eriachne obtusa*
(20) *E.* sp. Speck No. 4971– *E. foelscheana*	Woodland $A_2^{20}zz\ A_1^{10}z\ B_1^{4}zz\ C_2^{4}z\ C_1^{1}z$	South-eastern	25–30	Shales and sand-stones	Gentle slopes	Skeletal sands with sandstone outcrops	Good development of *Plectrachne pungens* and *Aristida hygrometrica*
(21) *E.* sp. Speck No. 5013– *E. grandifolia*	Woodland $A_2^{20}z\ A_1^{10}zz\ B_1^{4}zz\ C_1^{4}z\ C_1^{1}z$	Eastern	25–30	Shales and sand-stones	Gentle slopes	Hard yellow sands and fine-textured yellow podzolics	Good development of *Plectrachne pungens* and *Aristida hygrometrica*
(22) *E. grandifolia–* *E. alba–* *E. apodophylla*	Woodland $A_2^{30-40}z\ A_1^{15}zz\ C_2^{5}y\ C_1^{1}z$	Throughout the area	25–40	Shales and sand-stones	Levees and flats	Sandy levee soils	Good development *Plectrachne pungens*, annual *Sorghum* spp., and *Aristida hygrometrica*
(23) *Adansonia gregorii–* *E. grandifolia*	Woodland $A_2^{30}zzz\ A_1^{20}zz\ B_1^{6}zz\ C_1^{2}zz$	South-eastern	25–30	Shales and sand-stones	Steep slopes	Skeletal shales and sandstones	Sparse development of annual *Sorghum* spp.

TABLE 7

SUMMARIZED DETAILS OF E. TETRODONTA SUB-ALLIANCE (E. TETRODONTA–E. MINIATA ALLIANCE)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(24) *E. tetrodonta*	Forest and woodland $A_2^{40}y\ A_1^{15}zz\ B_1^{6}z\ C_2^{3}z\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Moderate to gentle slopes	Deep yellow sands, skeletal sands, with sandstone outcrops and skeletal laterite	Moderate development of *Plectrachne pungens*, annual *Sorghum* spp., and *Heteropogon contortus*
(25) *E. tetrodonta–E. miniata*	Forest and woodland $A_2^{45}y\ A_1^{20}z\ B_1^{8}z\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Moderate to gentle slopes	Deep yellow sands, coarse-textured yellow podzolics, and skeletal laterite	Moderate development of *Plectrachne pungens* and annual *Sorghum* spp.
(25*a*) *E. tetrodonta–E. miniata–Callitris intratropica*							
(26) *E. tetrodonta–E. miniata–E. polycarpa*	Forest and woodland $A_2^{50}y\ A_1^{20}y\ B_1^{8}z\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Gentle slopes and flats	Deep yellow sands and red medium sands	Fair development of *Plectrachne pungens*, annual *Sorghum* spp.
(27) *E. bleeseri–E. tetrodonta–E. miniata*	Forest and woodland $A_2^{35}y\ A_1^{10}z\ B_1^{8}zz\ C_2^{4}z\ C_1^{1}z$	Northern	35–40	Sandstone and quartzite	Gentle slopes	Lateritic podzolics	Fair development of annual *Sorghum* spp. and *Plectrachne pungens*
(28) *E. tetrodonta–E. confertiflora*	Woodland $A_2^{40}y–z\ A_1^{15}z\ B_1^{6}z\ C_2^{4}z\ C_1^{1}z$	Throughout the area except south-east	28–40	Sandstone	Flat tops and steep slopes	Skeletal laterite and skeletal sands with lateritic gravel and sandstone	Fair development of *Plectrachne pungens* with *Eriachne* spp.
(29) *E. tetrodonta–E. dichromophloia*	Woodland $A_2^{40}y–z\ A_1^{15}z\ B_1^{6}z\ C_2^{4}y\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Flat tops, sandstone ridges	Skeletal laterite, skeletal sands with laterite gravel and sandstone outcrops	Good development of *Plectrachne pungens* and annual *Sorghum* spp.
(30) *E. tetrodonta–E. miniata–E. dichromophloia*	Forest and woodland $A_2^{45}y\ A_1^{20}z\ B_1^{6}y\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Medium to gentle slopes	Skeletal sands	Fair development of *Plectrachne pungens* and annual *Sorghum* spp.
(31) *E. tetrodonta–E. miniata–E. foelscheana*	Forest and woodland $A_2^{45}y\ A_1^{20}z\ B_1^{8}y\ C_2^{4}z\ C_1^{1}z$	Central	30–35	Sandstone and quartzite	Medium to gentle slopes	Deep yellow sands and skeletal sands with lateritic gravel	Good development of *Plectrachne pungens* and patches of annual *Sorghum* spp.
(32) *E. tetrodonta–E. miniata–E. latifolia*	Forest and woodland $A_2^{45}y\ A_1^{25}z\ B_1^{6}z\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Sandstone and quartzite	Gentle slopes	Lateritic podzolics	Good development of *Chrysopogon* spp., *Plectrachne pungens*, *Sehima nervosum*, annual *Sorghum* spp., *Eriachne* spp., and *Sorghum plumosum*

TABLE 7 (*Continued*)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(33) *E. tetrodonta–E. jensenii*	Woodland $A_2^{50}z\ A_1^{25}z\ B_1^{8}y\ C_2^{4}z\ C_1^{1}z$	Central and southern	28–35	Volcanic rocks	Gentle slopes	Igneous red earths with sandy surface	Good development of *Plectrachne pungens*, *Aristida* spp., *Sehima nervosum*, and *Heteropogon contortus*
(34) *Callitris intra-ropica*	Forest $A_2^{40}y\ A_1^{20}z\ B_1^{8}z\ C_2^{4}z\ C_1^{1}z$	Mostly central and northern	30–40	Sand-stone and quartzite	Moderate to gentle slopes	Red medium sands	Fair development of *Plectrachne pungens* and annual *Sorghum* spp.

occurs in all but one association. *E. miniata* (woollybutt) is second in importance but is not so consistent and is much more patchy in distribution than *E. tetrodonta*. In the south-western parts of the area it extends beyond the range of *E. tetrodonta* and dominates the sandstone areas (Gardner 1923). These two species form the basic elements of the alliance, and the other species are associated with slight changes in habitat conditions.

E. polycarpa associates with *E. tetrodonta* and *E. miniata* on the deep sandy soils of the slight depressions, while the appearance of *E. dichromophloia* in the alliance usually indicates the presence of laterite or sandstone outcrops. In the extreme north the occurrence of laterite on high levels in sandstone country appears to correlate with the appearance of *E. bleeseri*, but where laterite is present on flats or depressions, *E. latifolia* may occur.

Callitris intratropica as well as forming pure stands on deep red sands (Plate 7, Fig. 2) and as a co-dominant with *E. tetrodonta* and *E. miniata* occurs in minor amounts throughout the sandstone country. The trees seen were 30–50 ft in height with boles not exceeding 18–24 in. in diameter. Although Gardner (1923) reports trees up to 80 ft in height, no trees of these dimensions were observed along the traverse routes.

The low tree layer of the sub-alliance is variable, usually moderately well developed but commonly discontinuous. The following species are representative: *Petalostigma quadriloculare, Gardenia pyriformis, Grevillea pteridifolia, G. cunninghamii, G. heliosperma, Persoonia falcata, Buchanania obovata, Ventilago viminalis, Planchonia careya, Eugenia suborbicularis, Brachychiton diversifolium*, and *Melaleuca* sp. nov. In some special habitats with lateritic soils (Foster land system) *Livistona humilis* forms a dense small tree layer in the *E. tetrodonta–E. latifolia* association.

The shrub layer is also moderately well developed though it always remains an open community. Many of the species in this layer are smaller forms of the low tree layer. The following is a representative list: *Petalostigma quadriloculare, Acacia sericata* var. *dunnii, Acacia monticola, Acacia* spp., *Grevillea agrifolia, Livistona loriphylla, Bossiaea phylloclada, Verticordia cunninghamii, Calythrix brachyphylla, Jacksonia argentea*, and *Jacksonia thesioides*.

The grass storey of this alliance is dominated by *Plectrachne pungens* and annual *Sorghum*. It is considered that during the "wet" these ground layers would be considerably supplemented by forbs of various kinds but as the survey was made at the end of the dry season and very extensive fires had occurred in the area, no determinations were possible.

(ii) E. phoenicea–E. ferruginea *Sub-alliance*.—This is the southern low-rainfall counterpart of the *E. tetrodonta* sub-alliance and although *E. tetrodonta* and *E. miniata* still occur throughout the area their place as the major vegetation unit of the Pago land system is replaced by the above sub-alliance.

Although classed as forest, it is much lower than its northern counterpart and apart from the slightly greater development of grass understoreys, in general physiognomy it resembles the scrub forests of Pidgeon (1942) and Speck (1952).

The upper tree storey is typically 25–35 ft high. The crowns though interlacing in places are frequently more open. The trunks are often gnarled and twisted and are seldom more than 12–18 in. in diameter. *Callitris intratropica* though sparsely distributed throughout the sub-alliance never forms stands as it does in the higher-rainfall areas.

The low tree layer is poorly developed and many of the species which in the northern higher-rainfall areas compose this layer are of only shrub height in the south. The *Grevillea* spp. are still prominent but patchy in distribution while in some areas *Acacia* spp. develop into thickets. The following are the most common species in this layer: *Acacia* spp., *Grevillea pteridifolia*, *Grevillea cunninghamii*, *Grevillea agrifolia*, *Petalostigma quadriloculare*, *Ventilago viminalis*, *Planchonia careya*, and *Gardenia* spp.

Most of these species are also present in the shrub layer with the addition of *Acacia sericata* var. *dunnii* and *Jacksonia thesioides*.

The grass understorey differs very little from its higher-rainfall counterpart. *Plectrachne pungens* and annual *Sorghum* are dominant but *Aristida hygrometrica* is more important than in higher-rainfall areas.

Five associations have been recognized (Table 8). There are possibly many more associations as the vegetation is very complex. The country is more broken and greater difficulty is therefore found in demarcating the topographic land units and this is reflected in the complexity of the vegetation.

This sub-alliance forms the major vegetation unit for Pago land system between approximately the 25-in. and the 30-in. annual rainfall belt which covers the southern and south-eastern portion of the area. It also occupies the corresponding units in the Buldiva and Karunjie land systems.

(iii) E. dichromophloia *Sub-alliance.*—This sub-alliance maintains strong relationships with the other two sub-alliances through its most characteristic species *E. dichromophloia*. The characteristic habitat of this related group of associations is the rugged sandstone areas (Table 9), and *E. dichromophloia* association also occurs on the various areas of skeletal lateritic soils.

The latter association (where it occurs on laterite) is a woodland 30–35 ft high. The lower tree storey is usually absent except for occasional palms (*Livistona humilis*) and the shrub layer is absent or extremely sparse. There is a well-developed *Plectrachne pungens* (soft spinifex) ground storey.

On the rugged sandstone areas the upper tree layer is considerably denser. The low tree and shrub layers are also well developed and contain all the species of the comparable layers of the other two sub-alliances with a greater number of Indo-Malayan elements, e.g. *Brachychiton* spp., *Terminalia* spp., and *Gardenia* spp.

The grass layer is very poorly developed and consists mainly of annual *Sorghum* and sparse *Plectrachne pungens* and a few forbs.

The *E. dichromophloia* sub-alliance occurring on the rugged sandstone country (Plate 1, Fig. 2) is the major vegetation of the Buldiva land system and occurs in smaller units in the Pago and Karunjie land systems. It also is very widely distributed through the Pago and Foster land systems on the numerous small lateritic ridges. With such an extensive north–south distribution it is to be expected that there would be some floristic differences between northern and southern areas. *Eucalyptus* sp.

TABLE 8

SUMMARIZED DETAILS OF E. PHOENICEA–E. FERRUGINEA SUB-ALLIANCE (E. TETRODONTA–E. MINIATA ALLIANCE)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(35) *E. phoenicea*	Woodland and forest $A_2{}^{35}y\text{–}z\ A_1{}^{15}zz\ B_1{}^{8}z\ C_2{}^{4}z\ C_1{}^{1}z$	Southern	25–30	Sand-stone and quartzite	Moderate to gentle slopes	Deep yellow sands, skeletal sands	Fair to moderate development of *Plectrachne pungens*, *Aristida hygrometrica*, and annual *Sorghum* spp.
(36) *E. phoenicea–E. dichromophloia*	Woodland $A_2{}^{35}z\ A_1{}^{15}zz\ B_1{}^{8}y\ C_2{}^{4}z\ C_1{}^{1}z$	Southern	25–30	Sand-stone and quartzite	Moderate to steep slopes	Skeletal sands and sandstone outcrops	Good development of *Plectrachne pungens*, *Aristida hygrometrica*, and annual *Sorghum* spp.
(37) *E. phoenicea–E. collina–E. ferruginea*	Woodland $A_1{}^{30}z\ B_1{}^{4-8}z\ C_2{}^{3}z\ C_1{}^{1}z$	Southern	25–30	Sand-stone and quartzite	Moderate to gentle slopes	Skeletal sands with sandstone	Poor development of *Plectrachne pungens*, annual *Sorghum* spp., and *Aristida hygrometrica*
(38) *E. ferruginea–E. phoenicea–E. dichromophloia*	Woodland $A_1{}^{35}z\ A_1{}^{15}z\ B_1{}^{8}y\ C_2{}^{3}z\ C_1{}^{1}z$	Southern	25–30	Sand-stone and quartzite	Moderate to gentle slopes	Skeletal sands with sandstone outcrops	Poor development of *Plectrachne pungens*, annual *Sorghum* spp., and *Aristida hygrometrica*
(39) *E. phoenicea–E. ferruginea*	Woodland $A_2{}^{35}z\ A_1{}^{15}z\ B_1{}^{8}y\ C_2{}^{3}z\ C_1{}^{1}z$	Southern	25–30	Sand-stone and quartzite	Moderate to gentle slopes	Skeletal sands with sandstone outcrops	Poor development of *Plectrachne pungens* and annual *Sorghum* spp.

TABLE 9

SUMMARIZED DETAILS OF E. DICHROMOPHLOIA SUB-ALLIANCE (E. TETRODONTA–E. MINIATA ALLIANCE)

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(40) *E. dichromophloia*	Woodland $A_2^{35}z\ B_1^{6-8}zz\ C_2^{4}z\ C_1^{1}z$	Throughout the area	25–40	Sandstone and quartzite and laterite-capped volcanic rocks	Rugged sandstone areas and lateritic flats and ridges	Skeletal sands with sandstone outcrops and skeletal laterite	Poor development of *Plectrachne pungens* on sandstone, moderate on laterite cover
(41) *E. dichromophloia*–*E. collina*	Woodland $A_1^{35}z\ B_1^{8}z\ C_2^{4}zz\ C_1^{1}zz$	Southern	25–35	Sandstone and quartzite	Rugged sandstone areas	Skeletal sands with sandstone outcrops	Poor development of *Plectrachne pungens*, annual *Sorghum* spp., and *Alloteropsis semialata*
(42) *E.* sp. Speck No. 4971–*E. dichromophloia*	Woodland $A_1^{20}z\ B_1^{6-8}z\ C_2^{4}zz\ C_1^{1}zz$	Northern and central	30–40	Sandstone and quartzite	Rugged sandstone country	Skeletal sands with massive sandstone outcrops (scarp top)	Poor development of annual *Sorghum* spp. and *Plectrachne pungens*
(43) *E. herbertiana*–*E. dichromophloia*	Woodland $A_1^{20}z\ B_1^{8}z\ C_2^{2}zz\ C_1^{1}zz$	Northern	35–40	Sandstone and quartzite	Rugged sandstone country	Skeletal sands with massive sandstone outcrops	Poor development of *Plectrachne pungens*
(44) *E. collina*	Woodland $A_1^{30}z\ B_1^{8}z\ C_2^{4}zz\ C_1^{1}zz$	Southern	25–35	Sandstone and quartzite	Sandstone outcrops	Skeletal sands with massive sandstone outcrops	Poor development of *Plectrachne pungens*
(45) *E. collina*–*E. terminalis*	Woodland $A_1^{35}z\ B_1^{8}z\ C_2^{4}zz\ C_1^{1}zz$	Southern	25–35	Sandstone and quartzite	Sandstone outcrops	Skeletal sands with massive sandstone outcrops	Poor development of *Plectrachne pungens*
(46) *E. dichromophloia*–*E. ferruginea*	Woodland $A_1^{35}z\ B_1^{8}z\ C_2^{4}zz\ C_1^{1}zz$	Throughout the area	25–40	Sandstone and quartzite	Sandstone outcrops	Skeletal sands with massive sandstone outcrops	Poor development of *Plectrachne pungens*
(47) *E. confertiflora*–*E. dichromophloia*	Woodland $A_2^{30}z\ A_1^{15}z\ C_2^{4}z\ C_1^{1}z$	Throughout the area	25–40	Sandstone and quartzite	Rugged sandstone areas and scarps	Skeletal sands with massive sandstone outcrops and skeletal laterite	Poor development of annual *Sorghum* spp. and *Plectrachne pungens*

Speck No. 4971 forms an association with *E. dichromophloia* on bare rocks in the north. It is found in the south also but on sands associated with shale areas and in association with *E. grandifolia* and *E. foelscheana*. *E. collina* is limited to the lower-rainfall areas, where it freely associates with a number of other species.

(*c*) E. latifolia *Alliance*

This small alliance is very widespread throughout the central and northern parts of the area. It is always a community of the flats or depressions on both coarse and fine-textured yellow podzolics and lateritic podzolics in the Barton and Kennedy, and to a lesser extent in the Pago and Foster land systems.

In the adjacent Ord–Victoria area (Perry 1956) it is included in the *E. tectifica* alliance. In the North Kimberley area, because it forms associations with most of the dominants of other large alliances and because these associations are distinctive, it was considered to be convenient to arrange them in a separate alliance. This alliance mostly presents a parkland-like appearance, particularly the *E. latifolia* association. In this the low tree layer is typically sparse or absent, has very few shrubs, and has well-developed ground storeys of *Chrysopogon fallax*, *Sehima nervosum*, *Themeda australis*, as well as *Plectrachne pungens*. In the other associations the small tree and shrub layers are variable. Increased density in the tree layers is correlated with a reduction in density of the ground storeys. Summaries of these associations are presented in Table 10.

(*d*) E. papuana *Alliance*

This alliance is widespread throughout the area, but is restricted to the stream-lines and levees and is therefore a minor part of a number of land systems but is more common to the levees of the volcanic and shale areas.

The communities are woodlands with widely spaced shapely trees 40–80 ft in height. The lower tree layer is sparse or absent and the communities generally have a parkland appearance. This is particularly true of the *E. papuana* association of the frontage country of the Karunjie land system (Plate 3, Fig. 2). The ground storey of this association consists mainly of the annual *Aristida hygrometrica*. The common ground storey of the *E. papuana* associations of the higher-rainfall areas is mainly *Sorghum plumosum*, with lesser areas of *Themeda australis*, *Sehima nervosum*, *Alloteropsis semialata*, *Dichanthium* spp., *Bothriochloa* spp., and annual *Sorghum*.

Although *E. camaldulensis* forms woodlands with *E. papuana* in the lower-rainfall areas it is more typically seen as a fringing community along the streams. The alliance is summarized in Table 11.

