SURVEY OF TOWNSVILLE-BOWEN REGION, 1950

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Survey of the Townsville - Bowen Region, North Queensland, 1950

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FOREWORD

Development of the lower Burdekin River on the east coast of Queensland has been under discussion for some years. In 1949 the Queensland Government submitted to the Commonwealth Government a formal proposal which involved damming the Burdekin River to provide water for irrigating an extensive area of levee and flood-plain country and for producing hydro-electric power. The Commonwealth Inter-departmental Committee which examined this proposal considered that more extensive information on the whole region, particularly its agricultural aspects, was required, and accordingly requested that the C.S.I.R.O. Land Research and Regional Survey Section conduct a rapid broad survey of the area between Townsville and Bowen extending 100 miles inland to the main ranges.

The objects of the survey, which was carried out in 1950, were to describe and map the inherent land characteristics of the region and to report on the possibilities of land use, including those related to the irrigation proposals that had been put forward.

SUMMARY

This report is concerned with the description of lands of the Townsville-Bowen Region, north Queensland, and the assessment of their agricultural potentialities. The region, which covers 6,000 sq. miles, lies between the Leichhardt Range and the coast. The various parts of this report deal with climate in relation to agriculture, geology, geomorphology, soils and their agricultural characteristics, vegetation communities, land systems, and the land-use groups and their potentialities.

The most widespread form of land use is grazing of beef cattle on natural pastures. Agricultural development is confined to better alluvial soils where sugar-cane and fruits and vegetables are produced, mainly under irrigation, the most important centres being Ayr, Home Hill, Giru, and Bowen.

Available irrigation water is being almost fully utilized and any major extension of irrigated agriculture will depend on the provision of additional supplies. One of the objectives of the survey was to investigate the possibilities of use by irrigated agriculture on the lands that might be commanded by the proposed Burdekin Diversion Weir.

The region has been subdivided by this survey into 19 land systems, which have been grouped into seven land-use groups. These are shown on the accompanying maps.

It is considered that 40,000-50,000 acres of the Levee Group, which are suitable for intensive irrigated agriculture, could be developed in the Lower Burdekin Valley. An additional 10,000 acres of similar lands along the Bowen River could be utilized if a suitable source of water can be provided.

Some extension of irrigated agriculture is possible in the Delta Group, but this must await the provision of additional water supplies to supplement the present underground resources.

Of the total area of 286,000 acres of the Flood Plain Group in the Lower Burdekin Valley, a large proportion could be commanded by the Burdekin Diversion Weir. The economic development of these lands by irrigation presents some difficulties, but there is every justification for intensive field experiments to determine the possibilities of economic production.

Small portions of the Sandy Group and Better Uplands Group in the Lower Burdekin Valley may be irrigated and portions of the Upland Group may be utilized for dry-land agriculture. Apart from such developments, the remainder of these groups and the Hill Country and Saline Lands Groups are satisfactory only for grazing purposes. Further investigation will be necessary before pasture improvement can be applied widely to these lands.

PART I. INTRODUCTION TO SURVEY OF THE TOWNSVILLE-BOWEN REGION

By C. S. CHRISTIAN*

In 1950 the Land Research and Regional Survey Section of the Commonwealth Scientific and Industrial Research Organization made a survey of the Townsville-Bowen region on the east coast of Queensland. The survey was conducted at the request of a Commonwealth Interdepartmental Committee, which was examining a proposal to develop the Lower Burdekin River Valley. This valley covers about one-quarter of the region surveyed.

Although the Lower Burdekin River project was not formally examined by the Commonwealth until 1949, discussions had previously taken place between the State authorities and the C.S.I.R.O. As a result of these discussions a soil survey of portion of the Lower Burdekin Valley had been undertaken by the Division of Soils, C.S.I.R.O., under the direction of G. D. Hubble†, and certain investigations of irrigated pastures were commenced at the State Regional Farm at Ayr by the Division of Plant Industry, C.S.I.R.O., cooperating with the State Department of Agriculture and Stock. In addition various investigations of the Burdekin Valley had been made at the instigation of the Queensland Bureau of Investigation.‡ Over a number of years much information on the agriculture of the delta country has been accumulated by the State Department of Agriculture and Stock, and more recently experiments have been conducted on the Burdekin River levee at Clare. Some previous botanical work had been done in portion of the Lower Burdekin Valley by L. S. Smith of the Queensland Department of Agriculture and Stock.