(*e*) E. polycarpa–E. apodophylla *Alliance*

This small alliance, with the exception of *E. alba* association, occupies the depressions, levees, and flats associated with stream-lines throughout the sandstone areas. As well as the floristic differences from the *E. papuana* alliance it differs in structure in that there is usually a well-developed and often quite dense low tree layer. These low tree layers are very variable and floristically differ very little from

TABLE 10

SUMMARIZED DETAILS OF E. LATIFOLIA ALLIANCE

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(48) *E. latifolia*	Woodland $A_2^{35}z\ B_1^{6}z\ C_2^{4}z\ C_1^{1}zz$	Central and northern	30–40	Volcanic rocks	Flats	Lateritic podzolics; coarse and fine-textured yellow podzolics	Moderate development of *Chrysopogon* spp., *Sehima nervosum*, *Plectrachne pungens*, *Alloteropsis semialata*, *Themeda australis*, and *Sorghum plumosum*
(49) *E. latifolia–E. tectifica*	Woodland $A_2^{30}z\ A_1^{10}z\ B_1^{8}z\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Volcanic rocks	Gentle slopes and flats	Varied fine and coarse-textured yellow podzolics; skeletal and igneous red earths with lateritic gravel	Good development of *Sehima nervosum*, *Chrysopogon* spp., *Plectrachne pungens*, *Heteropogon contortus*, and *Alloteropsis semialata*
(50) *E. latifolia–E. tetrodonta*	Woodland $A_2^{45}z\ A_1^{20}z\ B_1^{8}z\ C_2^{4}z\ C_1^{1}z$	Central and northern	30–40	Volcanic rocks	Gentle slopes and flats	Coarse and fine-textured yellow podzolics	Moderate development of *Chrysopogon* spp., *Eriachne obtusa*, and patches of *Plectrachne pungens*
(51) *E. latifolia–E. grandifolia–E. tetrodonta*	Woodland $A_1^{45}z\ B_1^{4}y\ C_2^{4}z\ C_1^{1}z$	Central	30–35	Volcanic rocks	Flats	Fine-textured yellow podzolics with lateritic gravel	Fair development of *Alloteropsis semialata*, *Plectrachne pungens*, *Eriachne obtusa*, and *Chrysopogon* spp.
(52) *E. latifolia–E. polycarpa–E. oligantha*	Woodland $A_2^{40}z\ A_1^{15}zz\ C_2^{4}z\ C_1^{1}z$	Central	30–35	Volcanic rocks	Flats	Deep light grey sands with some lateritic gravel	Moderate development of *Plectrachne pungens*, annual *Sorghum* spp., and *Chrysopogon* spp.

TABLE 11

SUMMARIZED DETAILS OF E. PAPUANA ALLIANCE

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(53) *E. papuana*	Woodland $A_1^{40}z\ C_2^{4}y\ C_1^{1}z$	Throughout the area	25–40	Volcanic rocks	River levees and gentle flats	Red levee soils, sandy levee soils	Varied development of *Sorghum plumosum*, annual *Sorghum* spp., and *Eriachne* spp.
(54) *E. papuana*–*E. apodophylla*	Woodland $A_1^{40}z\ C_2^{4}y\ C_1^{1}z$	Central and northern	30–40	Volcanic rocks	Flats and depressions	Complex soils of volcanic sandstone ecotone	Good development of *Sorghum plumosum*, *Alloteropsis semialata*, and *Eriachne* spp.
(55) *E. papuana*–*E. apodophylla*–*E. alba*	Woodland $A_1^{35}z\ C_2^{4}y\ C_1^{1}z$	Central and northern	30–40	Volcanic rocks	Depressions or flats	Complex soils of volcanic sandstone ecotone	Good development of *Sorghum plumosum*, *Sehima nervosum*, *Iseilema* sp., and *Themeda australis*
(56) *E. papuana*–*E. tectifica*	Woodland $A_2^{30}z\ A_1^{15}z\ B_1^{8}zz\ C_2^{4}y\ C_1^{1}z$	Central and northern	30–40	Volcanic rocks	Flats and levees	Red levee soils	Good development of annual *Sorghum* spp., *Sorghum plumosum*, *Themeda australis*, *Sehima nervosum*, and *Heteropogon contortus*
(57) *E. papuana*–*E. alba*	Woodland $A_1^{35}z\ C_2^{4}y\ C_1^{1}z$	Throughout the area	25–40	Shales and sandstones	Levees and river flats	Sandy levee soils	Varied development of *Sorghum plumosum*, *Sehima nervosum*, *Dichanthium* spp., *Bothriochloa* spp., *Alloteropsis semialata*, and annual *Sorghum* spp.

that of the *E. tetrodonta* sub-alliance. One of the most notable differences is the frequent dominance of this layer by species of *Grevillea* or *Melaleuca*. This difference also applies to the shrub layer.

The ground storeys are very variable, the major perennials being *Sorghum plumosum*, *Chrysopogon* spp., *Eulalia fulva*, and *Alloteropsis semialata*. In places, however, there is a prolific growth of annual *Sorghum* 6–8 ft high. *Aristida hygrometrica* increases in importance towards the southern lower-rainfall areas. Characteristics of this alliance are summarized in Table 12.

(*f*) Terminalia *Sp.*–Dichanthium fecundum *Alliance*

This alliance occurs on the small patches of grey soils of heavy texture in the Barton, Napier, and to a lesser extent the Kennedy land system. Commonly these communities may be classified as grasslands with or without sparse trees. Towards the north, in the higher-rainfall areas this tree layer increases and in the largest occurrences of these communities seen in the Barton land system, between the Carson and Drysdale Rivers, the tree layer was well developed. It consisted of almost pure stands of *Terminalia* sp. (probably an undescribed species near *T. volucris*) and in general physiognomy resembled the "orchard communities" of the Katherine–Darwin region (Christian and Stewart 1953). The valuable *Astrebla* spp. and *Iseilema* spp. common on similar soils in the adjacent Ord–Victoria area were absent and replaced by the less valuable *Dichanthium fecundum*, *Bothriochloa ewartiana*, and to a lesser extent *Sorghum plumosum*.

Further details of these grassland communities are described under "Blue Grass Pastures" (Part VII, Section II(*a*)), and other features are summarized in Table 13.

(*g*) E. brevifolia (*Mono-association*) *Alliance*

This community is not widespread in the North Kimberleys. It occurs only in the areas of lowest rainfall. It does not readily associate with other species but tends to form pure stands on low sandstone ridges and occasionally spreads over the adjacent fine-textured yellow podzolics in the Karunjie land system.

The community may be considered as an extension of the *E. brevifolia* association of the Ord–Victoria area (Perry 1956) where it is considered to be the low-rainfall equivalent of the *E. tetrodonta*–*E. miniata* alliance. It occupies a similar role in the North Kimberleys with the difference that the *E. phoenicea* communities are intermediate between the two. However, the *E. brevifolia* association only just reaches the area and only its northern extremities have been observed. It is expected that it would become increasingly important towards the south-eastern areas of lower rainfall, but no information on these parts is available. Its characteristics are summarized in Table 13.

(*h*) Melaleuca *Spp. Alliance*

Because of limited records only one association has been defined for this alliance. It is considered that more detailed work on these minor communities will reveal that there are several associations as there are in the Ord–Victoria area (Perry 1956.)

TABLE 12

SUMMARIZED DETAILS OF E. POLYCARPA–E. APODOPHYLLA ALLIANCE

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
(58) *E. polycarpa*	Woodland $A_2^{35}z\ A_1^{20}z\ B_1^{10}z\ C_2^{4}z\ C_1^{1}z$	Throughout the area	28–40	Sand-stone and quartzite	Depressions and levees	Deep light grey sands and sandy levee soils	Fair development of annual *Sorghum* spp., *Plectrachne pungens*, and *Aristida hygrometrica*
(59) *E. apodophylla–E. polycarpa*	Woodland $A_2^{35}z\ A_1^{15}zz\ C_2^{5}y\ C_1^{1}zz$	Throughout the area	25–35	Sand-stone and quartzite	Depressions	Deep light grey sands	Good development of annual *Sorghum* spp., *Chrysopogon* spp., *Eulalia fulva*, and *Sorghum plumosum*
(60) *E. apodophylla–E. polycarpa*	Woodland $A_1^{40}z\ C_2^{8}x\ C_1^{1}z$	Throughout the area	25–35	Sand-stone and quartzite	Depressions	Deep light grey sands	Good development of annual *Sorghum* spp., *Chrysopogon* spp., *Eulalia fulva*, and *Sorghum plumosum*
(61) *E. apodophylla–E. alba*	Woodland $A_1^{40}z\ C_2^{5}y\ C_1^{1}z$	Throughout the area	25–40	Sand-stone and quartzite	Depressions	Deep light grey sands	Good development of *Sorghum plumosum*, *Alloteropsis semialata*, and *Sehima nervosum*
(62) *E. alba*	Woodland $A_2^{40}z\ A_1^{15}z\ C_2^{4}y\ C_1^{1}z$	Throughout the area	25–40	Sand-stone and quartzite	Flats associated with streams	Red levee soils	Good development of *Dichanthium* spp., *Bothriochloa* spp., and *Sorghum plumosum*
(63) *E. apodophylla–E. polycarpa–E. grandifolia*	Woodland $A_2^{40}zz\ A_1^{25}zz\ B_1^{5}zz\ C_2^{6}y\ C_1^{1}z$	Southern	25–35	Sand-stone and quartzite	Depressions	Deep light grey sands	Patches very tall development of annual *Sorghum* spp. and *Chrysopogon* spp.
(64) *E. apodophylla–E. polycarpa–E. grandifolia–E. oligantha*	Woodland $A_2^{45}z\ A_1^{15}zz\ B_1^{3}zz\ C_2^{4}y\ C_1^{1}z$	Central	30–35	Sand-stone and quartzite	Flats and levees	Sandy levee soils	Good development of *Eulalia fulva*, *Aristida hygrometrica*, *Sehima nervosum*, and *Chrysopogon* spp.
(65) *E. oligantha*	Woodland $A_2^{45}z\ A_1^{15}zz\ B_1^{6}zz\ C_2^{4}y\ C_1^{1}z$	Central	30–35	Sand-stone and quartzite	Flats and levees	Sandy levee soils	Good development of *Aristida hygrometrica*, *Eulalia fulva*, and *Sehima nervosum*
(66) *E. apodophylla–E. clavigera–E. latifolia*	Woodland $A_2^{40}z\ A_1^{15}z\ B_1^{3}z\ C_2^{4}y\ C_1^{1}z$	Central	30–35	Sand-stone and quartzite	Flats and levees	Sandy levee soils	Good development of *Eulalia fulva* and *Aristida hygrometrica*
(67) *E. polycarpa–E. latifolia*	Woodland $A_2^{40}z\ A_1^{20}z\ B_1^{3}zz\ C_2^{4}z\ C_1^{1}z$	Northern	35–40	Sand-stone and quartzite	Depressions between sand-stone outcrops	Deep light grey sands	Fair development of annual *Sorghum* spp., *Plectrachne pungens*, and *Eriachne* spp.
(68) *E. polycarpa–E. clavigera*	Woodland $A_2^{35}z\ A_1^{20}z\ B_2^{10}zz\ C_2^{4}z\ C_1^{1}z$	Central	30–35	Sand-stone and quartzite	Flats and levees	Sandy levee soils and deep light grey sands	Moderate development of *Sorghum plumosum* and *Aristida hygrometrica*

TABLE 13

SUMMARIZED DETAILS OF SUNDRY VEGETATION COMMUNITIES

Association	Formation and Formula	Locality	Mean Annual Rainfall (in.)	Rock Type	Topography	Soil	Grass Understorey
Terminalia sp.–*Dichanthium fecundum* alliance							
(69) *Terminalia* sp.–*Dichanthium fecundum*	Woodland $A_1^{15}y\ B_1^{6}zz\ C_3^{3-4}y\ C_1^{1}z$	Distributed throughout northern volcanic areas	35–40	Volcanic rocks	Flats and depressions	Grey soils of heavy texture	Well-developed *Dichanthium* spp. and *Bothriochloa* spp. with less frequent patches of *Iseilema* sp., *Sorghum plumosum*, and *Chrysopogon* spp.
(70) *Dichanthium fecundum*–*Bothriochloa ewartiana*	Grassland $B_1^{4-6}zz\ C_2^{3-4}y\ C_1^{1}z$	Throughout volcanic areas—particularly Isdell R. area	25–40	Volcanic rocks	Depressions and flats	Grey soils of heavy texture	*Dichanthium* spp., *Bothriochloa* spp., and *Sorghum plumosum*
E. brevifolia association (mono-association alliance)							
(71) *E. brevifolia*	Woodland $A_1^{10}z\ B_1^{6}zz\ C_2^{4}z\ C_1^{1}z$	South-eastern	25–27	Shales and sandstones	Flats and gentle slopes	Fine-textured yellow podzolics and skeletal sandstone outcrops	Tall development of annual *Sorghum* spp., *Chrysopogon* spp., *Plectrachne pungens* (on the ridges), and *Aristida hygrometrica*
Melaleuca spp. alliance							
(72) *Melaleuca viridiflora*	Forest $A_2^{25}zzz\ A_1^{10-15}y\ C_2^{2}z\ C_1^{1}z$	South-eastern	25–30	Shales and sandstones	Flats and gentle slopes at foot of shale scarps	Skeletal soils with sandstone outcrops and yellow podzolics	Mainly *Aristida hygrometrica*
Brachychiton spp.–*Terminalia* spp.–*E. confertiflora* community							
(73) Associations not defined	Woodland (variable)	Throughout the area except south-east	30–50	Sandstone and quartzite	Very steep slopes, scarps	Skeletal sands and bare rock	Very sparse annual *Sorghum* spp.
Terminalia spp.–*Ficus* spp.–*Melaleuca* spp. community							
(74) Associations not defined	Fringing community (variable)	More or less continuous belt along streams throughout the area	30–50	Volcanic patches and sandstone and quartzite	Creekside variable	Varied levee soils	Variable
E. camaldulensis fringing community							
(75) *E. camaldulensis*–*Melaleuca* spp.	Fringing community	Along the streams throughout the area	25–40	Sandstone and shales	Stream-lines	Sandy levee soils	Variable
Mangrove community							
(76) Associations not defined	Forests (variable)	On mud flats of river estuaries in sheltered positions		Recent alluvial	Flats	Saline muds	—

The *Melaleuca viridiflora* association is found on the gentle slopes and flats at the foot of the shale scarps which are typical of the Karunjie land system. The association is named from the low tree layer and constitutes a dwarf forest; the trees are very dense and are 10–15 ft in height. The stands of this association occur within the area occupied by the *E. pruinosa* association and occasional trees of this species may appear as a very sparse tall tree layer with the stands of the *Melaleuca viridiflora* association. The association is summarized in Table 13.

(*i*) Brachychiton *Spp.*–Terminalia *Spp.*–E. confertiflora *Community*

This is the community of the sandstone scarps and gorges of the North Kimberleys. Although records were made at several points sufficient information is not available to attempt the erection of associations.

This community is very variable, but typically consists of two or more tree layers. Many of the same species occur in both layers. The foliage is mostly of the broad-leaved kind and even the eucalypts are much more leafy than is typical. Many of the trees belong to the deciduous Indo-Malayan element referred to by Gardner (1942) as being characteristic of the monsoon woodlands.

The main species of the tree layer are *Brachychiton* sp. nov., *Brachychiton paradoxum, Terminalia canescens, Eucalyptus confertiflora, Vitex glabrata, Planchonella* sp., and *Ficus orbicularis.*

The lower tree layers include *Gardenia megasperma, Strychnos lucida, Ehretia saligna, Ixiora* sp., *Atalaya variifolia, Gardenia pyriformis*, and *Buchanania obovata.*

The ground storeys were very poorly developed except for sparse annual *Sorghum.* For other details see Table 13.

(*j*) Terminalia *Spp.*–Ficus *Spp.*–Melaleuca *Spp. Community*

This community (Plate 6, Fig. 1) shows considerable affinity with the scarp community in that it also consists very largely of Indo-Malayan elements, and may be compared with the fringing forests of the Katherine–Darwin region (Christian and Stewart 1953) and of the Ord–Victoria area (Perry 1956). Christian and Stewart point out that where this fringing forest attains any width there is a tendency for the development of monsoon forests. This does not occur in any of the country seen in the North Kimberley area, but Gardner (1923) reports a much greater development of this community along the rivers in the western parts of higher rainfall and refers to them as river forest.

In a fringing community of this type there are trees of varying heights but tree layers are not very obvious. The most frequently occurring trees are *Terminalia platyphylla, Ficus coronulata, Ficus glomerata, Melaleuca cajuputi, Melaleuca saligna, Terminalia grandifolia*, and *Acacia mangium* var. *holosericea.*

(*k*) E. camaldulensis *Fringing Community*

As already pointed out, this species forms small patches of woodlands with *E. papuana* on the levees of the lower-rainfall areas; it is more typically limited to the actual banks of streams and together with *Melaleuca leucodendron* sens. lat. forms, in places, a magnificent fringing community 60–80 ft high. Several other species of *Melaleuca* are also involved but they mostly form a low tree layer. The low tree layers of these fringing communities are commonly very complex and sufficient detailed records are not available to list them. However, *Pandanus oderatissimus* is very common. This community is summarized in Table 13.

(*l*) *Mangrove Communities*

Dense thickets of mangroves occur on mud flats in sheltered parts of the river estuaries and extend up the rivers to tidal limits. These were not seen during the survey but aerial photographs show zonation of species as described for the Katherine–Darwin region (Christian and Stewart 1953) and for the adjacent Ord–Victoria area (Perry 1956). They have been described in some detail by Gardner (1923).

IV. References

Beadle, N. C. W., and Costin, A. B. (1952).—Ecological classification and nomenclature. *Proc. Linn. Soc. N.S.W.* **77**: 61–82.

Blake, S. T. (1953).—Botanical contributions of the Northern Australia Regional Survey. I. Studies on northern Australian species of *Eucalyptus*. *Aust. J. Bot.* **1**: 185–352.

Christian, C. S., and Perry, R. A. (1953).—The systematic description of plant communities by use of symbols. *J. Ecol.* **41**: 100–5.

Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. C.S.I.R.O. Aust. Land Res. Ser. No. 1.

Gardner, C. A. (1923).—Botanical notes, Kimberley Division of West Australia. W. Aust. Forests Dep. Bull. No. 32.

Gardner, C. A. (1942).—The vegetation of Western Australia. *Proc. Roy. Soc. W. Aust.* **28**: 11–87.

Perry, R. A. (1956).—The plant ecology of the Ord–Victoria area, north-western Australia. M.Sc. Thesis, University of Adelaide.

Perry, R. A., and Christian, C. S. (1954).—Vegetation of the Barkly region. C.S.I.R.O. Aust. Land Res. Ser. No. 3: 78–112.

Pidgeon, Ilma M. (1942).—Ecological studies in New South Wales. D.Sc. Thesis, University of Sydney.

Speck, N. H. (1952).—The ecology of the metropolitan sector of the Perth coastal plain. M.Sc. Thesis, University of Western Australia.

PART VII. PASTURES OF THE NORTH KIMBERLEY AREA, W.A.

By M. Lazarides*

I. General

Pastures generally are poor, lacking either the presence or density of better species (*Astrebla* spp., *Iseilema* spp., *Dichanthium* spp., *Bothriochloa* spp., *Enneapogon* spp., *Heteropogon* sp., and *Themeda australis*) of comparable areas in the Northern Territory and north Queensland. The main dominating grasses are *Plectrachne pungens* (soft spinifex†), *Chrysopogon fallax* (beard grass), *Sehima nervosum* (white grass), *Sorghum australiense*, *S. plumosum*, *S. stipoideum* (sorghum grasses), and *Aristida hygrometrica* (kerosene grass), and to a much lesser extent *Dichanthium* spp. and *Bothriochloa* spp. (blue grasses), *Themeda australis* (kangaroo grass), and *Heteropogon contortus* (bunch spear, locally known as red Burdekin grass). None of the valuable *Astrebla* spp. (Mitchell grasses) are represented while the few *Iseilema* spp. (Flinders grasses) present constitute a very minute proportion of the native pastures.

Pastoral assessments of carrying capacities are based upon yield observations, information from pastoralists in comparable areas, and experimental studies at the Katherine Research Station (Arndt and Norman 1959).‡

The main dominating species are mostly medium to tall, coarse, quick-growing, tussocky perennials palatable only in the younger stages of growth. For the greater part of the year, they provide only coarse unpalatable material of low nutritive value. The blue grasses are the most valued in the entire area but, being restricted to very small parts of the volcanic country, they form only a minor constituent in the overall pasture. Species of moderate to good nutritive value such as *Themeda australis* and *Heteropogon contortus* are more common, but are not dominant over large areas.

The soft spinifex pastures, though poor, deteriorate very little during the dry season and towards the end of long dry spells provide better pasturage than most other types. Also as they occur on deep sandy soils they respond quickly to light falls of rain and provide a valuable supplement when rainfall has been too light to promote growth on the medium to fine soils.

The hardy, tussocky nature of the dominating perennials reduces the danger of over-grazing to some degree in many of the pasture types. The pastures of the river frontages are most susceptible to this danger because of their proximity to water. Consistent over-grazing of the perennial-dominated northern frontages would result in the partial elimination of the better perennials and the domination by poor, wiry

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

† Common names used are the standardized plant names from C.S.I.R.O. Aust. Bull. No. 272.

‡ Arndt, W., and Norman, M. J. T. (1959).—Characteristics of native pasture on Tippera clay loam at Katherine, N.T. C.S.I.R.O. Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 3.

species such as *Aristida* spp. (wire grasses) and *Eriachne* spp. (Wanderrie grasses). In the south the pastures of the river levees are dominated by annual grasses, and they would be particularly susceptible to over-grazing and require intelligent management to avoid deterioration or complete elimination.

Some top-feed species were observed, but only in very limited quantities. They are most common in the heavy soil grasslands of the volcanic areas and include *Terminalia volucris* (rosewood), *Acacia* sp. (mimosa), *Bauhinia* sp., and *Carissa lanceolata* (konkerberry). *Ventilago viminalis* (supplejack) is also present, but generally restricted to the more rugged, hardly accessible, sandstone areas such as the Gibb Range.

II. Description and Grouping of Pastures

The pastures of the area have been divided into 15 types and have been classified into four groups (Table 14).

(a) *Blue Grass Pastures*

The dominating species of this pasture are *Dichanthium fecundum* (curly blue grass, locally known as bundle bundle), *D. superciliatum* (tassel blue grass), *D. sericeum* (Queensland blue grass), *D. annulatum* (sheda grass), *Bothriochloa ewartiana* (desert blue grass), and *B. intermedia* (forest blue grass). These species have the highest nutritive value of any in the area, but unfortunately they are not extensive. They are limited to the grey soils of heavy texture which occur over a considerable portion of the Isdell land system and as numerous smaller areas, from a few square chains to 20 acres, throughout the Barton land system.

The pasture is of patchy nature, but two layers are relatively prominent. The dominant species form a dense, medium-height community up to 3 ft high, generally on the banks and edges of the gilgais. The depressions produce a very mixed growth of shorter annual grasses such as *Brachyachne convergens*, *Panicum decompositum*, *Eragrostis japonica*, *Paspalidium* spp., *Brachiaria* spp., *Eriachne glauca*, *Elytrophorus spicatus*, and *Iseilema vaginiflorum*, and a number of forbs, generally legumes. Very tall species are rare though *Dichanthium superciliatum* often attains a height of over 4 ft. These grasslands are often associated with a sparse tree or shrub flora of *Terminalia volucris*, *Bauhinia* sp., *Carissa lanceolata*, and *Acacia* sp. Where these species grow in reasonable quantities, they supplement the value of the pasture by providing top feed.

In the Napier land system, this pasture is found in very small patches of heavy clay soil on moderate slopes or in depressions in the typical rugged topography. In these areas the pasture differs slightly in possessing some of the dominants of the adjacent types and a particularly high percentage of forbs as well. In the Kennedy land system this pasture is often associated with broad, shallow, gilgaied depressions where dense stands of *Melaleuca* spp. predominate.

(b) *Plume Sorghum Pastures*

This pasture is typical of the hilly, usually stony, strongly dissected parts of the Mornington volcanics (Napier land system) with predominantly skeletal soils and is characterized by robust perennials, numerous forbs and ephemerals, and ample density. The dominating grass, *Sorghum plumosum* (plume sorghum), is a tall, densely tufted perennial forming large tussocks which produce both reproductive and vegetative tillers. With adequate rainfall, vegetative tillers are produced after maturation of the inflorescence and remain palatable throughout the greater part of seasonal dry

TABLE 14

PASTURE GROUPS AND COMMUNITIES WITH NOTES ON THEIR ENVIRONMENT

Group	Pasture Community	Notes
Good pastures	(1) Blue grass pastures	Relatively small areas confined to grasslands associated with grey soils of heavy texture
Moderate pastures	(2) Plume sorghum pastures	Moderately extensive areas associated with grassy woodlands on shallow red soils of the lower slopes and levees of the volcanic country
	(3) Kangaroo grass pastures	Small areas under grassy woodlands on igneous red earths of the flatter volcanic country
	(4) Bunch spear grass pastures	Medium to small areas associated with woodlands on igneous or skeletal red earths of undulating volcanic country
	(5) Flinders grass pastures	Very small areas confined to grasslands on grey soils of heavy texture or to fringing woodlands on skeletal red earths
Poor pastures	(6) White grass pastures	Relatively large areas of undulating to rugged volcanic country under woodlands or forests on podzolic or red earth soils
	(7) Wire grass pastures	Very small areas in association with grasslands on grey soils of heavy texture
	(8) Beard grass pastures	Small areas in volcanic country associated with woodlands on red levee soils and igneous red earths
	(9) Silky browntop pastures	Very small areas in hilly volcanic country associated with woodlands on skeletal red earths
	(10) Fringing pastures	Very small areas associated with sandy levees and fringing communities
Very poor pastures	(11) Soft spinifex pastures	Large areas associated with forests on deep sands in sandstone country
	(12) Annual sorghum pastures	Large areas in rugged sandstone and volcanic country associated with forests and woodlands on skeletal sands and skeletal laterite
	(13) Cockatoo grass pasture	Relatively small areas of flat sandstone country associated with forests and woodlands on red and yellow sands
	(14) Wanderrie grass pastures	Relatively large areas in flat shaly country associated with woodlands and forests on yellow podzolic soils
	(15) Kerosene grass pastures	Small areas associated with woodlands on red levee soils and sandy levee soils

periods. Consequently, the species is particularly valuable by virtue of its palatability during its growing period and by its provision of edible fodder during the dry season, at which time it appears to form a major portion of the diet of grazing stock (Arndt and Norman 1959).

Though the difficult topography of areas concerned may hinder maximum utilization, pastures of this type are highly regarded.

(c) *Kangaroo Grass Pastures*

On some of the skeletal red earths of the Barton, Napier, and to a lesser extent Kennedy land systems, a pasture in which kangaroo grass (*Themeda australis*) predominates is developed. Though dominant, kangaroo grass is invariably associated with white grass, bunch spear grass, and a number of annual grasses and forbs. They compose a rather coarse pasture 4–6 ft high of fair density and of moderate nutritive value.

As with plume sorghum, *Themeda australis* produces both vegetative and reproductive tillers but it differs from plume sorghum in that growth ceases at the end of the rainy season and any incompletely developed tillers may or may not continue their growth in the following season. The species is palatable to cattle during its growth, but tends to be neglected in favour of *Sorghum plumosum* during the dry season (Arndt and Norman 1959).

This species was found to be far less common than expected from observations in the Ord–Victoria area in areas of volcanic origin. Its occurrence is insufficient to influence to any degree the regional value of pastures.

(d) *Bunch Spear Grass Pastures*

Dominated by *Heteropogon contortus* (bunch spear grass), this type is found as small units within the Napier and, to a lesser extent, Barton land systems. Commonly associated with skeletal volcanic soils on low, rocky rises and medium slopes, the pasture forms a relatively sparse, medium-height community under a mixed shrubby flora of *Terminalia* spp., *Calythrix* spp., *Erythrophloeum chlorostachys*, and *Cochlospermum* sp. Associated species include *Eriachne* spp., occasional *Plectrachne* spp. and *Chrysopogon* spp., and some shorter annuals. Forbs are also prominent, the most common being *Gomphrena canescens*, a herb 2–3 ft high much relished by stock. The dominating species is readily grazed when young, but rarely eaten after the spear-like seeds have matured. Burning produces a rapid regrowth of young, nutritious growth and the species is hardy enough to compete favourably with any undesirable species which the continued use of this practice may promote.

(e) *Flinders Grass Pastures*

Always associated with the blue grass pastures but inhabiting small, well-defined areas are the Flinders grass (*Iseilema* spp.) pastures. Where the surface is stony in undulating volcanic country in the Isdell and Barton land systems and in rocky creeks, stream-lines, and erosional gullies of the Napier land system, this species flourishes to the almost complete exclusion of any other species and forms a dense, short pasture of moderate value.

(*f*) *White Grass Pastures*

Although basically dominated by *Sehima nervosum* (white grass), which is not attractive to cattle (Arndt and Norman 1959), these pastures carry a good mixture of other medium to tall perennial grasses. Though fairly low in nutritive value, the dominating species form dense stands giving good coverage and the pasture may be regarded as one of the better in the area. It forms a very well-developed understorey in the woodlands of *Eucalyptus tectifica* alliance on the fine-textured yellow podzolic soils and igneous red earths of the Barton, Napier, and to a lesser extent Kennedy land systems.

Because of the dense, robust nature of the dominant perennials the shorter grass layer is generally absent and annual forbs are rare.

Another form of this pasture occurs in the Napier land system. In a small unit of the land system, *Sehima nervosum* dominates the stream-lines and small associated levees, forming a shorter, sparser, but almost pure pasture, which is less valuable han the more mixed stands.

(*g*) *Wire Grass Pastures*

This type is confined to the Isdell and Barton land systems, closely linked with blue grass pastures, and inhabits the gravelly ridges which separate the gilgais. The dominating species, *Aristida latifolia* (wire grass), is a tussocky perennial 3–4 ft high, of poor value as its vernacular name implies, and rarely grazed. It is always associated with a short (less than 12 in. high) community of worthless annuals, the most common being *Sporobolus australasicus* and *Tragus australianus*. These short-lived plants soon die out, leaving only bare ground for the greater part of the year.

(*h*) *Beard Grass Pastures*

This type is best developed on areas of igneous red earths and fine-textured yellow podzolic soils of the Kennedy land system. The dominating species are *Chrysopogon fallax* and *C. pallidus* (beard grasses), which are medium to tall, robust, tussocky perennials. According to Arndt and Norman (1959) they appear to be unpalatable to cattle at all times except for the first few weeks of growth.

(*i*) *Silky Browntop Pastures*

This type dominates soakage areas in the Kennedy, Napier, and to a lesser extent Barton land systems. The species *Eulalia fulva* (silky browntop), a medium to tall dense perennial, is rarely grazed and the pasture occurs only in very small units.

(*j*) *Fringing Pastures*

Dominating the sandy banks of creeks, rivers, stream-lines, permanent water-holes and lagoons of the Pago, Buldiva, and to a lesser extent Napier land systems, is a small but consistent pasture community which must be considered in the assessment of the pastoral value of the entire area. Such communities differ entirely from the adjacent pastures and often are more valuable. Generally, the dominating species include hardy perennials such as *Arundinella nepalensis*, *Ischaemum* sp., *Vetiveria* sp., *Coelorhachis rottboellioides*, and *Leptochloa digitata*, while common associated plants include slender annuals such as *Ectrosia* spp., *Pseudopogonatherum* sp., *Sacciolepis* sp., *Setaria* spp., sedges, and numerous smaller forbs.

(*k*) *Soft Spinifex Pastures*

The flat, undulating, sandy plains which form a large part of the Pago land system are consistently dominated by *Plectrachne pungens* (soft spinifex) with variable amounts of annual sorghum. Under the typical forest formation of the *Eucalyptus tetrodonta–E. miniata* sub-alliance on deep red and yellow sands, the spinifex forms a dense, medium-height to tall pasture. On moderate to steep slopes with skeletal, lateritic gravelly sands, the pastures are sparser and are intermixed with annual sorghum and a dense shrubby growth of *Calythrix* spp., *Petalostigma* spp., *Acacia* spp., and *Gardenia* spp. This pasture also predominates in relatively small areas in the Kennedy land system where skeletal sandy or lateritic gravelly soils occur on gentle slopes.

Shorter allied grasses are usually rare but *Aristida hygrometrica*, *A. browniana*, *Thaumastochloa* sp., *Schizachyrium* sp., *Setaria* spp., *Ichnanthus* spp., and *Eriachne* spp. are worthy of note. The majority of these species are slender, short-lived annuals and add little to the value of the overall pasture.

Though the value of this pasture is not high, natural water supplies are abundant in this land system and where this type can be grazed in conjunction with better pastures on volcanic soils its value may be increased.

(*l*) *Annual Sorghum Pastures*

These pastures are the poorest in the area and generally owe their inferiority to the presence of the dominating, worthless, short-lived *Sorghum australiense* and *S. stipoideum* (annual sorghums), and their inaccessibility to stock or isolation from better pasture types. *Plectrachne pungens* is commonly associated with the two dominants but occurs sparsely. *Triodia* sp. (buck or hard spinifex), which lacks the grazing value of the soft spinifex, also occasionally occurs in association with other worthless species such as *Eriachne* spp. and *Schizachyrium* spp.

The pasture is one of irregular density, generally being very sparse with large intervening areas of bare sandstone or laterite outcrops. However, where habitats are favourable, such as periodically flooded depressions or creek lines and rugged, rocky, steep slopes of the Napier land system, the dominating species grow profusely in dense stands often 10 ft high.

Some small value may be derived from the presence of limited quantities of top-feed species growing in conjunction with this pasture, the most prominent being *Ventilago viminalis*.

These pastures are typical of the Buldiva land system, the greater part of which must be regarded as completely useless for stock grazing. In the Foster land system, they occupy very small areas of laterite outcrops.

(*m*) *Cockatoo Grass Pastures*

These pastures occur in small to medium areas generally in the Pago land system, but sometimes also in the Buldiva land system and volcanic areas. They dominate coarse-textured podzolized soils in broad shallow depressions which are probably periodically flooded. Though relatively small in area, these pastures differ markedly from and generally are more valuable than the adjoining pastures. In the Pago land system, they provide valuable alternative grazing to the spinifex pastures, while in the Buldiva land system they often provide the only areas accessible for grazing.

The dominant species, *Alloteropsis semialata* (cockatoo grass), is a particularly hardy perennial about 3 ft high with a strongly developed root system. After long periods of drought or firing, the foliage and culms are frequently not visible, but even light rainfall will promote succulent growth. In these habitats this species is often associated with *Panicum* sp., sparse *Plectrachne pungens*, sedges, and forbs.

(*n*) *Wanderrie Grass Pastures*

This pasture type predominates in the shaly areas of the Karunjie land system. Often the community dominates gentle slopes or flats at the foot of shale scarps, but it may be found in a variety of habitats where skeletal soils overlie shales. The dominant species, *Eriachne obtusa* (Wanderrie grass), is a particularly wiry perennial less than 3 ft high which is not readily grazed and forms a sparse worthless pasture. Sometimes this species is associated with shorter, slender annuals less than 12 in. high, but more often there are large intervening spaces of bare ground.

In the Napier land system, the pasture occupies very small areas of low, rocky rises with a skeletal, cherty soil. In such habitats, the sparse pasture may contain associated slender annual grasses such as *Schizachyrium* sp., *Tripogon* sp., and *Rottboellia formosa*. This type may be regarded as one of the poorer in the area.

(*o*) *Kerosene Grass Pastures*

On the deep sandy levee soils of the Drysdale, Gibb, and Chapman Rivers and their major tributaries, a very mixed, medium-height pasture community is found. The dominating species are *Aristida hygrometrica* (kerosene grass) and *Perotis rara* (comet grass), both slender, wiry annuals less than 3 ft high which mature and rapidly dry out producing coarse, spear-like seeds. Their grazing value is limited to a very short period of young growth. Commonly associated with the two dominants are a large number of other annual, but shorter, grasses and forbs including *Aristida browniana*, *Panicum* spp., *Ichnanthus* spp., *Brachiaria* spp., *Eriachne* spp., and *Setaria* spp. Taller annuals or perennials, such as *Dichanthium* spp. and *Sorghum* spp., are rare.

The grazing value of these pastures is highest when they are young but they lack bulk and would be readily eaten out.

PART VIII. LAND SYSTEMS OF THE NORTH KIMBERLEY AREA, W.A.

By N. H. Speck*

The natural complexity of land surface characteristics commonly encountered in surveys of this size enforces simplification. Therefore a composite unit, the land system, which enables a mass of detail to be mapped as complexes of country, has been used.

The concept of land units and land systems as an appropriate technique for comprehensive surveys and land classification on a large scale was developed by Christian and Stewart (1953), who defined it as "an area or group of areas throughout which can be recognized a recurring pattern of topography, soils, and vegetation". The nature of the land system has been described in more detail by Christian (1952, 1958). It has since been used for surveys in monsoonal and semi-arid northern Australia (Townsville-Bowen region, Queensland (Stewart and Perry 1953), Barkly region (Stewart, Christian, and Perry 1954), and other regions on which reports are in preparation) and in modified form in New Guinea (Taylor and Stewart 1958).

The various units comprising a land system are *land units*. A simple land unit has a particular soil and a particular vegetation community associated with a particular topographic form. In order to simplify presentation of land systems with a large number of simple land units, the simple land units are grouped into a number of complex land units.

Because of the recurring pattern it is possible to construct a typical block diagram showing the interrelationships of each land system. The land units are described in tabular form (Tables 16–24) under the headings: topography, relative areas, soils, vegetation, and pastures. The numbers given in the vegetation and pastures columns refer to the numbers used for the various associations and pastures in Tables 5–13 and Table 14 respectively. Dominant associations and pastures for each land unit are in bold type. Although these units generally occur in the order and relationship shown in the block diagram, it should not be supposed that they always do so. Also, land units with very similar characteristics occur on different land systems with different associated units or with different proportions of the various units.

As well as describing the land characteristics, the land system descriptions also have brief notes on location and general description, drainage, and geology and geomorphology. Notes on climate have not been included because of the general nature of the distribution of the land systems. The various aspects of this factor are fully covered in Part II.

Three of the land systems closely resemble land systems mapped in other surveys and have been given the same names. The remainder have been named after some physical feature within the area of the land system.

A map showing the distribution of the nine land systems of the area accompanies this report and a summary of their main characteristics is given in Table 15.