The formal proposal submitted by Queensland to the Commonwealth Government in 1949 involved damming the Burdekin River, irrigation of an extensive area of levee and flood plain country, and the production of hydro-electric power.

In the course of the examination the Inter-departmental Committee considered that more extensive information of the whole region was required, particularly concerning the agricultural aspects. Accordingly the Land Research and Regional Survey Section was requested to conduct a rapid broad survey of the country between Townsville and Bowen extending about 100 miles inland to the main ranges.

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

† Hubble, G. D., and Thompson, C. H. (1953).—Soil survey and land-use potential of the Lower Burdekin Valley, north Queensland. C.S.I.R.O. Aust. Soils Land Use Ser. No. 10.

‡ Department of the Coordinator General of Public Works. Report on the Burdekin River irrigation, hydro-electric, and flood mitigation project, 1949.

The objectives of this survey were to describe and map the inherent land characteristics of the region and to report on the possibilities of land use, including those related to the irrigation proposals that had been put forward.

I. General Description of the Region

The region surveyed covers an area of 6400 sq. miles between the Leichhardt Range and the coast. The Lower Burdekin River traverses the central portion of the region in a generally northerly direction and, with its tributaries, drains about half the area. The remainder is drained by shorter coastal streams flowing in the same general direction.

The Leichhardt Range, which consists of hills ranging from 1000 to 2000 ft. above sea-level, forms the south-western boundary of the region. Between it and the coast the country has been maturely dissected with extensive alluviation in the main valleys and along the coast. Throughout this section there are scattered high mountain residuals. The coastal mountains, which are the highest in the region, rise to 4000 ft. above sea-level.

The base rocks of the region are of Palaeozoic age, but the alluvia are of Pleistocene and Recent age.

The region is one of the driest sections of the Queensland east coast. Annual rainfall varies from nearly 50 in. at the coast to about 25 in. in the inland portion. Approximately 80 per cent. of the annual rainfall occurs between December and April. Temperatures are moderately high and frosts are unknown in the potentially arable areas.

The extensive area of steeply sloping mountains and hills is covered by skeletal soils. Of the remaining soils many are solonized, but a variety of other soils, including black earths, red-brown earths, red podsolic soils, and immature alluvial soils, occurs within the region.

The vegetation is mainly *Eucalyptus* open forest, but small patches of softwood forest occur on the mountain slopes and coastal sand dunes, and some of the heavy soils carry grassland.

There are four major centres of population in the region. Townsville (population 35,200) is a major port for north-central and western Queensland, exporting meat, sugar, wool, and minerals. Bowen (population 3,350) is a smaller port from which fruits and vegetables from the nearby district, and coal from Collinsville, are exported. The Ayr-Home Hill district (population 12,700) is an intensively developed sugar-cane area situated on the Burdekin River delta. Collinsville (population 1,786) is a coal-mining centre about 50 miles inland from Bowen.

The first three centres, located along the coast, are connected by the Great Northern Railway and the main coastal road. Collinsville is served by road and rail from Bowen. Just south of Townsville the Hughenden-Cloncurry railway and road connect with the coastal systems. The remainder of the region is served by an irregular network of roads and tracks mostly serving cattle properties.

The beef-cattle industry is the most widespread in the area surveyed. The natural pastures are used for fattening of store cattle obtained from inland centres or bred within the region. Large killing works are located at Ross River and Alligator Creek near Townsville, and at Merinda near Bowen. These works kill about 44,000, 56,000, and 30,000 head per annum respectively.

The dairy-cattle industry is small, its full output being used in the fresh milk supply of the major population centres.