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

TABLE 15

SUMMARY OF MAIN CHARACTERISTICS OF LAND SYSTEMS OF THE NORTH KIMBERLEY AREA

Land System and Area	Geomorphology and Geology	General Topography	Major Soils	Major Vegetation Communities	Major Pastures
Barton (2000 sq. miles)	Erosional plains on volcanic rocks (Mornington volcanics)	Gently undulating with widely spaced low hills	Igneous red earths and skeletal red earths with smaller areas of fine-textured yellow podzolics and grey soils of heavy texture	Woodlands: *E. tectifica–E. grandifolia* alliance with patches of *E. latifolia* and *E. papuana* alliances	Mostly moderate pastures of white grass with smaller areas of plume sorghum, kangaroo grass, bunch spear grass, beard grass, and blue grass
Kennedy (1200 sq. miles)	Erosional plains on volcanic rocks, almost entirely on Mornington volcanics	Gently undulating	Igneous red earths and skeletal red earths with some yellow podzolics and patches of sand and lateritic soils	Woodlands and forests: *E. tectifica–E. grandifolia* alliance and *E. tetrodonta–E. miniata* alliance with patches of *E. tectifica* alliance	Mostly moderate pastures of white grass, kangaroo grass, and bunch spear grass, but with considerable areas of beard grass and soft spinifex
Isdell (160 sq. miles)	Erosional plains on volcanic rocks, Mornington volcanics with small areas on younger volcanics	Flats and very gentle slopes	Grey soils of heavy texture with some igneous red earths and yellow podzolics	Grasslands with sparse trees and woodlands: *Terminalia* sp.–*Dichanthium fecundum*; *E. tectifica–E. grandifolia* alliances	Mostly good pastures of blue grasses, white grass, plume sorghum, bunch spear grass, kangaroo grass, and beard grass
Napier (3900 sq. miles)	Maturely dissected plateaux on volcanic rocks (Mornington volcanics and Hart basalt)	Hilly, steep to moderate slopes	Mostly skeletal red earths with smaller patches igneous red earths and patches of grey soils of heavy texture	Woodland: *E. tectifica* sub-alliance and various fringing communities along the streamlines	Mostly moderate pastures of white grass, plume sorghum, but with considerable area of beard grass and annual sorghum
Foster (1100 sq. miles)	Immaturely dissected lateritic plateaux on volcanic rocks; Mornington and younger volcanics	Mesas and undulating uplands	Mostly skeletal laterite with smaller areas of yellow podzolics, lateritic podzolics, and igneous red earths	Woodland and forest: *E. tetrodonta–E. miniata*, *E. tectifica–E. grandifolia*, and *E. latifolia* alliances	Mostly very poor pastures of soft spinifex and annual sorghum with smaller areas of plume sorghum, kangaroo grass, bunch spear grass, white grass, and beard grass
Pago (7900 sq. miles)	Gently undulating undissected plateaux and erosional plains of the dissected sandstone plateaux and flatter parts of cuestas and structural plateaux; King Leopold, Warton, and Mt. House sandstones	Gentle slopes sometimes separated by scarps	Predominantly deep yellow sands, skeletal sands, and smaller areas of red medium sands, deep light grey sands, and lateritic podzolics	Woodlands and forest: predominantly *E. tetrodonta–E. phoenicea–E. dichromophloia* alliance with smaller areas of *E. polycarpa–E. apodophylla* and *E. latifolia* alliance	Mostly very poor pastures of soft spinifex and annual sorghum, and additional in the south, kerosene grass
Karunjie (1800 sq. miles)	Parts of the cuestas and structural plateaux; Warton and Mt. House shales and sandstone	Gentle slopes commonly at foot of shale scarps	Predominantly yellow podzolics and skeletal soils	Woodlands and forest: predominantly *E. grandifolia* sub-alliance with smaller areas of *E. phoenicea* sub-alliance, *Melaleuca* spp. alliance, and *E. brevifolia* association	Mostly very poor pastures of soft spinifex, annual sorghum, and kerosene grass

TABLE 15 (*Continued*)

Land System and Area	Geomorphology and Geology	General Topography	Major Soils	Major Vegetation Communities	Major Pastures
Buldiva (16,000 sq. miles)	The more rugged parts of the maturely dissected sandstone plateaux and of the cuestas and structural plateaux. King Leopold, Warton, and Mt. House beds and Walsh tillite	Rugged steep slopes with numerous scarps and gorges	Predominantly skeletal sands with much bare rock	Woodlands and forest: *E. tetrodonta–E. phoenicea–E. dichromophloia* alliance	Predominantly very poor pastures of annual sorghum and soft spinifex
Carpentaria (270 sq. miles)	Depositional plains consisting of recent saline muds	Mostly wet salt flats	Saline muds	Fringing communities of mangroves	No pastures

I. Barton Land System (Area 2000 Sq. Miles)

This land system (Table 16) consists of gently undulating volcanic country with widely spaced low hills with grassy woodland vegetation on shallow or rather leached soils (Plate 4, Fig. 2). The name is taken from the Barton Plains, to the east of the lower Drysdale River. It is of similar origin to the Frayne land system of the Ord–Victoria area, but its soils and vegetation are somewhat different owing to the wetter climate and different parent rocks.

This land system, which is some of the best potential cattle country in the area, is widely scattered throughout the area and the larger areas are relatively easily accessible.

II. Kennedy Land System (Area 1200 Sq. Miles)

This is also gently undulating volcanic country but the vegetation is forest and woodland (Plate 5, Fig. 1) and there are more yellow podzolic soils, lateritic soils, and sandy soils and less grey soils of heavy texture than in Barton and Frayne land systems. It is named from Kennedy Creek, a tributary of the Gibb River to the north of Gibb River homestead. It is moderately good pastoral country. The largest area is along Kennedy Creek and there are also smaller areas, not always accessible, further to the west. Table 17 contains the detailed description.

III. Isdell Land System (Area 160 Sq. Miles)

This is the third land system consisting of gently undulating volcanic country with widely spaced low hills. No areas of this land system were visited in the field but from air-photo interpretation it appears that it contains similar units to the Barton land system, but in very different proportions. The Isdell land system has very large areas of grey soil of heavy texture carrying grassland with scattered trees (Plate 5, Fig. 2).

The land system is named from the Isdell River in the extreme south of the area. It is considered good pastoral country but is limited to a few comparatively small areas in the vicinity of the Isdell River that have already been alienated. Table 18 contains a detailed description.

IV. Napier Land System (Area 3900 Sq. Miles)

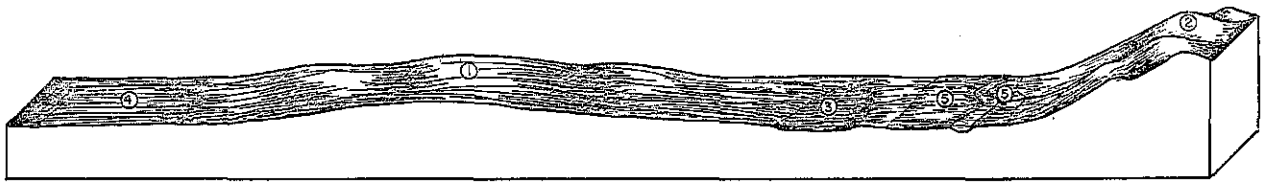
This land system consists of the hilly, more rugged parts of the volcanic country (Plate 4, Fig. 1). It has a grassy woodland vegetation on shallow stony or rather leached soils. It is very similar in soils and vegetation to the Napier land system of the Ord–Victoria area and the name is used for this country also. It is rated as moderate pasture country and is widespread in all except the eastern part of the area. Table 19 contains a detailed description.

V. Foster Land System (Area 1100 Sq. Miles)

This is laterite-capped volcanic country consisting of numerous small mesas and some larger undulating upland areas commonly fringed by a scarp on their southern or eastern edges. Except for grassy woodlands along the stream-lines the vegetation is forest with variable pastures on skeletal lateritic soils. The name was chosen from

Table 16

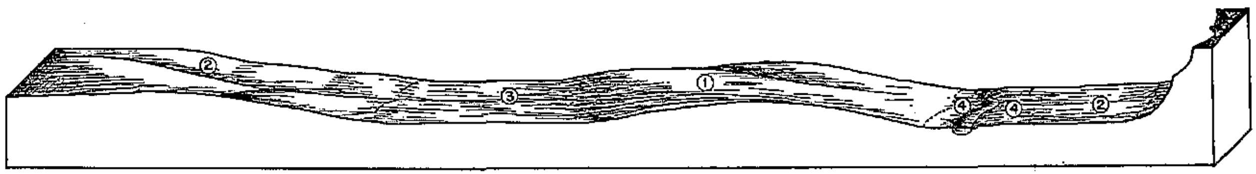
Barton Land System (Area 2000 sq. miles)

Location and general description	Gently undulating volcanic country with grassy woodland vegetation and shallow or leached soils that occurs widely scattered throughout the area				
Drainage	Flooding during the wet season restricted to narrow river flats. Subrectangular drainage of sparse intensity				
Geology and geomorphology	Part of the erosional plains on volcanic rocks, mostly on Mornington volcanics, with some small areas on Hart basalt and younger volcanics in the south-east and south-west				
Block diagram					
	(1)	(2)	(3)	(4)	(5)
Topography	Gentle slopes	Low rocky hills and medium slopes	Shallow depressions	Flats	Stream-lines and levees
Relative areas	Large	Small	Very small	Small	Small
Soils	Mostly igneous red earths and skeletal red earths; smaller areas of fine-textured yellow podzolics	Predominantly skeletal red earths with some igneous red earths	Grey soils of heavy texture	Mixed lateritic podzolics and coarse and fine-textured yellow podzolics	Mostly red levee soils but with some igneous red earths
Vegetation*	Woodlands: *E. tectifica–E. grandifolia* (**1**, **2**, 10, 13, 14, 15) alliance	Woodlands: *E. tectifica–E. grandifolia* alliance (1, 2, 8)	Grassland with variable small trees: *Terminalia* sp.–*Dichanthium fecundum* alliance (**69**, **70**)	Woodlands: *E. latifolia* alliance (**48**, **49**, 50, 51)	Fringing community and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. papuana* (53, 54, 55, **56**, 57) and *E. tectifica–E. grandifolia* (1, **3**) alliances, and *E. camaldulensis–Melaleuca* spp. (75) community
Pastures*	Predominantly moderate pastures (2, 3, 4, **6**); numerous small patches of good pastures (1), poor pastures (8), and very poor pastures (15)	Mostly moderate pastures (**2**, 3, 4, 5); patches of poor pastures (8, 9); large areas of very poor pastures (**12**)	Mostly good pastures (**1**); smaller areas of moderate pastures (2, 5)	Predominantly moderate pastures (3, **6**) and poor pastures (8); some very poor pastures (11, 13)	Mostly moderate pastures (2, 6); some poor pastures (8); small areas good pastures (1); some very poor pastures (15)
Distribution of units	Unit 1 is the major unit in which unit 2 occurs as widely spaced low hills; units 3, 4, and 5 occur as linear bands along drainage-ways and stream-lines; unit 4 occurs only in the central and northern part of the area				

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants

Table 17

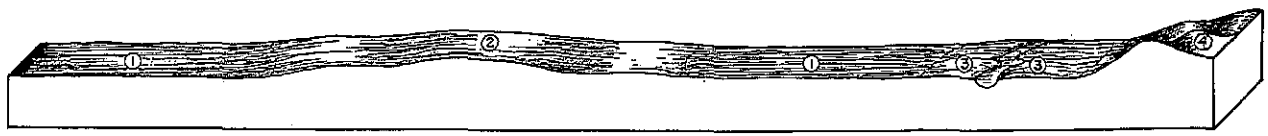
KENNEDY LAND SYSTEM (AREA 1200 SQ. MILES)

Location and general description	Gently undulating volcanic country with mostly open forest vegetation and shallow sandy or leached soils confined mostly to the central and southern parts of the area			
Drainage	Sub-angular or sub-parallel; sparse. Flooding limited to narrow river flats and depressions			
Geology and geomorphology	Part of the erosional plains on volcanic rocks, almost entirely on Mornington volcanics. In many places there is only a thin veneer of volcanics and the soils are partly formed on the underlying sandstones			
Block diagram				
	(1)	(2)	(3)	(4)
Topography	Gentle slopes or undulating	Gentle slopes or undulating	Flats	Stream-lines and levees
Relative area	Large	Medium	Small	Very small
Soils	Mostly igneous red earths and skeletal red earths, with smaller areas of fine-textured yellow podzolics	Predominantly deep yellow sands, patches medium red sands, skeletal sands and small ridges of skeletal laterite	Mixed lateritic podzolics, coarse and fine-textured yellow podzolics	Mixed red levee soils and sandy levee soils
Vegetation*	Woodlands and forests: *E. tectifica*–*E. grandifolia* alliance (**1**, **2**, 5, **6**, 10, 13, 14, **15**); *E. tetrodonta* (33) sub-alliance	Forests: *E. tetrodonta* (**24**, **25**, 26, **31**) and *E. dichromophloia* (40) sub-alliances	Woodlands: *E. latifolia* alliance (**48**, **49**, 50, 51)	Fringing community and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. polycarpa*–*E. apodophylla* (61, 65, **67**, 68, 69); *E. papuana* (53, 54, 55, 56, 57) alliances; *E. camaldulensis*–*Melaleuca* spp. (**75**) community
Pastures*	Predominantly moderate pastures (2, 3, 4, **6**) and poor pastures (8); few small patches good pastures (1)	Mostly very poor pastures (**11**, 12); smaller areas moderate pastures (3, **6**) and poor pastures (8)	Predominantly poor pastures (6), some moderate pastures (2, 4), and some very poor pastures	Mixed very poor pastures (**15**), poor pastures (8), and moderate pastures (2, 6)
Distribution of units	Units 3 and 4 are linear bands along the drainage-ways and watercourses and units 1 and 2 occur in a complex of small irregular areas			

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

TABLE 18

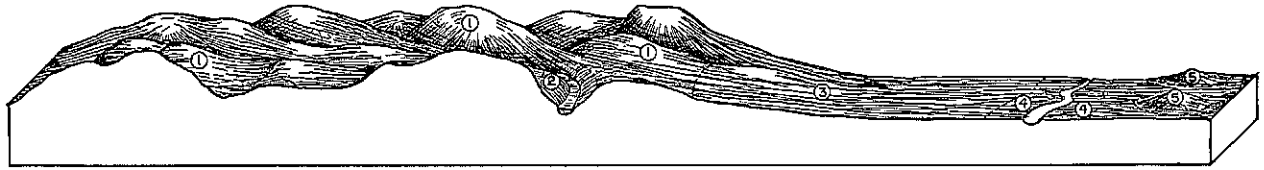
ISDELL LAND SYSTEM (AREA 160 SQ. MILES)

Location and general description	This gently undulating volcanic country with cracking clay soils carries grassland and grassy woodlands. It is confined to several relatively small areas in the south-western part of the area			
Drainage	Flooding during wet season restricted to narrow river flats. Subrectangular drainage of moderate intensity			
Geology and geomorphology	Part of the erosional plains on volcanic rocks formed mostly on Mornington volcanics with small areas on younger volcanics in the south-west			
Block diagram				
	(1)	(2)	(3)	(4)
Topography	Flats or very gentle slopes	Gentle slopes undulating	Stream-lines and levees	Low rocky hills and moderate slopes
Relative areas	Large	Medium	Small	Very small
Soils	Grey soils of heavy texture	Mostly igneous red earths and skeletal red earths, smaller areas of fine-textured yellow podzolics	Mostly red levee soils, but with some igneous red earths	Predominantly skeletal red earths with some igneous red earths
Vegetation*	Grasslands with sparse trees: *Terminalia* sp.–*Dichanthium fecundum* alliance (70)	Woodlands: *E. tectifica–E. grandifolia* alliance (**1**, **2**, 5, 10, 13, 14, **15**)	Fringing community and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. papuana* alliance (53, 54, 55, **56**, 57); *E. tectifica–E. grandifolia* alliance (1, 3)	Woodlands: *E. tectifica–E. grandifolia* alliance (1, 2, **8**)
Pastures*	Mostly good pastures (**1**) but with some smaller patches of moderate pastures (2)	Predominantly moderate pastures (3, 4, **6**); some very poor pastures (15)	Mostly moderate pastures (2, 6); some poor pastures (8); very small areas good pastures (1); some very poor pastures (15)	Mostly moderate pastures (**2**, 3, 4, 5); moderate areas very poor pastures (12); smaller areas poor pastures (8, 9)
Distribution of units	Units 1 and 2 occur commonly in a complex pattern; unit 3 occurs as linear bands along the drainage-ways and stream-lines; unit 4 occurs in unit 2 as widely spaced low hills			

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

Table 19

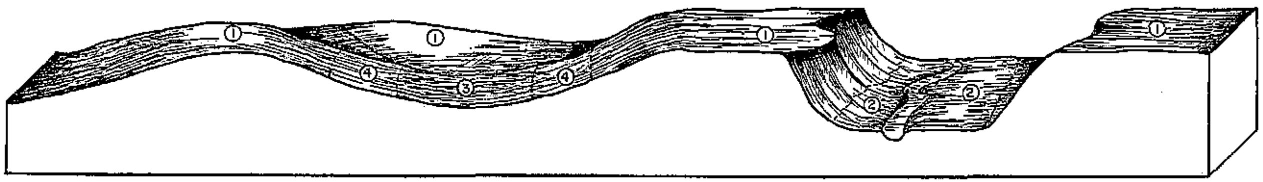
NAPIER LAND SYSTEM (AREA 3900 SQ. MILES)

Location and general description	Hilly volcanic country, with grassy woodland vegetation and shallow stony soils, that occurs widely scattered throughout the area				
Drainage	Moderate, sub-angular; no areas subject to flooding during wet season				
Geology and geomorphology	Maturely dissected plateaux on volcanic rocks, formed mostly on Mornington volcanics, but also on Hart basalt				
Block diagram					
	(1)	(2)	(3)	(4)	(5)
Topography	Rugged with steep to moderate slopes	Small rocky stream-lines	Moderate slopes with occasional depressions	Stream-lines and associated levees	Low rocky rises
Relative areas	Large	Very small	Medium	Small	Very small
Soils	Mostly skeletal red earths; patches of igneous red earths	Mostly skeletal red earths with very small pockets of grey soils of heavy texture	Mixed skeletal red earths and igneous red earths, patches of fine-textured yellow podzolics	Mostly red levee soils, some igneous red earths	Skeletal soils with cherty rock fragments
Vegetation*	Woodlands: *E. tectifica* sub-alliance (1, 2, 8)	Woodlands: *E. tectifica* sub-alliance (**2**)	Woodlands: *E. tectifica* sub-alliance (**1**, **2**, 10)	Fringing community and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. papuana* (53, 56, 57, 65) alliance; *E. tectifica* (1, **3**, **4**, **10**) sub-alliance and *E. camaldulensis*–*Melaleuca* spp. (75) community	Forests: *E. tectifica* sub-alliance (7)
Pastures*	Large areas of very poor pastures (**12**); considerable areas of moderate pastures (2, 4, 6); smaller patches of poor pastures (8)	Mostly moderate pastures (2, 5, 6) and very poor pastures (12); small patches of good pastures (1)	Mostly moderate pastures (2, **3**, **4**, **6**); smaller areas poor pastures (8)	Mostly moderate pastures (2, 3, 4, 6); some poor pastures (8); some very poor pastures (15)	Very poor pastures (**11**, **12**, 13, 15)
Distribution of units	Units 1 and 2 form an irregular complex pattern; units 2 and 4 occur as linear bands throughout units 1 and 3; unit 5 occurs as irregular small areas near the point of contact with adjoining sandstone areas				

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

Table 20

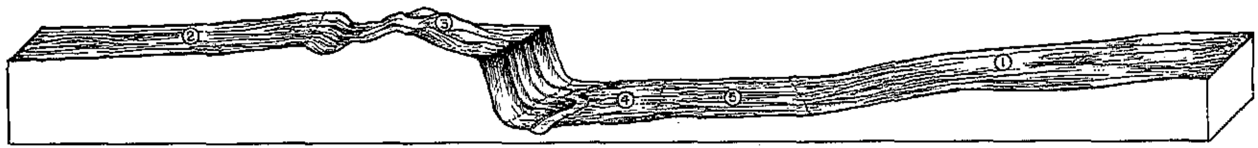
FOSTER LAND SYSTEM (AREA 1100 SQ. MILES)

Location and general description	Laterite-capped, volcanic mesa and plateau country with open forest vegetation and gravelly soils confined to central-northern and south-western parts of the area			
Drainage	Sparse, limited to small stream-lines between mesas, and widely spaced stream-lines of dendritic pattern on uplands			
Geology and geomorphology	Immaturely dissected lateritic plateaux on volcanic rocks, formed on Mornington and younger volcanics. The laterite cappings of the higher parts appear to be remnants of a Tertiary land surface			
Block diagram				
	(1)	(2)	(3)	(4)
Topography	Tops of mesas and upland parts of undulating areas	Slopes, flats, and stream-lines between mesas	Flats between the laterite uplands	Lower portions of the gentle slopes
Relative areas	Large	Small	Medium	Very small
Soils	Skeletal laterite	Mixed red levee soils, igneous red earths, and skeletal red earths	Fine-textured yellow podzolics	Lateritic podzolics
Vegetation*	Woodlands and forests: *E. tetrodonta* (**24**, **25**, 28, **29**) and *E. dichromophloia* (**40**) sub-alliances	Woodlands: *E. tectifica–E. grandifolia* (**1**, **3**) and *E. papuana* (53, 54) alliances	Woodlands: *E. latifolia* alliance (**48**, **50**) (*Livistona* sp. forms well-developed understorey)	Woodlands: *E. tectifica* sub-alliance (**1**)
Pastures*	Mostly very poor pastures (**11**, 12); lesser areas of moderate pastures (4)	Mostly moderate pastures (**2**, 3, 4, 6) but with considerable areas of poor pastures (8)	Mostly poor pastures (8); smaller areas of very poor pastures (**11**, 13, 14)	Mixed very poor (**11**) and poor (8) pastures
Distribution of units	Unit 1 consists of small areas of isolated flat tops of small mesas and large areas of undulating uplands in the hollows and slopes of which are formed units 3 and 4; unit 2 separates the mesas			