The agricultural industries, which are mainly confined to irrigated crops on the better alluvial soils, cover only a small area in the region. Water for irrigation is obtained by pumping from shallow wells and from streams. The major crop is sugar-cane. The chief centres are Ayr and Home Hill, with a small area at Giru, where some non-irrigated cane is grown. The industry supports four mills, Kalamia, Pioneer, Inkerman, and Giru, which collectively crush nearly 900,000 tons of sugar-cane per annum. A small, flourishing fruit and vegetable industry dependent upon export to the south has been developed on the alluvia of the Don River near Bowen, the main exports being tomatoes, mangoes, and pineapples. At Major Creek and other small areas near Townsville, fruit and vegetables are grown for local consumption.

About 240,000 tons of coal are mined annually at Collinsville and Scottville. Much of this coal is coked at Bowen for use at Mt. Isa. Salt works at Bowen produce 13,000-14,000 tons of salt per annum and there are various small industries in Townsville.

II. Survey Procedure

The survey was conducted by the Section's Regional Survey Unit which had previously made several extensive regional surveys in northern Australia. Personnel of this survey consisted of G. A. Stewart, pedologist; R. A. Perry, botanist; D. M. Traves (Bureau of Mineral Resources), geologist; M. Lazarides, botanical assistant. The Officer in Charge of the Section, C. S. Christian, accompanied the unit for a large portion of the survey. L. S. Smith and S. T. Blake, of the State Department of Agriculture and Stock, were attached to the survey for botanical work. Each accompanied the unit for about half the period. P. J. Skerman, Agricultural Officer of the Queensland Bureau of Investigation, who was responsible for some of the earlier work in the Lower Burdekin Valley, accompanied the unit during the first week. At the conclusion of the field work, the survey unit and regional officers of the State Department of Agriculture and Stock, G. A. Christie and N. Adams, inspected selected areas and discussed problems of utilization.

A full cover of vertical aerial photographs at scales of 1/30,000 (90 per cent.) and 1/15,000 (10 per cent.) was available. Aerial photo mosaics at a scale of 2 in. = 1 mile were available for 30 per cent. of the region, reasonably accurate military maps at 1 in. = 1 mile for 40 per cent., and maps compiled from aerial photographs by the National Mapping Section of the Department of Interior, Canberra, for the remaining 30 per cent.

Preliminary examination of aerial photographs and the pertinent geological, soil, and botanical literature was done at Canberra prior to the field work. From the examination of the aerial photographs a preliminary map was made of the different types of country as identified by aerial photographic patterns. An itinerary of land traverses was then planned so that these types of country might be examined and the land systems mapped. About 1,800 miles of traverses were made during the 2 months field season. In general the land traverses conformed to the preliminary plan, but certain modifications were made as field data were accumulated.

Field procedure followed the methods developed by the unit on previous surveys and outlined by Christian and Stewart (C.S.I.R.O. Aust. Land Res. Ser. No. 1, 1953).

Aerial photographs were marked with land system and geological boundaries and these marked photographs were used to draw the various maps prepared for publication by the National Mapping Section of the Department of the Interior.

III. Acknowledgments

It is desired to acknowledge the help of the Queensland Department of Agriculture and Stock for making available the various officers mentioned who contributed substantially to this survey, and of Mr. G. D. Hubble for making available his own data on the soils of the Lower Burdekin Valley and for many helpful suggestions.

Thanks are due to the non-scientific members of the Survey Unit whose efforts were essential to the success of the field work, and to Miss Margaret Mills for much assistance in the final preparation of this report.

PART II. CLIMATE IN RELATION TO AGRICULTURE IN THE TOWNSVILLE-BOWEN REGION

By C. S. CHRISTIAN* and R. O. SLATYER*

I. GENERAL CLIMATIC CHARACTERISTICS

The climate of the region is warm and subhumid with a marked summer rainfall maximum. There are two main seasons, a hot, wet summer period of variable duration and intensity and a warm, dry winter period. Seasonal changes are slow and are associated with a regular annual temperature movement.

Rainfall is the dominating climatic factor influencing plant growth in this region. Temperatures are moderate to high throughout the year and are rarely limiting.

(i) *Rainfall*.—Rain falls mostly between October and April, with the greatest concentration between January and March. The predominant source of rainfall is the south-east trade wind, but much rain is also received from tropical influences, particularly tropical cyclones and associated disturbances. During the winter months the tropical influences move to the north. The small amounts of rain received during this period are mainly a result of the abating influence of the trade wind.

Important features of rainfall in this region are amount, distribution, and reliability of annual rainfall, number of rainy days per year, and the intensity of rainfall.

Most of these factors are related to distance from the coast, but the small size of the area, the paucity of recording stations, and the influence of topography, prevent all but the most marked relationships from being observed. Along much of the coastline, total annual rainfall exceeds 40 in. and the mean number of rainy days per year exceeds 60. At Townsville an average of 42 in. of rain are recorded annually on 76 days. Rainfall is less and the number of wet days fewer at inland stations. Woodstock receives an average of 32 in. on 40 days, and Mingela 24 in. on 35 days.

Variations to this general pattern are caused by the influence of local topography and occur particularly in the proximity of mountain masses, which rise abruptly from the surrounding country. For example, Giru at the foot of Mt. Elliot receives 5 in. more rain annually than Ayr on the Burdekin river delta.

The intensity of rainfall is high and consequently active erosion proceeds on all major slopes and bare surfaces. The average fall per wet day is of the order of 70 points. It is higher during the summer months and at several stations it exceeds 100 points per wet day during the wettest month.

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TABLE 1

SUMMARY OF DATA ILLUSTRATING DISTRIBUTION AND VARIABILITY OF RAINFALL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Townsville (50 years)													
Total rainfall	1074	1017	674	224	96	108	67	50	86	118	190	516	4220
Number of wet days	12	13	11	5	5	4	3	2	3	4	5	9	76
Rain/wet day	90	78	61	45	19	27	22	25	29	29	38	57	56
Variability (%)	56	57	67	84	92	92	117	122	125	104	93	84	30
Ayr (50 years)													
Total rainfall	948	1027	634	224	94	137	71	53	86	88	155	434	3951
Number of wet days	9	10	8	4	4	3	2	2	2	2	4	7	57
Rain/wet day	105	103	79	56	24	46	36	27	43	44	39	62	69
Variability (%)	64	67	79	96	95	92	121	123	122	105	102	81	36
Bowen (50 years)													
Total rainfall	935	870	603	227	113	155	69	72	66	77	124	450	3761
Number of wet days	11	11	9	6	5	4	3	2	2	3	4	7	67
Rain/wet day	85	79	67	38	23	39	23	36	33	26	31	64	56
Variability (%)	71	60	82	87	86	80	117	112	106	92	92	79	33
Woodstock (50 years)													
Total rainfall	802	791	534	149	95	93	46	55	44	65	165	364	3203
Number of wet days	8	8	6	3	2	2	1	1	1	1	2	5	40
Rain/wet day	100	99	89	50	48	47	46	55	44	65	83	73	80
Variability (%)	59	67	72	96	99	105	116	132	145	100	105	87	38

TABLE 1 (*Continued*)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Woodhouse (36 years)													
Total rainfall	755	709	540	174	63	161	73	53	52	80	145	338	3143
Number of wet days	8	7	4	3	1	2	1	1	1	1	2	5	36
Rain/wet day	94	101	135	58	63	81	73	53	52	80	73	68	87
Variability (%)	68	60	74	107	112	94	133	125	121	118	109	61	34
Strathmore (30 years)													
Total rainfall	602	562	379	154	65	144	93	59	64	92	212	387	2813
Number of wet days	8	8	6	2	2	2	2	1	1	2	3	6	43
Rain/wet day	75	70	63	77	33	72	47	59	64	46	70	64	65
Variability (%)	63	69	64	109	113	82	115	125	115	90	72	61	34
Charters Towers (50 years)													
Total rainfall	533	472	392	125	68	106	66	46	74	66	123	312	2383
Number of wet days	9	9	8	4	3	4	3	2	2	2	4	6	56
Rain/wet day	59	52	49	31	23	27	22	23	37	33	31	52	43
Variability (%)	62	60	62	85	97	99	104	129	121	96	93	60	26
Mingela (50 years)													
Total rainfall	549	541	413	105	94	107	46	33	43	52	119	279	2381
Number of wet days	7	6	5	2	1	2	2	1	1	1	3	4	35
Rain/wet day	78	90	83	53	94	54	23	33	43	52	40	70	68
Variability (%)	60	72	77	102	100	112	124	141	136	113	84	69	34

Source of data — Daily rainfall records from Commonwealth Meteorological Bureau for years 1900-1949 for Townsville, Ayr, Bowen, Woodstock, Charters Towers, and Mingela, 1913-1948 for Woodhouse, and 1917-1946 for Strathmore.