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

TABLE 21

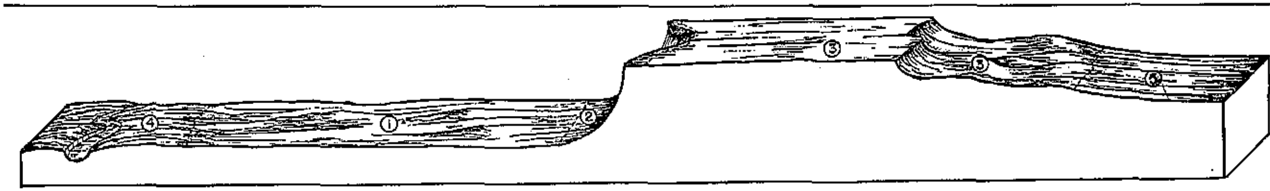
PAGO LAND SYSTEM (AREA 7900 SQ. MILES)

Location and general description	Gently undulating sandstone country with open forest vegetation and deep sandy soils, found throughout the area except in the extreme west				
Drainage	Angular, rectangular, sparse. Flooding during wet season limited to small flat areas adjacent to stream-lines				
Geology and geomorphology	This land system consists of the undissected plateaux and erosional plains of the dissected sandstone plateaux (King Leopold beds) together with the flatter parts of the cuestas and structural plateaux on sandstones of the Warton beds and Mt. House beds that have deep sandy soils				
Block diagram					
	(1)	(2)	(3)	(4)	(5)
Topography	Gentle slopes sometimes separated by scarps	Gentle slopes, generally on elevated flat-tops	Moderate to steep slopes with sandstone outcrops or scarps	Levees and depressions along stream-lines	Small flats
Relative areas	Large	Medium	Small	Small	Small
Soils	Predominantly deep yellow sands, with smaller areas of red medium sands, and patches of skeletal sands	Mostly lateritic podzolics with small areas of skeletal laterite	Skeletal sands, and considerable bare rock	Sandy levee soils and some deep light grey sands	Deep light grey sands
Vegetation*	Forests: *E. tetrodonta–E. miniata* alliance (**24**, **25**, 25*a*, 26, 34, **35**, **36**, **37**, **38**, **39**, 40)	Forests and woodlands: *E. tetrodonta* (27) and *E. dichromophloia* (40) sub-alliances; *E. latifolia* (48) alliance	Woodlands and forests: *E. tetrodonta–E. miniata* (**40**, **41**, **42**, 43, 44, 45, **46**, **47**, **37**, **38**) alliance; *Brachychiton* spp.–*Terminalia* spp.–*E. confertiflora* (73) community	Fringing communities and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. papuana* (53) and *E. polycarpa–E. apodophylla* (61, **66**, **67**, 68, 69, 71) alliances; *E. camaldulensis–Melaleuca* spp. (75) community	Woodlands: *E. polycarpa–E. apodophylla* (**61**, 62, 63, 64, **66**) alliance
Pastures*	Mostly very poor pastures (**11**, 12, 13); patches of poor pastures (8); minor patches of moderate pastures (2, 4)	Mostly very poor pastures (**11**, **12**, 13); patches of poor pastures (8) and moderate pastures (2, 3, 4, 6)	Very poor pastures (11, 12, 13, 15); minor patches of moderate pastures (4)	Predominantly very poor pastures (**12**, 13, **15**); smaller areas of moderate pastures (6) and poor pastures (8)	Mostly very poor pastures (11, **12**, 13, **15**); smaller areas of moderate pastures (2); some poor pastures (8, 9, 10)
Distribution of units	Unit 1 occurs as large irregular areas throughout which unit 3 forms small patches or linear bands associated with scarps; units 4 and 5 occur as linear bands along stream-lines and seepage areas; unit 2 occurs as irregular patches mostly in northern parts of the area				

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

TABLE 22

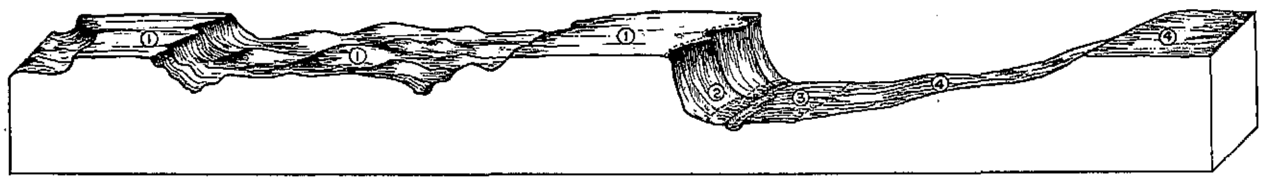
KARUNJIE LAND SYSTEM (AREA 1800 SQ. MILES)

Location and general description	This gently sloping or undulating shale country with sandstone-capped scarps is confined mainly to the south-eastern and eastern parts of the area. It has grassy woodlands and shrubby forests with leached or stony soils				
Drainage	Irregular, moderate. Small low-lying areas adjacent to the rivers may experience flooding during wet season				
Geology and geomorphology	Parts of the cuestas and structural plateaux formed on shales of the Warton beds and Mt. House beds				
Block diagram					
	(1)	(2)	(3)	(4)	(5)
Topography	Flat to gentle slopes often at foot of shale scarps	Steep slopes of scarps	Flat tops and rugged dissected country	Stream-lines and levees	Elevated gentle slopes
Relative areas	Large	Very small	Medium	Small	Small
Soils	Mostly fine and coarse-textured yellow podzolics with some skeletal sands	Skeletal soils and bare rock	Skeletal sands and sandstone outcrops	Varied sandy levee soils	Mixed hard yellow sands and fine-textured yellow podzolics
Vegetation*	Woodlands and forests: *E. grandifolia* sub-alliance (13, **14a**, **15**, **16**, 17, 18, 19, 21); *E. brevifolia* association (71); *Melaleuca* spp. alliance (72)	Woodlands: *E. grandifolia* sub-alliance, steeper slopes (23), lower slopes (11), and *E. brevifolia* association (71)	Forests and woodlands: *E. dichromophloia* (40, **41**, 45, 46, **47**) and *E. phoenicea* (35, 36, **37**, **38**, 39) sub-alliances	Fringing community and woodlands: *Terminalia* spp.–*Ficus* spp.–*Melaleuca* spp. community; *E. papuana* alliance (**55**); *E. grandifolia* sub-alliance (**11**, 12); *E. camaldulensis*–*Melaleuca* spp. community (75)	Woodlands: *E. grandifolia* sub-alliance (**21**)
Pastures*	Mostly very poor pastures (**11**, 12, 14, **15**); smaller areas of poor pastures (8)	Very sparse very poor pastures (**12**)	Very poor pastures (**11**, 12, **15**)	Very poor pastures (**11**, 12, **15**)	Very poor pastures (**11**, **15**)
Distribution of units	Units 1 and 4 are mostly linear associated with unit 2 at the bottom of the scarp; unit 3 at the top of the scarp and unit 5 at various elevations form irregular areas				

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

TABLE 23

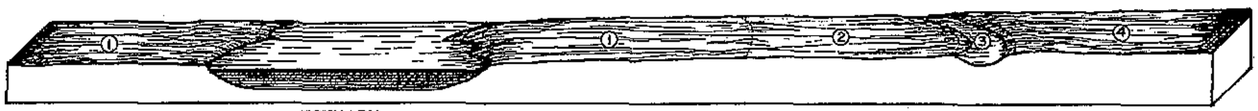
BULDIVA LAND SYSTEM (AREA 16,000 SQ. MILES)

Location and general description	Rugged sandstone country with open forest vegetation on sandy soils with rock outcrops, widely distributed throughout the area			
Drainage	Angular; moderate. No flooded areas during the wet season			
Geology and geomorphology	The more rugged parts of maturely dissected sandstone plateaux and of the cuestas and structural plateaux; King Leopold, Warton, and Mt. House beds and Walsh tillite			
Block diagram				
	(1)	(2)	(3)	(4)
Topography	Rugged very steep slopes, much bare rock	Steep-sided gorges and scarps	Stream-lines and seepage areas	Stepped moderate slopes and flat tops
Relative areas	Large	Very small	Very small	Small
Soils	Skeletal sands, much bare rock	Skeletal soils and bare rock	Sandy levee soils with patches of deep light grey sands	Mostly deep yellow sands, smaller areas of medium red sands
Vegetation*	Forests and woodlands: *E. tetrodonta–E. miniata* alliance (**37**, **38**, **40**, **41**, **42**, 43, 44, 45, **46**, **47**, 73)	Woodlands: *Brachychiton* spp.–*Terminalia* spp.–*E. confertiflora* community (73)	Fringing community and woodland: *E. papuana* (53) and *E. polycarpa–E. apodophylla* (61, 62, 63, 64, **66**, **67**, 68, 69, 71) alliances; and *E. grandifolia* sub-alliance and *E. camaldulensis–Melaleuca* spp. (75) community	Forests: *E. tetrodonta–E. miniata* alliance (**24**, **25**, 26, 30, 34, **35**, **36**, **37**, **38**, **39**, 40)
Pastures*	Mostly very poor pastures (**11**, **12**, 13); patches of moderate pastures (2, 4); minor patches of poor pastures (8, 11)	Sparse very poor pastures (**12**)	Predominantly very poor pastures (12, 13, **15**); smaller areas moderate pastures (2, 6); minor areas poor pastures (8)	Mostly very poor pastures (**11**, 12, 13); patches of moderate pastures (2, 4); minor patches of poor pastures (8)
Distribution of units	Unit 1 occurs as the dominant unit through which the rest are distributed. Unit 2 occurs as scarps which in the east commonly form the western boundaries of geological beds. Unit 4 is formed on gentle slopes or small flat tops, and unit 3 occurs as linear bands in drainage ways			

* Numbers in Vegetation and Pastures columns refer to associations and pastures listed in Tables 5–13 and Table 14 respectively. Numbers in bold type indicate dominants.

TABLE 24

CARPENTARIA LAND SYSTEM (AREA 270 SQ. MILES)

Location and general description	Estuarine flats with mangrove vegetation and saline soils, sparsely distributed near the mouths of the main rivers			
Drainage	Dendritic, centrifugal; of variable intensity			
Geology and geomorphology	Depositional plains consisting of saline muds liable to tidal inundation			
Block diagram				
	(1)	(2)	(3)	(4)
Topography	Wet salt flat	Moist salt flat	Small stream-line	Dry salt flat
Relative areas	Medium	Medium	Small	Medium
Soils	Saline muds	Saline muds	Saline muds	Saline muds
Vegetation	Mangroves along sides of estuaries	Bare	Mangroves	Bare
Pastures	No pastures	No pastures	No pastures	No pastures
Distribution of units	Units 1, 2, and 4 occur as more or less parallel bands between the estuary and the adjacent high country, unit 3 occurs irregularly within unit 2			

the Foster Range, near the centre of the area. In the adjacent Ord–Victoria area the Franklin land system is of similar geomorphic origin but its vegetation and pastures are different because of lower rainfall (15–25 in.).

This land system is confined mostly to the northern and central part of the area with some smaller areas in the south-west. Only the lower slopes of the mesas would be accessible but generally the large upland areas are accessible from adjacent high country. Details are summarized in Table 20.

VI. Pago Land System (Area 7900 Sq. Miles)

The Pago land system consists of undulating sandstone country or gently sloping plains bounded by sandstone scarps. It has forest and woodland vegetation (Plate 2, Fig. 1) on deep sandy soils. This country was first examined near the site of the old Pago Mission in the extreme north, and takes its name from this area. It is considered poor pastoral country. Its value is improved in that while it is widely distributed throughout the area, its major occurrences are adjacent to the larger accessible volcanic areas. Details of this system are summarized in Table 21.

VII. Karunjie Land System (Area 1800 Sq. Miles)

This land system consists of gentle slopes and small plains of shale country, together with the adjoining shale and sandstone scarps (Plate 3, Figs. 1 and 2). The vegetation is grassy woodlands and depauperate forests on skeletal and yellow podzolic soils. The name Karunjie was selected because a considerable portion of Karunjie station consists of this land system. It commonly merges imperceptibly into the Pago land system and also contains outcrops of the more resistant rugged sandstones typical of the Buldiva land system. This land system is rated as poor pastoral country. In the Ord–Victoria area similar country was included in the Jasper land system.

Because the long narrow plains typical of this land system are usually bounded on one side by a precipitous scarp they provide favourable traversing conditions throughout their length but are extremely difficult to cross. This is extremely important in the selection of new stock routes. The distribution of this land system is almost entirely limited to the east and south-western parts of the area. It is further described in Table 22.

VIII. Buldiva Land System (Area 16,000 Sq. Miles)

This rugged sandstone country (Plate 1, Figs. 1 and 2) of forest and woodlands and skeletal sandy soils is virtually the same as the Buldiva land system of the Katherine–Darwin region (Christian and Stewart 1953) and the Ord–Victoria area. It is also equivalent to parts of the Jasper land system of the Ord–Victoria area, but the latter is far more complex and includes much shale and some sandstone country.

This land system is related to Pago land system, being formed on similar sandstone, but it is much more rugged and has a very high proportion of skeletal sandy soils and rock outcrop. The vegetation and pastures are similar but with a higher proportion of the coarser pasture species.

It is rated as very poor pasture country. Although it is widely distributed throughout the area (almost 50 per cent.) much of it is geographically isolated and is generally inaccessible to stock. Where it is accessible it would increase the difficulties of mustering and management of stock. Further details are given in Table 23.

IX. Carpentaria Land System (Area 270 Sq. Miles)

This land system consists of saline mud flats which are liable to flooding at high tide. Some of these are bare and some are covered with mangrove communities. This land system was not examined in the field but from air-photo interpretation it appears to be very similar to the mud flats near Wyndham which are a part of the Carpentaria land system of the Ord–Victoria area. In that area, the Carpentaria land system also includes saline meadows with *Sporobolus virginicus* grassland or *Xerochloa imberbis* grassland, and sand dunes with variable vegetation, but these units appear to be completely absent in the North Kimberley area. The mud flats are nowhere extensive but occur at the estuaries of most of the main rivers of the area. Further details are summarized in Table 24.

X. References

Christian, C. S. (1952).—Regional land surveys. *J. Aust. Inst. Agric. Sci.* **18**: 140–6.

Christian, C. S. (1958).—The concept of land units and land systems. Proc. 9th Pacif. Sci. Congr., 1957. Vol. 20. pp. 74–81.

Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. C.S.I.R.O. Aust. Land Res. Ser. No. 1.

Stewart, G. A., and Perry, R. A. (1953).—The land systems of the Townsville–Bowen region. C.S.I.R.O. Aust. Land Res. Ser. No. 2: 55–68.

Stewart, G. A., Christian, C. S., and Perry, R. A. (1954).—The land systems of the Barkly region. C.S.I.R.O. Aust. Land Res. Ser. No. 3: 112–49.

Taylor, B. W., and Stewart, G. A. (1958).—Vegetation mapping in the Territories of Papua and New Guinea conducted by C.S.I.R.O. Proc. U.N.E.S.C.O. Symp. on Methods of Study of Tropical Vegetation: 127–36.

PART IX. PRESENT AND POTENTIAL LAND USE OF THE NORTH KIMBERLEY AREA, W.A.

By G. A. Stewart and N. H. Speck*

I. Present Land Use

Part of the south-eastern section of the area is occupied by the two most northerly cattle stations, Karunjie and Gibb River (see land system map). The cattle from these stations are walked either over the very rough stock route to Wyndham or to Glenroy Air Beef. Glenroy station is just south of the area surveyed.

Parts of the south-western section of the area are occupied by the Cleanskin lease with small portions of a number of other leases. Their outlets for cattle are either to Glenroy or by the arduous overland stock route to Derby.

In the west the Kunmunya Mission and Munja Aboriginal Reserve occupy the only areas with reasonable terrain and pastures. They are both accessible only from the sea, being cut off from the hinterland by extensive areas of very rugged sandstone country. The form of land development at these centres was not ascertained.

At Kalumburu Mission on the north coast a small herd of cattle is run and some land is cultivated, but all of the products are for consumption at the Mission.

A recently granted pastoral lease to the south of Kalumburu Mission is approximately 500 sq. miles in extent. It includes some of the best pastoral country in the area, being almost entirely volcanic country with moderate pastures. The lease is very well watered but development has only just commenced and only 40 head of stock were run at the time of the survey.

Cleanskin cattle, probably originating from Gibb River station, were seen up to 80 miles north of that station. Even though it was mid dry season the cattle were in good condition. In general their conformation was good in spite of the fact that little or no new blood could have been introduced for some considerable time.

The number of natives living in this area is not known. As in all other parts of Australia, they are nomadic hunters with no general interest in or aptitude for agriculture. However, they do show an aptitude for stock work and the development of the cattle industry will be possible only with native stock hands.

In general the degree of development and standards of cattle husbandry on the stations along the southern edge of the area are very low. This is due in part to the nature of the country and in part to the difficult access to either Derby or Wyndham by both motor roads and stock routes. The aerial transport of beef from the inland killing centre at Glenroy is an interesting recent development (see Part X).

II. Climate and Water in Relation to Pastoral Development

Although the country is subject annually to a long dry period, it has already been pointed out in Part II that not only are the rainfall (25–50 in.) and estimated length of the pastoral growing season (20 wk) adequate to ensure the growth of the

* Division of Land Research and Regional Survey, C.S.I.R.O., Canberra, A.C.T.

natural pastures but rainfall reliability is also fairly high and the region could be expected to be reasonably free from droughts.

Natural water supplies throughout the area are generally good. There are a number of major rivers in the area, which, while they do not necessarily flow for the whole year, provide at least a series of fine permanent water-holes (Plate 6, Figs. 1 and 2). Many of the smaller streams, particularly those that rise in the sandstone areas, also have permanent water-holes. In the volcanic areas the small streams have fewer permanent pools and the provision of water supplies will be necessary in some localities. The streams in the sandstone country are, in some places, steep-banked and water would have to be pumped for stock. More particulars of water supply are given in Part X.

III. Stock-carrying Capacity of the Pastures

The tall coarse pastures typical of this area are not satisfactory for sheep but they could be utilized for cattle-raising. Because of the short summer wet season, the natural pastures produce a large bulk of low nutritive value and throughout the long dry season the cattle are largely dependent on dry mature pasturage. The factor limiting the carrying capacity of such natural pastures is their ability to support cattle when nutritive value is at its lowest, i.e. at the end of the dry season. As in comparable parts of northern Australia, burning of the tall coarse natural pastures will almost certainly be common. To get the best results burning should take place during the dry spells of the wet season. This will be possible where the pastures are carrying the last year's dead material. Experience at Katherine, N.T., has been that mid wet season burns produce appreciable recovery growth before the rains end, but the common practice of burning at the end of the wet gives little recovery (Arndt and Norman 1959).

The pasture communities are described in Part VII of this report and their relative distribution is shown in the description of the land systems (Part VIII). As the pasture communities are greatly mixed in any particular area, in the following discussions of carrying capacities the complex of pastures of a land system, and not the individual pasture communities, are rated.

In the estimation of carrying capacities a particular level of development must of necessity be assumed, because the number of stock carried will vary considerably with amount of fencing, number of watering points, general stock husbandry, and pasture management.

The estimates quoted below are based on data gathered in the adjacent Ord–Victoria area, i.e. it should be possible to carry the estimated stock numbers if the degree of development is similar to that existing in the Ord–Victoria area at the present time.

IV. Land-use Groups

As the agricultural potential is more limited than that of live-stock, the land systems have been grouped into three land-use groups, primarily on the basis of their suitability for development for beef-cattle raising (Table 25). These groups, named

TABLE 25

AREAS OF LAND SYSTEMS AND LAND-USE GROUPS IN VARIOUS TYPES OF COUNTRY

Land-use Group	Land System	Area (sq. miles)	Area (% of total)	Southern Alienated Country (sq. miles)	Country Considered Unsuitable for Cattle (sq. miles)	Isolated Country Otherwise Suited for Cattle (sq. miles): Kunmunya	Isolated Country Otherwise Suited for Cattle (sq. miles): Munja	Potential Cattle Country (sq. miles): Mt. Synnott	Potential Cattle Country (sq. miles): King Edward–Drysdale
Group 1 lands	Barton	2,000	6·0	220	250	—	190	40	1,300
	Kennedy	1,200	3·0	400	50	—	60	230	430
	Isdell	160	0·5	130	—	—	5	20	—
	Napier	3,900	11·0	490	560	490	250	450	1,700
	Total	7,200	21·0	1,200	860	490	500	740	3,400
Group 2 lands	Foster	1,100	3·0	7	140	—	—	110	840
	Pago	7,900	23·0	770	2,800	8	—	100	4,300
	Karunjie	1,800	5·0	410	1,100	20	—	—	210
	Total	11,000	31·0	1,200	4,100	30	—	210	5,400
Group 3 lands	Buldiva	16,000	47·0	1,800	10,300	350	570	230	2,800
	Carpentaria	270	0·8	—	22	70	50	8	20
	Total	16,000	48·0	1,800	10,300	420	620	240	2,800
	Grand total	34,000		4,200	15,300	930	1,100	1,200	11,600

Group 1 (moderate pastoral lands), Group 2 (poor pastoral lands), and Group 3 (very poor pastoral lands), are described below and notes on the constituent land systems are given.

(a) *Group* 1 (*Moderate Pastoral*) *Lands*

These are the lands with high proportions of moderate pastures that would be relatively easily accessible to stock. They include Barton, Kennedy, Isdell, and Napier land systems, all of which are found on volcanic rocks. These pastures will be the backbone of any development of the cattle industry in this area.

(i) *Barton Land System.*—The white grass pastures predominate in this land system and their value is considerably enhanced by the many small patches of blue grass (good pastures) (Plate 5, Fig. 2) and other moderate pastures (kangaroo grass, spear grass, and plume sorghum) (Plate 4, Fig. 2). These patches of good pastures vary in size from an acre to 20 acres or more. These blue grass pastures are likely to be preferentially grazed but when they are overgrazed or when they are boggy during the wet season a variety of alternative pasturage is available. Much of this country is watered by the main rivers but away from these the water supplies in small tributary streams are inadequate and some artificial watering points will almost certainly be necessary. All parts of this land system would be readily accessible to stock. Its carrying capacity has been estimated at 10 beasts per sq. mile.

(ii) *Kennedy Land System.*—Beard grass and white grass pastures are predominant and, as in the Barton land system, there are many patches of good and other moderate pastures. However, it also contains a higher proportion of poor and very poor pastures and consequently its assessed carrying capacity is somewhat lower—8 beasts per sq. mile. This land system is not so well watered by major streams as the Barton land system but this is partly compensated for in that generally permanent pools would be available in the smaller streams of adjacent sandstone country. In other places watering points would need to be provided. All parts of the land system would be easily accessible to stock (Plate 5, Fig. 1).

(iii) *Isdell Land System.*—Although blue grass pasture predominates it also contains numerous smaller areas of moderate pastures (white grass, kangaroo grass, bunch spear grass, and plume sorghum) as in the Barton land system. All parts of this land system would be readily accessible to stock. The estimated carrying capacity of 14 beasts per sq. mile is the highest for the area. The water supplies of this land system (Plate 5, Fig. 2) in general resemble those of the Barton land system.

(iv) *Napier Land System.*—Very poor pastures (annual sorghum) dominate the crests and the steeper slopes. The lower slopes and valley bottoms mostly have moderate pastures (white grass, kangaroo grass, bunch spear grass) with smaller patches of good pastures (blue grass). Much of this country is poorly watered and unless water is available in neighbouring sandstone country or from large streams flowing through the land system, artificial water supplies will be required. Only the steeper parts of very poor pastures would not be accessible to stock. Its carrying capacity has therefore been estimated at 7 beasts per sq. mile (Plate 4, Fig. 1).

(b) *Group* 2 (*Poor Pastoral*) *Lands*

These are lands with a high proportion of very poor pastures. Access by stock is more difficult than in the Group 1 lands because of the occurrence of steep scarps, particularly in the eastern part of the area. Some of the pastures on the coarse-textured soils are made slightly more valuable because of their rapid response to light rains. However, because of the high percentage of very poor pastures and the lack of alternative moderate pastures as well as problems of accessibility, these lands should be developed for cattle-raising only in conjunction with Group 1 lands.

(i) *Foster Land System.*—Although the very poor soft spinifex pasture predominates in this country its pastoral value is considerably increased by frequently recurring smaller areas of poor pastures (beard grass) on the flats between the lateritic uplands, and moderate pastures (white grass, kangaroo grass, plume sorghum, and bunch spear grass) along the numerous small stream-lines.

Accessibility in the mesa country would be limited to the stream-lines and lower slopes, but stock could generally find access to the larger upland undulating areas from adjacent high country.

This country is poorly watered and unless supplies are available in adjacent land systems, artificial watering points will generally need to be provided. Carrying capacity has been estimated at 6 beasts per sq. mile.

(ii) *Pago Land System.*—This land system has mostly soft spinifex pastures with appreciable proportions of annual sorghum pastures, and an increasing proportion of kerosene grass pastures in the southern parts. There are only very small patches of moderate pastures associated generally with special habitats (Plate 2, Figs. 1 and 2).

Although much of this country is readily accessible, a series of scarps in the eastern part of the area makes access to some parts of the land system difficult or even impossible. Natural water supplies would generally be adequate for the development of the cattle industry. The estimated carrying capacity for this country is 4 beasts per sq. mile.

(iii) *Karunjie Land System.*—As in the Pago land system the pastures are assessed as very poor (soft spinifex, kerosene grass, annual sorghum, and Wanderrie pastures) with only a small proportion of poor pastures (beard grass). A slightly compensating feature is the fact that the softer shale beds from which this type of country has developed become the natural stream-lines and so it is particularly well watered and stock are inclined to congregate on these small frontage areas. Carrying capacity of this country is estimated at 4 beasts per sq. mile (Plate 3, Figs. 1 and 2).

(c) *Group* 3 (*Very Poor Pastoral*) *Lands*

The Buldiva and the Carpentaria land systems have been placed in this group because of their general inaccessibility or isolation and other difficulties associated with possible development.

(i) *Buldiva Land System.*—The pastures of this rugged sandstone country, like the Group 2 lands, consist almost entirely of very poor pastures (annual sorghum and soft spinifex) but with a higher percentage of the coarser annual sorghum pasture.

There are some poor pastures (perennial sorghum and beard grass) and small pockets of moderate pastures (white grass, plume sorghum, and bunch spear grass). While parts of this land system would be accessible to stock and it is generally well watered, the rocky and steep terrain would make stock management and mustering extremely difficult and would have a high nuisance value in that it would provide a natural hideout for scrub cattle. It is therefore recommended that it should be excluded from consideration in any estimates concerned with the development of the North Kimberley area (Plate 1, Figs. 1 and 2).

(ii) *Carpentaria Land System*.—From examination of aerial photographs this land system in this area consists entirely of mangrove and mud flats with no pasture. It appears to lack the saline meadow and sand dunes of parts of the Ord–Victoria area. It is mostly isolated by surrounding rugged country and would be of no value for cattle-raising.

V. General Considerations for the Development of the Cattle Industry

On overall northern Australian standards the pasture lands of this area can be rated only as moderate to very poor. For example, the Mitchell grass pastures of Argyle, Wave Hill, and the central Barkly Tableland are much superior. Pastures similar to those of this area occur in the belt of country between Wyndham, Katherine, and Borroloola, and the degree of development of the cattle industry is lower in this belt than in the areas of superior pastures mentioned above.

The abundance of surface waters in most parts of this area is advantageous in many ways but it makes the handling and management of stock much more difficult, particularly in hilly country, and fencing will be necessary in order to maintain a satisfactory standard of stock management. Careful planning of fences to make full use of the natural barriers, e.g. the many steep sandstone scarps in the eastern part of the area, volcanic mesas, etc., could greatly reduce costs. Also, in the planning of the leases, the scarps should be studied in aerial photographs to ensure that lands included within a lease boundary are not completely cut off by these scarps. The most prominent scarp in the area is the north–south sandstone scarp along the eastern edge of the Group 1 lands. Except for two major breaks this scarp is more or less continuous across the area. Access through this scarp is essential if it is desired to utilize the larger areas of Group 2 lands to the east in conjunction with the Group 1 lands.

In view of the limited areas of Group 1 lands (21 per cent. of the area mapped) and the larger areas of Group 2 lands (31 per cent.), the only practical form of development is to utilize adjacent accessible areas of Group 2 lands in conjunction with the Group 1 lands.

To permit a suitable standard of animal husbandry it would be desirable for each pastoral lease to have sufficient of the Group 1 lands to carry a larger proportion of its proposed cattle numbers, for example properties running 6000 to 8000 cattle, which is reasonable for this region, might well contain Group 1 lands to carry 3000 to 4000 cattle.

VI. Possibilities for the Extension of the Cattle Industry

In assessing the possibilities for the extension of the cattle industry it is necessary to consider not only the pastoral quality of the lands as described in the previous paragraphs but also the geographic association and accessibility of various pastoral types, i.e. the overall suitability in terms of tracts of country.

In this part of the report tracts of country are considered in the following groups (see Fig. 8 and the land system map):

(*a*) Southern alienated country.
(*b*) Isolated country otherwise suitable for cattle.
(*c*) Potential cattle country.
(*d*) Country considered unsuitable for cattle.

(*a*) *Southern Alienated Country*

This is country over which leases for cattle stations have been granted and it is, to a greater or lesser degree, already being developed for cattle-raising. The western and northern mission and aboriginal reserves and the isolated northern lease have not been included because they are, as far as is known, virtually undeveloped for cattle.

These southern alienated lands extend across most of the southern part of the area and occupy almost 13 per cent. of the total area (see land system map, Table 25, and Fig. 8), which includes 21 per cent. of the Group 1 lands (1200 sq. miles). The Isdell land system, which has the highest estimated carrying capacity, is almost entirely restricted to this country. These southern Group 1 lands have an estimated carrying capacity of approximately 11,000 cattle. If the Group 2 lands are utilized in conjunction with these, the estimated carrying capacity would reach 15,000. Present numbers of cattle on leases are not available but it is not expected that the above figure would have been reached.

(*b*) *Isolated Country Otherwise Suitable for Cattle*

The two tracts of country, Munja and Kunmunya, included in this group are adjacent to the west coast and are isolated from one another and from other country suitable for cattle by rugged sandstone country.

(i) *Munja Country.*—This country is situated on the Calder River. For convenience the boundary is shown of the Munja Aborigine Reserve but as well as including the 500 sq. miles of Group 1 lands it includes 620 sq. miles of Group 3 lands. Most of the Group 1 lands are in a compact accessible unit separated from the Group 3 lands by a scarp which would form a natural barrier to stock. There are no areas of Group 2 lands that could be developed in association with the Group 1 lands. The estimated carrying capacity of the Group 1 lands is 4000 cattle.

This country is accessible only from the sea via Walcott Inlet, which is not an easy waterway to negotiate (Easton 1922, p. 26), or by air. Because of this the country could be developed for cattle-raising only with great difficulty. It appears to be best adapted to the purpose for which it is now being used.

(ii) *Kunmunya Country.*—This includes the Kunmunya Mission Reserve and the country to the west of it. It consists almost entirely of Group 1 lands (Napier land system) surrounded by rugged sandstone country. As with Munja country, its access is only from the sea or by air and, as Easton (1922) pointed out, the relatively small area that could be served (estimated carrying capacity of 3500 head) would not justify the installation of port facilities.

Approximately half of the Group 1 lands are within the Mission Reserve and there are no obvious prospects of developing the remainder.

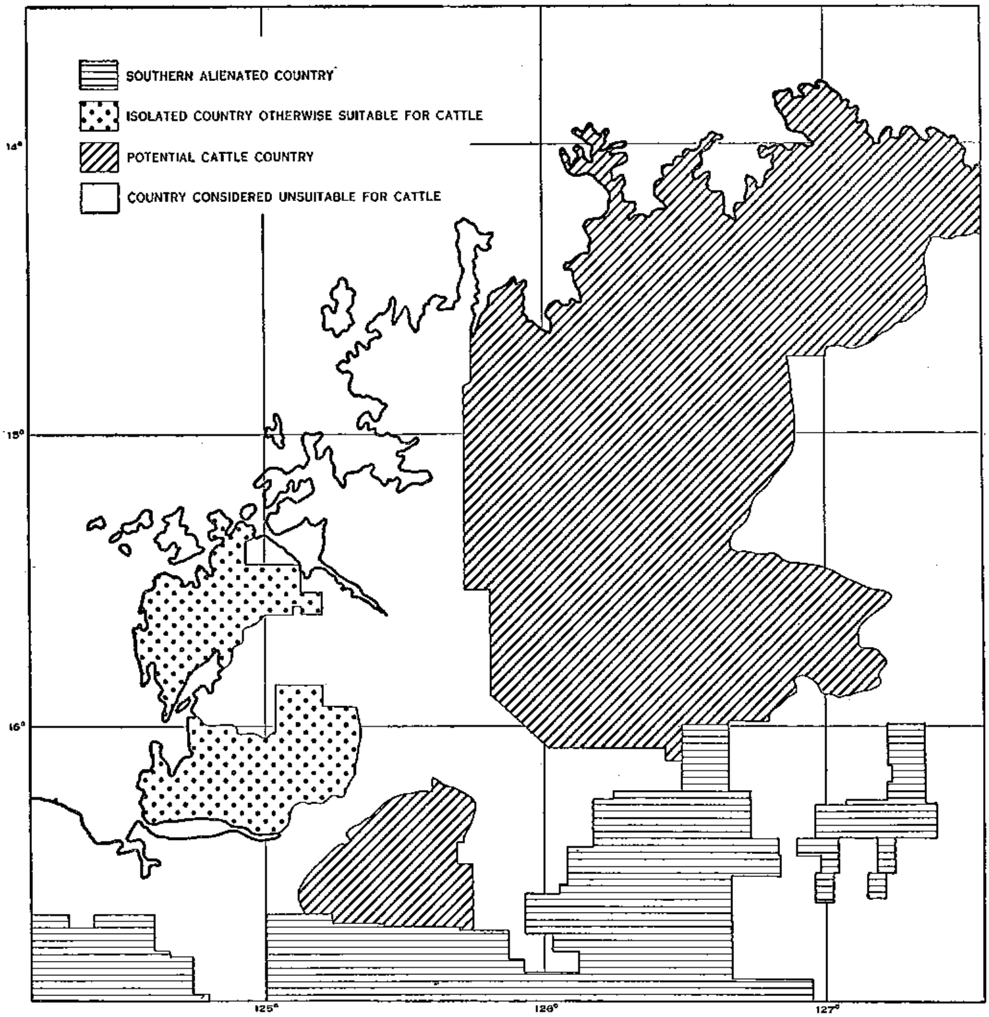


Fig. 8.—Arrangements of types of country into groups according to varying suitability for extension of the cattle industry.

(c) Potential Cattle Country

These tracts include the country that has reasonably compact accessible areas of Group 1 lands capable of carrying 2000 or more head of cattle, together with areas of accessible Group 2 land that could be developed in association with them. By necessity some Group 3 lands not worthy of development are included.

Two tracts of country have been included in this group: the King Edward–Drysdale country and the Mt. Synnott country (see land system map, Tables 25 and 26, Fig. 8).

(i) *King Edward–Drysdale Country.*—This country covers 11,600 sq. miles, i.e. one-third of the surveyed area. Of this amount only 29 per cent. is Group 1 lands, 46 per cent. is Group 2 lands, and the remaining 25 per cent. is Group 3 lands. The Drysdale River Mission Reserve (Kalumburu) and the cattle lease adjoining it have been included in this country because they are virtually undeveloped for cattle and their potential should be considered in conjunction with the surrounding accessible country.

The eastern boundary of this tract of country has been determined by the possibility of access through the series of roughly parallel sandstone scarps. For example, the poorer country to the east of the Carson River, although close to Group 1 lands, is separated from them by an inaccessible scarp and so this scarp becomes the practical eastern boundary. Further to the south this scarp is lower and accessible and so the boundary has been extended to the next scarp, which ultimately joins up with alienated country in the south. In the north-east the boundary has been carried back over several lines of scarps, which do not appear quite so formidable, to terminate at the King George River.

To the west the terrain is rugged but there are no continuous scarps and the boundaries were drawn more arbitrarily.

Excluding the Kalumburu Mission and the adjoining cattle lease, this tract of country could be divided into six holdings with estimated carrying capacities of approximately 7000 cattle, of which at least half could be run on Group 1 lands. The existing cattle lease consists almost entirely of Group 1 lands with an estimated carrying capacity of 3200 cattle. This lease could be extended to take in Group 2 lands of equivalent carrying capacity.

Almost all of these holdings would be readily accessible from the recently constructed road from Gibb River to the north coast. Export of stock to market and import of materials to the properties present a problem, as stock routes and motor roads to Derby and Wyndham are difficult, and alternative forms of transport should be considered. Easton (1922) came to the conclusion that the only location suitable for a port and accessible from inland was Napier Broome Bay. Such a port would serve the whole of the King Edward–Drysdale country. Another possible alternative is the development of aerial transport as in the Glenroy Air Beef project (Anon. 1955).

(ii) *Mt. Synnott Country.*—This second area lies between the Isdell and Charnley Rivers (land system map and Fig. 8). It is accessible from the south and south-east through the King Leopold Range. It may be possible to find an easterly stock route over the 20 miles or so of rugged country to the Mt. Barnett volcanic country but it is unlikely that a suitable stock route to the north could be found that would link it directly with the King Edward–Drysdale country. There are several sandstone and laterite-capped scarps which may provide problems of accessibility within this country. It contains approximately 740 sq. miles (62 per cent.) of Group 1 lands (Tables 25 and 26).

TABLE 26

ESTIMATE OF CATTLE-CARRYING CAPACITY OF POTENTIAL CATTLE COUNTRY

Land-use Group	Land System	Estimated Beasts per Sq. Mile	Potential Cattle Country					
			Mt. Synnott Country			King Edward–Drysdale Country		
			Area		Estimate of Cattle-carrying Capacity	Area		Estimate of Cattle-carrying Capacity
			(sq. miles)	(% of total)		(sq. miles)	(% of total)	
Group 1 lands	Barton	10	40		430	1,300		13,000
	Kennedy	8	230		1,800	430		3,400
	Isdell	14	20		300	—		
	Napier	7	450		3,200	1,700		12,000
	Total		740	62	5,700	3,400	29	2[illegible],000
Group 2 lands	Foster	6	110		700	800		5,000
	Pago	4	100		400	4,300		17,000
	Karunjie	4	—		—	210		800
	Total		210	18	1,100	5,400	46	23,000
Group 3 lands	Buldiva	0–4	230		—	2,800	—	—
	Carpentaria	0	8		—	20	—	—
	Total		240	20	—	2,800	25	—
	Grand total		1,200		6,800	11,600		51,000

Future development of the Mt. Synnott country will largely be limited to the Group 1 lands because the rugged and inaccessible nature of the surrounding country prevents access to Group 2 lands. If the problems of accessibility can be overcome, it is estimated that the carrying capacity will exceed 6500 cattle.

(d) *Country Considered Unsuitable for Cattle*

This includes the country that does not include a reasonable proportion of Group 1 lands. It makes up 45 per cent. of the area surveyed. In the west it is mostly rugged sandstone country (Group 3 lands) with some small inaccessible patches of Group 1 lands. Because of the difficulties of stock management and access it is never likely to be developed for cattle. The eastern part is characterized by the predominance of rough sandstone country, the absence of Group 1 lands, and the considerable areas of Group 2 lands (Pago and Karunjie land systems). It is considered that these lands are not suitable for development by the cattle industry at the present time but future changes in economic and transport conditions may make its development feasible.