Reliability of total annual rainfall is low and the mean deviation from the mean, expressed as a percentage of the mean, exceeds 30 per cent. throughout the area. This variability is due mainly to the erratic nature of rain received from tropical influences.

A summary is given in Table 1 of data illustrating the distribution and variability of rainfall at seven locations in the surveyed area and at Charters Towers, which is about 20 miles beyond the western margin.

(ii) *Temperature and Humidity.*—Temperature and humidity records are available only for the three coastal stations, Townsville, Ayr, and Bowen, and the inland station of Charters Towers. These records are summarized in Table 2. From these limited data several characteristics are obvious.

The annual temperature regime is regular and changes slowly from season to season. Temperatures remain high throughout the year, regional extremes of temperature being recorded at the inland centre where the moderating influence of the ocean has less effect.

Here during the summer mean monthly maxima approach 95°F., and daily maxima frequently exceed 100°, but on the coast mean monthly maxima range between 85 and 90° and daily maxima of 100° seldom occur. During the winter mean monthly maxima show less relationship with distance inland. They are of the order of 75-80° with inland temperatures 1-2° higher than those at the coast. During this period daily maxima of 90° are of rare occurrence in the region. Minima are appreciably lower at inland stations. In the summer mean monthly minima are of the order of 70-75° on the coast, and 65-70° inland. During the winter the corresponding figures are 55-60° and 50-55°. Foley (1945) reports that occasional winter frosts are recorded on the highlands, but the potentially arable land of the surveyed area is normally frost free.

Relative humidity remains higher on the coast than inland. Mean monthly relative humidity along this coastal strip persists above 60 per cent. and exceeds 70 per cent. for four summer months. At Charters Towers it falls to 50 per cent. in November and never exceeds 70 per cent.

II. Climatic Factors of Significance to Dry-land Agriculture

The seasonal distribution of rainfall is such that there is scope for dry-land agriculture only during the summer period. At this time temperature is mostly at an optimum level for plant growth and low temperature is not a limiting factor. Most of the region has an average rainfall greater than 25 in., but its distribution is not always satisfactory for crop production. The length of the period over which sufficient rains to maintain crop growth are received is a more important factor than total rainfall. The available data have been examined by several methods to estimate the length of this period, but in the absence of more temperature

TABLE 2

TEMPERATURE (°F.) AND RELATIVE HUMIDITY (%) RECORDS FOR FOUR STATIONS

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Townsville	Max.	86.9	87.0	86.2	84.1	80.4	76.6	75.5	76.8	79.7	82.5	84.5	86.3	82.2
	Min.	75.8	74.9	73.4	69.6	64.2	60.8	68.4	60.4	65.3	70.5	73.5	75.6	68.5
	R.H.	73	73	71	67	65	67	65	64	64	65	66	71	68
Ayr	Max.	88.7	88.1	87.1	85.5	82.1	77.9	76.8	78.7	82.1	85.2	87.7	89.1	84.1
	Min.	72.6	72.3	70.4	66.1	59.9	56.0	53.0	54.7	59.5	64.8	68.5	72.0	64.2
	R.H.	71	73	73	69	67	68	67	66	63	61	60	65	67
Bowen	Max.	87.8	87.5	86.4	83.9	79.7	76.2	75.2	77.1	80.5	83.7	85.8	87.8	82.6
	Min.	75.1	74.5	73.1	69.5	63.3	59.3	56.5	58.5	63.0	68.4	71.7	73.9	67.2
	R.H.	71	74	74	73	70	71	68	68	66	65	64	68	69
Charters Towers	Max.	92.3	90.6	88.6	85.8	81.1	76.5	76.3	79.7	85.0	90.3	93.5	94.4	86.2
	Min.	70.9	70.2	68.2	63.0	57.4	53.1	50.9	53.3	58.1	62.9	67.3	69.2	62.0
	R.H.	65	68	67	63	63	67	62	62	59	56	55	60	62