VII. Pasture Improvement

At the present time there is no proven method of economically raising the nutritive level of the native pastures described in this report. The areas dealt with are so vast and the return per unit area is so small (a few pence per acre) that better pasture species can be introduced only where the species can establish itself by the broadcasting of seed. For example, it may be possible to improve the pasture of frontage areas by replacing the low-value annual *Aristida hygrometrica* with the perennial buffel grass (*Cenchrus ciliaris*). This grass has spread rapidly along similar river frontages in other parts of northern Australia, e.g. along the Leichhardt River, western Queensland.

It is probable that Townsville lucerne (*Stylosanthes sundaica*) could be readily established in some parts of the region. It tolerates low levels of fertility but it cannot withstand competition from tall grasses. It has the double advantage of not being readily grazed by cattle or horses while green and being a protein-rich standing hay for grazing in the dry season when the native pastures are at their lowest nutritive level. Experience at Katherine (Anon. 1959) indicates that it establishes and spreads fairly rapidly in heavily grazed white grass and kangaroo grass pastures on finer-textured soils, so that it should be possible to establish it in over-grazed parts of Barton, Kennedy, and Napier land systems. Also it may be possible to establish it in some of the short sparse pastures, e.g. soft spinifex pastures, of the Karunjie and Pago land systems.

If Townsville lucerne can be established in the above ways in small horse paddocks scattered over a property it would probably be a more economical way of providing better dry-season nutrition for horses than the growing of fodder crops.

VIII. The Horse Industry

The horse industry is considered to be important only because of its relationship to the cattle industry. The use of horses is largely confined to the dry season when natural fodders are at a very low nutritive value. Because of this, the period in which horses remain in a sufficiently fit condition to be worked is extremely short. At the present time little or no effort is being made to supplement the natural pastures on the stations operating in the south of the area. Instead, they rely on a number of "plants" of horses which are each worked and rested alternately for short periods during the mustering season. The annual turn-off from these stations is limited by the efficiency of the horses of these mustering plants. The terrain is rugged, distances great, and natural difficulties many, and the strain on these horses is correspondingly great.

Horse paddocks should be located away from the "frontage areas", thus avoiding the risk of grazing *Crotolaria retusa* and consequent loss of valuable horses from "walkabout" disease.

IX. Agricultural Potentialities

In Part II it was pointed out that the northern part of the area (with 30–50 in. annual rainfall and an estimated agricultural growing period of 12–16 wk) appears to be suitable for seasonal monsoonal agriculture but that fodder crops could probably be grown throughout the area.

At the present time very little agriculture is practised in monsoonal Australia, being limited to a few peanut farms along some of the major rivers near Darwin and several farms for the production of fruit and vegetables for the local market at Darwin. Agricultural investigations being carried out in monsoonal Australia include: investigations by C.S.I.R.O. of the possibility of dry-land agriculture at Katherine, N.T. (rainfall 36 in.); investigations by the Northern Territory Administration and commercial interests of the possibility of rice-growing, utilizing natural flooding of low-lying lands; and investigations by C.S.I.R.O. in conjunction with the Western Australian Department of Agriculture on the possibilities of irrigated agriculture on heavy clay soils at Kimberley Research Station near Wyndham, W.A.

While there are large areas of arable soils not utilized for agriculture near the existing lines of communication, e.g. the Katherine–Darwin country and the Wyndham area, there is unlikely to be agricultural development in the North Kimberleys except in a very limited way for fodder crops for horses. The production of fodder crops for cattle is not likely to be worth while until the industry reaches a higher level of development than that existing in the adjacent Ord–Victoria area at present.

The most extensive arable soils in the area are the deep sands. Their agricultural behaviour is not known but from experimental results at Katherine (Anon. 1959) they would appear to have some advantages over finer-textured soils.

At Katherine promising results with peanuts and sorghum have been obtained on fine-textured soils of the Tippera and Elliott families but agricultural husbandry of a high standard is necessary. The igneous red earth and fine-textured yellow podzolic soils of this region which are similar to the Tippera and Elliott respectively occur mostly as small patches amongst shallow soils. There would probably be sufficient arable areas to furnish the cultivation of small areas of fodder crops for supplementary feeding.

The grey soils of heavy texture, which are similar to the soils of Kimberley Research Station, would also probably produce satisfactory yields of fodder crops.

All soils of the area are almost certainly deficient in phosphate and crops are not likely to succeed without the application of phosphatic fertilizer.

The small-scale intensive production of fodder by irrigation would be possible in selected areas but would be justified only for horses at the present time.

X. The Timber Industry

Although almost all of the North Kimberley area is covered by either eucalypt forests or woodlands, they are unsatisfactory for commercial development of the timber industry. The forests are of the open type and the trees generally are small. The tallest trees seen were 80–100 ft high, but typically they would average 40–50 ft in height. Very few trees measure more than 24–30 in. in diameter. Many of the boles of the larger trees are piped, which spoils them for milling purposes.

The forests of Kimberley pine (*Callitris intratropica*), which were described by Gardner (1923), were also disappointing. This pine yields a fine timber which is durable and not attacked by termites. Although it is sparsely distributed throughout the eucalypt forests of the sandstone areas, it also forms small pure stands (Plate 7, Fig. 2) with trees averaging 40–50 ft in height and boles seldom more than 18 in. in diameter in the northern higher-rainfall areas. Nowhere in the areas seen were these communities abundant or extensive. However, this timber should prove to be very valuable for local needs in the development of the cattle industry.

Among the best sources of millable timber observed were the fringing forests associated with streams. Here fine trees of red gum (*E. camaldulensis*) and cajiput (*Melaleuca leucodendron* sens. lat.) commonly reach the height of 100 ft with boles 2–3 ft in diameter.

The structural and other qualities of the various timbers have been described by Gardner (1923) and although a number of fine timbers occur, their sources are so scattered and the country so inaccessible and isolated that they would have very little commercial value.

There is, however, sufficient timber available throughout the area for all the local requirements in the pastoral development of the area.

XI. References

Anon. (1955).—Report. Commonwealth Advisory Panel on Air Transport of Cattle or Beef. (Commonw. Govt. Printer: Canberra.)

Anon. (1959).—Katherine Research Station Progress Report 1946–56. C.S.I.R.O. Aust. Div. Land Res. Reg. Surv. (Mimeo.)

Arndt, W., and Norman, M. J. T. (1959).—Characteristics of native pasture on Tippera clay loam at Katherine, N.T. C.S.I.R.O. Aust. Div. Land Res. Reg. Surv. Tech. Pap. No. 3.

Easton, W. R. (1922).—Report on the North Kimberley district of Western Australia. W. Aust Dep. North-west Publ. No. 3. (Govt. Printer: Perth.)

Gardner, C. A. (1923).—Botanical notes, Kimberley Division of Western Australia. W. Aust Forests Dep. Bull. No. 32. (Govt. Printer: Perth.)

PART X. ECONOMIC ASPECTS OF THE CATTLE INDUSTRY OF THE NORTH KIMBERLEY AREA, W.A.

By R. A. Patterson*

The immediate development of the North Kimberley area depends on the beef-cattle industry.

The fact that attempts to settle this area through agricultural or pastoral development have not been successful suggests strongly that the potential of the area in these fields is very limited.

The cattle industry in the East and West Kimberley districts was firmly established before 1900, but according to statistics of cattle numbers, it has made relatively little progress since the 1920s. Like all other cattle areas of northern Australia it was, and very largely still is, established on the open range system. Permanent water in association with pastures capable of growing cattle are the basic requirements of cattle-raising. Market outlets are few and their location results in Kimberley cattle travelling long distances over difficult stock route conditions. Mortality is still high, few female cattle are marketed, and the overall rate of turn-off is low. The opening of Wyndham meatworks in 1919 provided the cattle industry in the Kimberleys with an outlet for fat cattle. In addition cattle were exported to the Philippines between 1920 and 1930.

Although cattle prices have always been at a low level in the Kimberleys it is not the main reason why the North Kimberley area has not been developed for cattle-raising. Where adequate water and pasture exist, together with some prospects for marketing cattle, regardless of how remote, the history of the development of the Australian cattle industry has shown that the pioneering cattlemen would have taken advantage of these natural resources. Other factors in settlement such as remoteness, disease and parasites, hostile natives, and lack of communications must be considered, but our history provides ample evidence that all of these handicaps have been overcome in the past.

In the North Kimberley area good supplies of permanent water exist. Besides water, the two most important essentials in establishing cattle-raising are the availability of sufficient quantities of pasture capable of being utilized by stock, and a market for store or fat cattle. It is fairly obvious that the absence of either or both of these essentials constitutes the principal reason for the failure of the cattle industry to become established there.

The North Kimberley survey has shown that, in general, the pastures of this area are inferior to those where cattle-raising is being conducted in other parts of the Kimberleys. In the East Kimberley district the present cattle numbers related to the total pastoral area leased for cattle show a stocking rate of approximately 10 head of cattle per sq. mile. In the West Kimberley district the rate of the area used for cattle production is approximately 12 head of cattle per sq. mile.

* Bureau of Agricultural Economics, Canberra, A.C.T.

The conditions applying to pasture species and the availability of water supplies in the Darwin Gulf district of the Northern Territory resemble those in the North Kimberley area. In general the Darwin Gulf district must be regarded as inferior cattle-fattening country. Tall and coarse native pastures which are typical of the area provide an abundance of roughage but are of very low nutritive value once the dry season sets in. The present cattle numbers in the pastoral area leased for cattle-raising in the Darwin Gulf district give a stocking rate of approximately 2·5 head per sq. mile. This rate, of course, is not to be regarded as the potential of the district but, even with improved transport facilities (which would enable younger store cattle to be marketed) and more effective animal husbandry practices, the overall potential for cattle-raising in this district, in the absence of improved feeding practices, appears to be low.

Because of the quarantine restrictions imposed in the Kimberleys and the Northern Territory on the movement of store cattle to fattening areas, the cattle enterprise in the North Kimberley area would be established predominantly on a breeding and fattening basis. Unless technology, such as irrigation or improved pastures, can be introduced in nearby cattle areas no fattening of store cattle can be made a payable proposition, the turn-off from the North Kimberley area will comprise mainly aged and inferior fat cattle.

Cattle tick and buffalo fly, together with diseases enzootic throughout the cattle areas in northern Australia, can all be expected to present problems in animal husbandry in the North Kimberley area. Although there may be some scope for the introduction of Zebu blood in preference to British breeds a higher degree of cattle control would be necessary, especially in some of the rugged sandstone areas where plentiful supplies of permanent water are available.

Another problem to be faced, especially by those who have not had experience in the north cattle country, is the availability of suitable labour. Unless sufficient family labour to work the property exists, native labour would need to be relied upon entirely. The scarcity of efficient white stockmen is becoming more pronounced each year and because of the remoteness of the North Kimberley area, special incentives would need to be available to attract efficient men to this area.

Because of the heavy risks associated with beef production the size of properties would need to be large enough to carry a sufficient number of cattle to ensure a reasonable financial return. The low carrying capacity of the country prohibits heavy capitalization per beast area on property improvement. Further, the cost of fencing and water construction must be related to the income from turn-off rather than to the number of cattle carried. At the expected level of cattle prices the return per beast area will be very low. Adverse seasonal conditions can be expected to cause serious mortality in breeding-stock and calves unless better pastures can be introduced. Even if the country could be sufficiently fenced to provide a reserve area, the existing native pastures, although spelled, could not be expected to provide much benefit in time of drought. Mortality in drought years would probably be higher than in any other area of northern Australia because of the difficulties in moving cattle.

During the last four years cattle prices in the export areas have fallen. On the other hand the costs of raising beef cattle are still rising. Unless increased efficiency or increased productivity can be achieved, this upward trend in the cost of production in the northern Australian beef production areas can be expected to continue in the immediate future. As income levels represent one of the principal determinants of property size, such a degree of income fluctuation as has occurred in the last few years makes it difficult to specify minimum property size. Based on the present level of production costs in the Kimberleys, it is considered that 4000 cattle would constitute a minimum herd in the North Kimberley area. With this herd size an annual average of at least 300 bullocks should be available for turn-off if the physical limitations imposed by disease, parasites, and inferior pastures, together with an inadequate market, can be overcome.

I. Market Outlets

The degree of success in establishing the cattle industry in the North Kimberley area will be largely influenced by the opportunity available for marketing the turn-off. At present the outlets for marketing fat cattle in the Kimberleys are:

(*a*) Droving to Wyndham meatworks;
(*b*) Droving to the Glenroy Air Beef scheme;
(*c*) Droving to Broome meatworks;
(*d*) Droving to Derby for live shipment to Robbs Jetty or for shipment to eastern markets.

In turning off fats from the North Kimberley area, however, it is unlikely that many cattle will move to Broome and Derby because of the distances involved and the conditions on the stock route. A contributing factor is the limited shipping space available from Derby to Perth. The influence of price also must be fully considered. In the past the average return to growers delivering cattle to Wyndham meatworks has been higher than the return from Broome.

The obvious outlet for cattle in this area appears to be either to Wyndham or to the Air Beef abattoirs at Glenroy. It is unlikely that many female cattle will be marketed although with judicious herd control and management, speyed, barren, and young culled cows should be able to travel the distance in normal seasons.

The establishment of a suitable stock route from the central part of the area to Wyndham will depend on a closer examination of the country to the east of the Drysdale River. The best route appears to be from the south of the Ashton Range travelling southwards across the Drysdale and Damper Rivers and swinging east at Wades Bluff, crossing the Ellenbrae and finally entering the valley below New York Jump Ups. Based on observations made by the owners of Karunjie and Gibb holdings, sufficient feed and water would be available for cattle moving on this route. The stock route from New York Jump Ups to Wyndham traverses stony, hilly country and, unless cattle are nursed, condition can be lost rapidly on this section. It is possible that feeder stock routes from the areas around the Gibb and Drysdale Rivers could lead into this main route.

The Air Beef scheme was established at Glenroy in 1949. Its objective was to provide an outlet for fat cattle from an area in which development was hindered because of the inaccessible nature of the country and the difficulty in moving cattle to market. The principal arguments in support of the establishment of the killing facilities at Glenroy were:

(*a*) It was an area which lacked roads and was poorly served by stock routes.
(*b*) Cattle unable to walk the distance to Wyndham could be treated.
(*c*) Losses involved in droving long distances could be diminished.
(*d*) Cattle could be marketed at younger ages and the carcass yield would be of a higher grade.
(*e*) Losses in periods of adverse seasonal conditions could be reduced.

Despite certain obvious advantages of Glenroy Air Beef the unavoidably high operational costs of such an enterprise make it economically unsound and without the assistance of a subsidy it is doubtful if the abattoirs could continue to operate. The Commonwealth Advisory Panel appointed by the Commonwealth Government in September 1954 to inquire into the air transport of cattle and beef in northern Australia made a report on the air beef technique. With regard to the practicability and the economics of air beef operations it was concluded (Anon. 1955*) that:

(*a*) Within economic flying range, air transport of chilled beef from inland abattoirs is quite practical to freezing works at a port of export as frozen beef; to inland freezing works for freezing and transport by refrigerated rail or road vans to a port for export; to local markets for immediate sale.

(*b*) The relatively high costs associated with inland killing, air transport, and subsequent treatment of the beef at Wyndham, as shown by the operations of Air Beef Pty. Ltd., are due primarily to circumstances associated with the operation of isolated inland abattoirs of low output.

Although the economic implications of air beef centres are unfavourable, full consideration should be given to the establishment of such a scheme if it is considered essential to settle and develop the North Kimberley area. The amount of subsidy assistance necessary may be much smaller in the long term than the capital and maintenance involved in the construction of roads and stock routes.

If Air Beef Pty. Ltd. continues to operate at Glenroy it may be able to attract cattle from the southern portions of the North Kimberley area. This stock route would provide fairly soft travelling for most of the distance and is capable of substantial improvement by the establishment of additional water points.

The development of road transport of cattle to either Derby, Glenroy, or Wyndham from the North Kimberley area cannot be seriously considered at this stage. Cost of road construction in this area to make possible the efficient movement of road trains could not be justified.

During the past few years several proposals have been advanced for the transport of live cattle by air to fattening areas or killing centres in the north of Australia. These proposals are based on the assumption that large air freighters could be operated at substantially reduced costs and the rate of turn-off from store areas

* Anon. (1955).—Report. Commonwealth Advisory Panel on Air Transport of Cattle or Beef. (Commonw. Govt. Printer: Canberra.)

would be significantly increased. Because of the lack of marketing opportunities for store cattle bred in the North Kimberley area the air lift would be comprised of fat cattle only.

The Commonwealth Advisory Panel's findings on the possibility of air transport of cattle were:

(*a*) With the types of aircraft at present available, the air transport of fat or store cattle could be difficult and would not be economic.
(*b*) The air transport of weaners is practicable (though difficult) but it would not be economic, for except on very short stages the direct cost of the operation would be greater than the gross value of the stock.
(*c*) The air transport of stud stock is both practicable and economic.

If profitable markets for live fat cattle can be established in the Asian countries, the North Kimberley area would be favourably situated for the supply of cattle to these areas. Landing barges similar to those used for the transport of fat cattle from Cape York Peninsula could be employed to move cattle from the northern shores of the Kimberley area. After investigations into stock route conditions are made it may also be found that transporting fat cattle by water to Wyndham is a more profitable proposition than walking them to Wyndham or other outlets.

II. Cost of Development

The assessment of stock numbers in the North Kimberley area besides being based fundamentally on natural land classification must be closely related to economic influences such as the degree of property improvement and the standard of animal husbandry envisaged as well as the financial return from cattle sold.

The estimated number of cattle which this area could support is based on a level of improvements, fencing, and watering facilities which would ensure that a fair measure of controlled breeding and management could be achieved. At this standard* breeding mortality and calf survival should be reasonably consistent and should enable cattle numbers to be maintained at a stable level.

Total cattle numbers for the area will also be influenced by the size of properties and the location of boundaries and subdivision fencing. In many areas the carrying capacity of sandy country situated adjacent to volcanic country will be increased or made safer if fences can be located so that the two land types can be grazed in association with each other.

The greatest asset of this area as far as the cattle industry is concerned is the good supply of permanent stock water. As water represents one of the heaviest development costs, expenditure on artificial waters will be lower than in other areas of the Kimberleys. This will be an important compensating factor against the low carrying capacity of the major portion of the area.

Although there are good supplies of timber suitable for housing, yards, fencing, and buildings, construction costs can be expected to be high. A considerable saving

* The level of improvement and management is higher than that used in Part IX and the estimated stocking is consequently somewhat higher.

in fencing costs will be possible if fences can be planned in relation to the many natural sandstone barriers.

The following estimates of development expenditure are related mainly to the country reasonably accessible to the newly constructed roads, with emphasis on the location of areas of better pasture. In the area surveyed the availability of natural waters appears to fall broadly into three sections (see land system map). Investment in fencing and water improvements considered necessary to establish the cattle industry in these three sections is examined below.

(1) From Gibb River holding northwards to the Drysdale River good supplies of permanent water are available, particularly in the western portion. Country in the vicinity of Plain, Pindan, Bamboo, Middle, and Whisky Creeks has access to permanent water in all seasons. Large rock-holes exist in Whisky Creek and there are numerous springs feeding into the other creeks. Bamboo Creek is a running stream fed by a spring and provides excellent stock water in the sandy country.

Between Whisky Creek and Gibb River holding there is a scarcity of permanent water although small springs and soaks would provide water for some months of the year, the duration depending on the season. North Creek is poorly watered from the junction while only shallow non-permanent holes occur in Kennedy Creek.

No worth-while permanent water exists in Donkey Creek, which traverses forested volcanic plains country and flows into the Drysdale River. A few small holes and billabongs provide water for about seven months a year but these would not be capable of watering large numbers of stock for this period. Despite the scarcity of permanent water, cattle grazing in the vicinity of Donkey Creek would only be three to six miles from permanent water in the tributaries of the Drysdale River.

The area to the west of Gibb River and North Creek appears to be fairly well watered with permanent water-holes in Bottle Tree, Sullivan, and Nuggett Creeks. Here there are permanent waters in the tributaries of the Drysdale River from east of Donkey Creek down to the vicinity of Bottle Tree Creek.