Source of data, Coun. Sci. Industr. Res. Aust. Pamph. No. 42, 1933.

and humidity recording stations in the region use has had to be made of rainfall alone in many instances. Hence the method for determining the "period of adequate rainfall" used in the report by Christian and Stewart (1953) on the Katherine-Darwin region was finally adopted.

Field experiments have shown that this method gives reasonably satisfactory estimates for Katherine. The criteria have been modified slightly for the Townsville-Bowen region to make allowance for the more humid conditions prevailing in that region.

(i) *Period of Adequate Rainfall*.—To estimate when moisture conditions adequate for safe crop establishment first occur, an arbitrary figure has been adopted, namely a total of at least 2 in. of rain in one week. When this criterion is satisfied but not followed by a 28-day period of "adequate rainfall" (defined below) the season is regarded as having made a false start. If this occurs a new start is considered to be made at the end of the first 28-day period of "adequate rainfall".

TABLE 3

TIME OF COMMENCEMENT AND LENGTH OF PERIOD OF "ADEQUATE RAINFALL"

	Townsville	Ayr	Bowen	Woodstock	*Strathmore*	Woodhouse	Charters Towers	Mingela
Mean date of commencement	Jan. 4	Jan. 11	Jan. 12	Jan. 15	Jan. 9	Jan. 15	Jan. 18	Jan. 18
Deviation from mean date exceeded in one year out of four (weeks)	5.5	4.0	4.1	3.6	5.2	3.7	3.9	3.1
Mean length of period of "adequate rainfall" (weeks)	13.4	12.2	11.6	10.6	9.9	10.8	9.6	9.0

Using this criterion, which thus discards false starts in the season, it is found that the time of commencement of the period of adequate rainfall at any locality is subject to considerable variation, which shows little uniformity throughout the region. The mean commencement dates for the various stations in the region lie in a fortnightly period between early and mid January, and are slightly earlier for stations with a higher total annual rainfall. Mean dates of commencement and the expected variation are shown for eight localities in Table 3.

To define "adequate rainfall" the arbitrary figure of a minimum total of $2\frac{1}{4}$ in. of rain within a 28-day period has been adopted. The period of adequate rainfall is defined as the total number of weeks over which consecutive 28-day periods, assessed at 14-day intervals, satisfy this criterion. From Table 3 it will be observed that the mean period varies from 9.0 weeks at Mingela to 13.4 weeks at Townsville.

(ii) *Estimated Growing Period.*—The length of the period of adequate rainfall, as defined above, does not represent the exact length of the growing season which, with a given rainfall period, may vary according to the type of crop, its stage of growth, soil type, drainage, and crop and soil husbandry. Plant growth may continue after the conclusion of the period of adequate rainfall until the accumulated reserves of soil moisture are exhausted. The rate of exhaustion will vary with the foregoing

TABLE 4

LENGTH OF ESTIMATED GROWING PERIOD IN WEEKS

	Townsville	Ayr	Bowen	Woodstock	Strathmore	Woodhouse	Charters Towers	Mingela
Mean length of estimated growing period	17.4	16.2	15.6	14.6	13.9	14.8	13.6	13.0
Length of period exceeded in 75% of years	15.5	14.0	14.4	12.2	12.1	11.0	11.8	10.6
Mean length of period for the above 75% of years	20.7	19.3	18.0	17.3	16.0	16.9	16.1	15.7

factors and in some years may be slowed by additional light rains which do not satisfy the criterion and therefore do not influence the estimated period. A period of 4 weeks, representing a mean period of growth that may be expected following the completion of the period of adequate rainfall, has been added to obtain a figure for the total length of the estimated growing period (Table 4). To give a more comprehensive picture than that obtained from the mean value for this estimate, the length of the period that has been exceeded in 75 per cent. of the years is also given in Table 4 with the mean value for the years when this minimum is exceeded.

It is of interest to compare these figures, determined from rainfall alone, with those calculated from the $P/S.D.^{0.75}$ ratio of Prescott and Thomas (1949) and the $P/(T + 10)$ ratio used by Miles (1947), for the four stations from which temperature and relative humidity records are available (Table 5).

TABLE 5

DATE OF COMMENCEMENT AND LENGTH OF GROWING SEASON

	Townsville	Ayr	Bowen	Charters Towers
1. Based on $P/S.D.^{0.75}$ relationships				
Approximate date of commencement (where $P/S.D.^{0.75}$ exceeds 4)	Nov. 10	Nov. 20	Nov. 20	Dec. 1
Length of growing season				
(*a*) $P/S.D.^{0.75} > 4$ (sufficient to initiate growth)	5.7 months	5.4 months	5.6 months	4.3 months
(*b*) $P/S.D.^{0.75} > 8$ (sufficient to maintain growth under conditions of low transpiration)	4.3 months	3.9 months	4.1 months	2.7 months
(*c*) $P/S.D.^{0.75} > 12$ (sufficient to maintain growth under conditions of medium transpiration)	3.4 months	3.2 months	3.3 months	0 months
(*d*) $P/S.D.^{0.75} > 16$ (sufficient to maintain growth under conditions of high transpiration)	2.7 months	2.6 months	2.6 months	0 months
2. Based on $P/(T+10)$ relationships. Approximate date of commencement	Dec.	Dec.	Dec.	Dec.
Length of "agricultural growing season"	3.3 months	3.4 months	3.2 months	3.2 months
3. Based on "adequate rainfall" criterion. Mean date of commencement	Jan. 4	Jan. 11	Jan. 12	Jan. 18
Mean length of "estimated growing period"	17 weeks	16 weeks	16 weeks	14 weeks

These different estimates of length of growing season obtained by the various methods are primarily a result of differences in the calculated dates of commencement of the season. This is mainly due to the fact that the methods of Prescott and Thomas, and of Miles, do not specifically allow for the occurrence of false starts in the season, which are recorded and automatically discarded by the "adequate rainfall" method.

(iii) *Other Climatic Factors*.—A further factor that concerns dry-land agriculture is the intensity of rainfall. The mean amount of rain per wet day is about 70 points throughout the region. It is greatest in summer when falls of 2 in. per day are of frequent occurrence. At Townsville the mean figure for the period December-April is 76 points whereas that for the remainder of the year is less than 30 points. The corresponding figures for Brisbane are 41 and 31. It is evident that, with such a high average intensity of rainfall during the summer, soil erosion on cultivated land is a hazard to be considered. High intensity of rainfall can also have a very adverse effect on the surface structure of cultivated soils.

The importance of temperature during the summer growing period in regions such as this is mainly the adverse effect of excessively high temperatures, probably coupled with low relative humidity. The occurrence of heat-wave conditions at Clermont, where high temperatures have had adverse effects on sorghum crops in recent years, has been reported by the Queensland Bureau of Investigation (1950).

Daily temperature records have not been examined for the Townsville-Bowen region, but from the comparison of mean monthly maximum temperatures and relative humidities, it would appear that the risk of damaging periods of high temperatures was somewhat less in this more maritime region. The risk can be expected to increase with distance inland and thus be greater in the areas with lower rainfall.

III. Climatic Factors of Significance to Irrigated Agriculture

Temperature assumes more importance in relation to irrigated agriculture in this region, especially in the more inland areas where temperatures may drop to levels low enough during the winter months to retard growth of some tropical crops or pastures. Length of day, as a separate factor, and in association with temperature, may also have a retarding effect on growth rate of summer-growing species during these months. Conversely the growth of winter-growing crops and pastures may be adversely influenced by the high temperatures and high relative humidities that occur during the summer months.

Rainfall assumes an indirect rather than direct relationship. Features to be considered are the period for which irrigation will be needed, the effect of winter or "out-of-season" rains on irrigation practice, and the effect of excessive falls of rain during the natural rainfall season.