From inquiries made at Karunjie and Gibb River stations it is reasonable to anticipate that good supplies of underground water exist at depths of around 150 ft in the sandstone and mixed sandy plain country. On the other hand, it will probably be more difficult to obtain underground water in the volcanic areas. However, owing to the abundance of permanent water nearby and the close proximity of sandstone country, any lack of water on the volcanic country in this area should not have any marked effect on carrying capacity.

It is estimated that the standard of improvements necessary to maintain stock numbers based on the carrying capacity of the various land classes in this area would be:

One artificial water per 150 sq. miles		£2000 per equipped point
15 miles of fencing per 100 sq. miles (assuming advantage is taken of natural barriers)		£200 per mile erected
Estimated area		2350 sq. miles
Estimated stocking		12,000 cattle
Development costs—Water	£30,000	
Fencing	£69,000	£99,000

(2) In an area of about 1300 sq. miles situated south of the Morgan River in the north and bounded by the King Edward River in the west, Damper Creek in the east, and extending southwards to the Woodhouse and Drysdale Rivers, little permanent water is available.

Permanent water-holes exist in the tributaries of the Drysdale River in the south-eastern part of this country but there are no good supplies of water available to the higher-carrying volcanic country. Throughout the volcanic country there are numerous small holes which, although containing good supplies at the time of the survey, could not be classed as providing permanent watering facilities for large numbers of cattle. Some small holes were seen in the Carson River but judging by the cattle pads in the vicinity of the holes, only small numbers of cleanskins drank there. With a few hundred head watering daily, these holes would not have more than seven months' duration. In the south-eastern portion of the forested volcanic country, seepages and a "black-soil" spring were noticed which could indicate that good water supplies may be available at shallow depth. Although the King Edward River was not seen, it is known to contain permanent holes.

Permanent holes are situated in the Drysdale flowing through the sandy country but there is little information available on the water potential in Damper Creek or its branches. As a large proportion of this drier section (about 40 per cent.) consists of volcanic country, the average water point development will be more costly than in the Gibb River area owing to greater depth and the possibility of bore failures. The construction of open dams in this type of country would depend on the suitability of the soil and soil investigations would be necessary to determine this.

It is estimated that the standard of improvement necessary to maintain stock numbers based on the carrying capacity of the various land classes in this area would be:

One artificial water per 80 sq. miles		£2500 per equipped point
15 miles of fencing per 100 sq. miles (assuming advantage is taken of natural barriers)		£200 per mile erected
Estimated area		1300 sq. miles
Estimated stocking		7000 cattle
Development costs—Water	£40,000	
Fencing	£39,000	£79,000

(3) The northern portion of the King Edward–Drysdale area is traversed by the Drysdale, King Edward, Carson, and Morgan Rivers. It is one of the best permanent-watered areas in northern Australia.

The driest portions appear to be confined to small areas in the north-west and to some of the sandy coastal country. The volcanic country with the exception of parts of the Napier land system is well watered.

It is estimated that the standards of improvement necessary to maintain stock numbers based on the carrying capacity of the various land classes in this area would be:

One artificial water per 250 sq. miles	£2000 per equipped point
15 miles of fencing per 100 sq. miles (assuming advantage is taken of natural barriers)	£200 per mile erected

Estimated area		4050 sq. miles
Estimated stocking		25,000 cattle
Development costs—Water	£32,000	
Fencing	£126,000	£158,000

The total investment considered necessary on water improvements and fencing in the area surveyed is estimated at £336,000. The cattle potential and development costs of water and fencing are estimated as follows:

Estimated area		7700 sq. miles
Estimated stocking		44,000 cattle
Development costs—Water	£102,000	
Fencing	£234,000	£336,000
Turn-off of cattle*		5245
Gross value at Wyndham		£104,000

* Assuming satisfactory stock routes to Wyndham.

APPENDIX TO PART X

Estimated Costs of Beef Production in the North Kimberley Area, W.A.

By F. Thomas*

This appendix has been prepared to supplement the appraisal given in Part X.

The cattle numbers of turn-off (44,000 head and 5245 head respectively) and the assumptions made in Part X are accepted, including the footnote "assuming satisfactory stock routes to Wyndham".

For clarity the whole area has been treated as an established unit with constant turn-off.

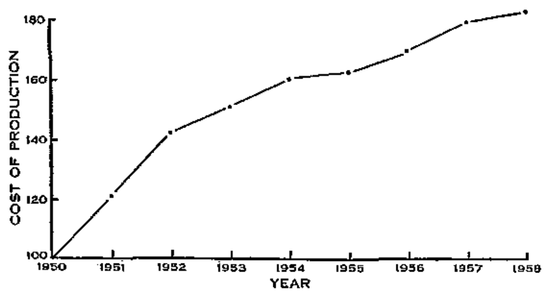


Fig. 9.—Beef cost of production index 1950–58.

No economic data are available from properties in the North Kimberleys and the data presented in Tables 27 and 28 and in Figure 9 are based on an unpublished report of a survey of the costs and cost structure of beef-cattle production in northern Australia by the Bureau of Agricultural Economics (Beef Cattle Production—An Index of Cost Movements July 1950—January 1958).

Figure 9 shows the increase in cost of production of beef on extensive beef-cattle properties in northern Australia over the period 1950–58.

In Table 27 the average cost structure in 1950 and 1958 of a sample of Western Australian beef-cattle properties has been converted to estimated costs of running 44,000 head of cattle. Some marked trends in cost structure over the period are apparent but some of these may not apply in the North Kimberleys, e.g. increased rates and taxes and rent, lower inward freight.

In Table 28 estimates of cost of production based on the cost index are related to returns obtained from Wyndham meatworks over the period 1950–58 to obtain an assessment of net margin and net margin per head turn-off. The low prices at Wyndham for 1957 and 1958 are attributable to drought conditions.

* Bureau of Agricultural Economics, Canberra, A.C.T.

It is nevertheless likely that, with the general cost trend plus extra costs particular to the North Kimberleys, input figures may be 15 to 20 per cent. higher than those quoted here. This, together with probably less than average returns because of the long hard stock route the cattle must traverse, would considerably reduce the margin of profit quoted.

TABLE 27

ESTIMATES OF COST OF BEEF PRODUCTION RUNNING 44,000 HEAD IN THE NORTH KIMBERLEY AREA

	1950			1958		
	Cost 1950 = 100 (£)	Cost Structure (%)	Cost Structure Subtotals (%)	Cost 1958 = 183 (£)	Cost Structure (%)	Cost Structure Subtotals (%)
Labour						
Owner/operator	2,625	6·71	44·91	6,644	9·29	39·74
Other hired labour	14,934	38·20		21,776	30·45	
Depreciation						
Structures	498	1·27		701	0·98	
Plant	2,030	5·19	8·22	3,597	5·03	6·39
Horses	687	1·76		272	0·38	
Maintenance						
Structures	1,089	2·79	9·46	2,110	2·95	7·87
Plant	2,609	6·67		3,518	4·92	
General station costs						
Rates and taxes	213	0·54		5,750	8·04	
Insurance	325	0·83		822	1·15	
Oils and fuels	1,544	3·95	8·70	1,455	2·02	14·65
Inward freight	1,302	3·33		937	1·31	
Dip materials	21	0·05		1,523	2·13	
Minor station costs						
Miscellaneous	789	2·02	2·02	1,952	2·73	2·73
Marketing						
Commission	411	1·05	6·17	393	0·55	12·52
Droving	2,001	5·12		8,560	11·97	
Interest						
Breeders	5,495	14·05		4,262	5·96	
Structures	401	1·03		665	0·93	
Fences	241	0·62	18·24	622	0·87	10·87
Plant	289	0·74		858	1·20	
Water	395	1·01		1,251	1·75	
Horses	309	0·79		114	0·16	
Rentals						
Rent	879	2·25	2·25	3,712	5·19	5·19
Total gross cost	39,100	100	100	71,500	100	100

TABLE 28

ESTIMATED COSTS OF PRODUCTION AND MARGIN OF PROFIT, NORTH KIMBERLEY AREA, 1950–58

(Based on 5245 turn-off from 44,000 head of cattle)

	1950	1951	1952	1953	1954	1955	1956	1957	1958
Cost index*	100	121	143	151	160	163	169	179	183
Turn-off	5245	5245	5245	5245	5245	5245	5245	5245	5245
Wyndham price†	£12/10/11	£15/8/1	£19/12/6	£20/13/1	£20/19/0	£25/10/0	£22/7/7	£18/0/3	£18/0/0
Output‡	£65,825	£80,773	£102,933	£108,309	£109,883	£133,748	£117,331	£94,935	£94,410
Input§	£39,100	£47,311	£55,913	£59,041	£62,599	£63,694	£66,196	£70,028	£71,514
Margin (net)‖	£26,725	£33,462	£47,020	£49,268	£47,284	£70,054	£51,135	£24,907	£22,896
Margin per head¶	£5·10	£6·38	£8·96	£9·39	£9·02	£7·76	£9·75	£4·75	£4·37

* See Figure 9.
† Actual return per head to grower.
‡ Turn-off × Wyndham price.
§ Based on £39,100 = 100 in 1950.
‖ Output minus input.
¶ Margin (net) divided by turn-off.

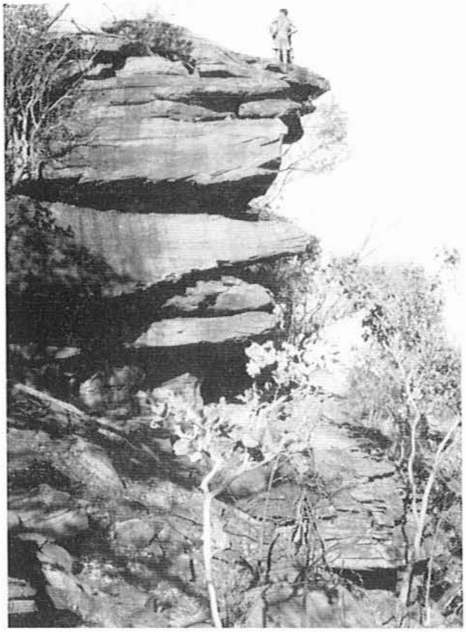


Fig. 1.—Almost half the area consists of rugged sandstone country with a high proportion of rock outcrops (Buldiva land system). Steep scarps and deep gorges severely restrict accessibility in many parts.

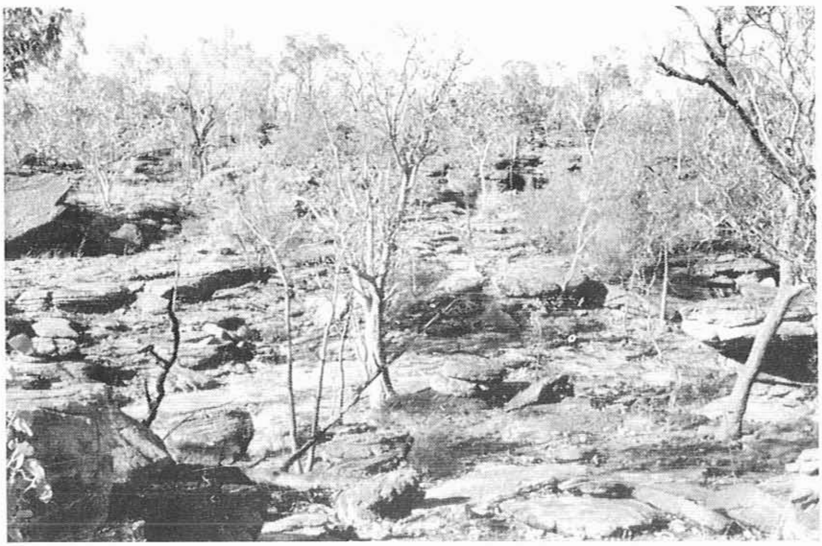


Fig. 2.—The less rugged country (Buldiva land system) has very poor pastures (Group 3 lands) but is well watered. Mustering and stock control would be extremely difficult in this country and it would prove a liability in the development of the cattle industry in that it would provide ideal "hideouts" for scrub cattle.

Fig. 1.—The gently sloping sandstone country (Pago land system, 7900 sq. miles) makes up more than two-thirds of the Group 2 lands which cover 31 per cent. of the total area. It is chiefly open forest, growing on deep sandy soils. The pastures are generally sparse soft spinifex (*Plectrachne pungens*).

Fig. 2.—The depressions within Pago land system, although variable, commonly have dense tall annual *Sorghum* with patches of moderate and poor pasture species.

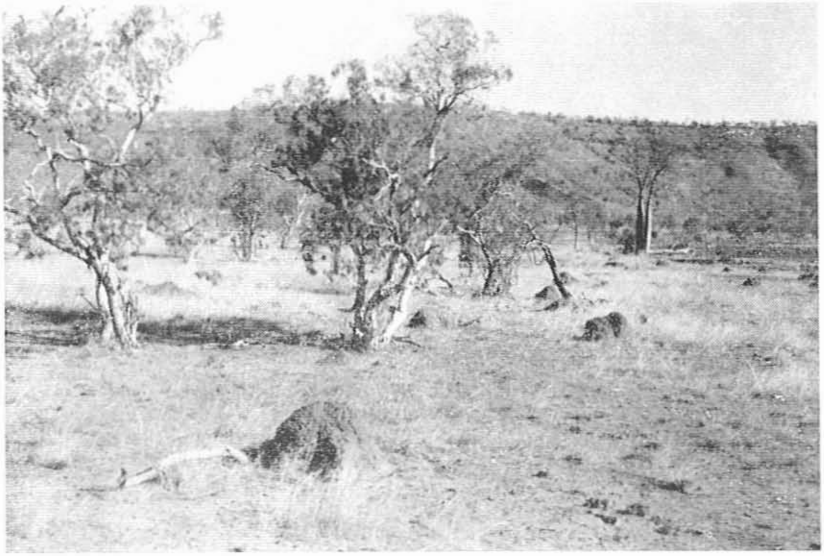


Fig. 1.—The Karunjie land system (1800 sq. miles) consists of shale country, including gently sloping plains and steep scarps. It is considered that these Group 2 lands are only worthy of development where they can be used in association with the Group 1 lands.

Fig. 2.—The narrow frontages along the streams (Karunjie land system) carry an open woodland vegetation and very poor pastures. This is partly compensated for by being commonly well watered. Where conveniently placed they form the natural routes of the area.

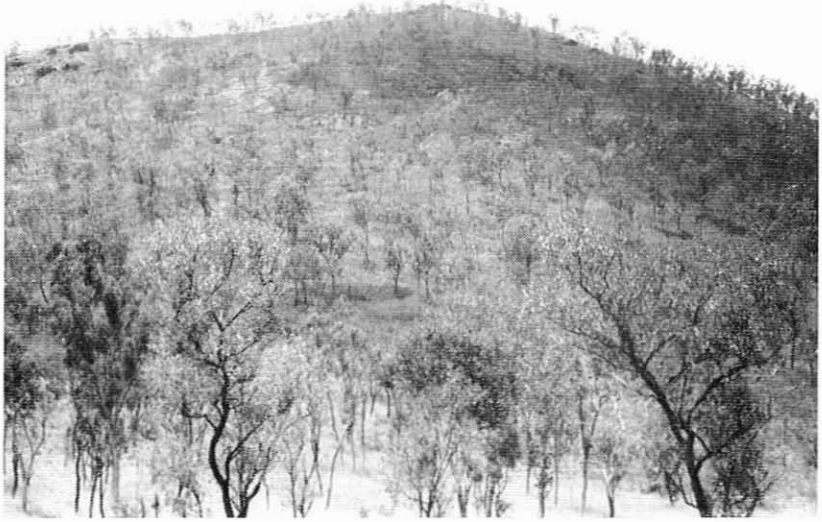


Fig. 1.—Extension of the cattle industry will be largely centred on the Group 1 lands with volcanic rocks, which cover 21 per cent. of the area. More than half of this is hilly country of the Napier land system (3900 sq. miles). It would mostly be accessible to cattle and carries a variety of pastures as an understorey to open woodlands.

Fig. 2.—The gently undulating country of Barton land system (2000 sq. miles) also carries grassy woodlands and has slightly better pastures.

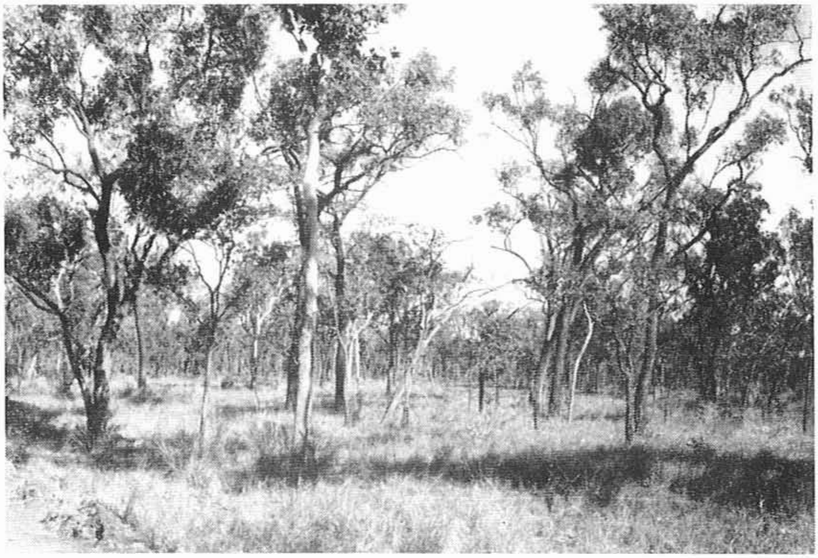


Fig. 1.—A less extensive part of the Group 1 lands is the Kennedy land system (1200 sq. miles), which mostly has an open forest vegetation. Although the pastures generally resemble those of the Barton land system, they are more varied and have considerable areas of soft spinifex and beard grass pastures.

Fig. 2.—The Isdell land system (160 sq. miles), which is dominantly grassland (blue grass) with low deciduous trees, contains the best pastures of the area. Virtually all of this land system is already occupied by cattle stations along the southern edge of the area.

Fig. 1.—On the whole the region is well watered by permanent water-holes and streams which are generally bordered by dense fringing communities. In the sandstone country some of the waters may be inaccessible to stock and pumping may be necessary.

Fig. 2.—Although the larger streams commonly contain large permanent pools, artificial watering points will probably be necessary in some of the Group 1 lands to ensure utilization of all the country.

Fig. 1.—The only form of land development that appears possible at the present time is the utilization of native pastures for the raising of beef cattle. The southern part of the area is already used for this purpose, e.g. Karunjie and Gibb River stations. It is considered that a further 11,500 sq. miles of the King Edward–Drysdale country and 700 sq. miles of the Mt. Synnott country are worthy of development for cattle. Their estimated cattle-carrying potentials are 51,000 and 5700 head respectively.

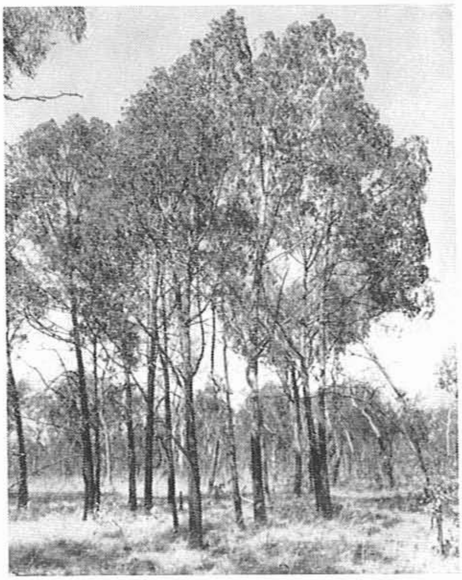


Fig. 2.—Pine (*Callitris intratropica*) is widely scattered on sandstone country but it occurs as small patches or isolated trees in the eucalypt open forest. The eucalypts are generally unsatisfactory for milling purposes. There are no forests worthy of commercial exploitation but the timber resources are adequate to meet the needs of the developing cattle industry.