(i) *Period of Irrigation Required.*—The estimated growing periods given for several locations in Table 4 indicate that rainfall should be sufficient for many summer-growing species. For short-season summer species grown near the coast irrigation would be required to supplement rainfall only in occasional years, but would be necessary more frequently further inland. Long-season summer-growing and perennial species would require supplementary irrigation in most years at all locations.

Winter-growing species will depend almost entirely upon irrigation. The occurrence of winter rains is too erratic and is restricted to periods too short for satisfactory growth of these species.

(ii) *Effect of Abnormal Rains.*—Rain is not always an advantage in an irrigation area. Out-of-season rains or excessive falls of rain during the normal growing season may affect cultural and irrigation practices and in some instances cause waterlogging, especially on land that has just been irrigated. In this region falls of 2 in. of rain in one day during the winter period are received approximately once in 10 years, with slightly greater frequency on the coast. Such out-of-season rains, mostly received in June, are not likely to affect irrigation practices to any great extent. However, excessive falls during the normal rainfall season are likely to be more serious. On the average, falls of 7 in. within one week have occurred in coastal areas once each year. Such falls are considered to be sufficient to cause waterlogging and local flooding on land likely to be irrigated. In inland areas the frequency of such falls has been of the order of one in three years.

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PART III. BRIEF OUTLINE OF THE GEOLOGY OF THE TOWNSVILLE-BOWEN REGION

By D. M. Traves*

The Townsville-Bowen Region is situated in the northern portion of the former Tasman Geosyncline, which came into existence in early Palaeozoic time. Lower Palaeozoic rocks do not outcrop in this region and the outcropping Devonian and Permian rocks represent later stages in the history of the geosyncline in which sedimentation ceased at the end of the Permian Period in this region. Except for the alluvia deposited over large areas in the major valleys and along the coastline in Quaternary time, the geology of the region is closely associated with the Tasman Geosyncline.

The oldest rocks outcropping are the Reid Beds of Middle Devonian age, which consist of limestones overlain by sandstones, agglomerates, and tuffs. They occur as small, isolated outcrops in the north-west portion of the region and their relationship to other sediments has not been determined because all outcrops examined were surrounded by alluvia or granite.

The Upper Devonian rocks are largely volcanic and consist mainly of rhyolitic, andesitic, and dacitic lavas, bedded porphyries and porphyrites, agglomerates, and tuffs. These volcanics have been moderately folded, faulted in many places, and intruded by dykes and granites.

Permian rocks occur mainly in the south-west portion of the region, in the Bowen Syncline. The structure plunges to the south-east and is asymmetric with a steep north-eastern limb. The dip of the beds is commonly 5°-10°, but increases to 40° on the north-eastern limb. The Permian rocks have been divided into Lower, Middle, and Upper Bowen Formations. All three formations occur over much larger areas in the central portion of the syncline, south of the region surveyed.

In most places the Lower Bowen Formation overlies granite, but in some places it unconformably overlies Devonian rocks. The Formation consists mainly of andesites, basalts, tuffs, agglomerates, and rhyolites, but interbedded shales, sandstones, and some coal seams occur.

The Middle Bowen Formation has been divided into two units. The lower unit, Collinsville Coal Measures, consists of sandstones, tuffaceous sandstones, shales, conglomerates, and some coal seams. These outcrop in a semicircle to the south and west of Collinsville and are conformable with the Lower Bowen Formation. The upper unit, the Marine Series,

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consists of sandstones laid down conformably on the Collinsville Coal Measures. They also outcrop in a semicircle following the structure of the Bowen Syncline.

The Upper Bowen Formation of freshwater tuffaceous sandstones with some shales and limestones occurs in the central portion of the syncline within the circular outcrop of the Marine Series with which they are conformable.

Granites, granodiorites, and diorites are widespread throughout the region. They probably represent a number of phases of granitic injection extending from the end of the Devonian to Permian time.

The large areas of Quaternary Alluvia along the major rivers and in the coastal plains are described fully in Part IV of this report. The geology of the region has been described in more detail (Traves 1951).*

* Traves, D. M. (1951).—"A geological reconnaissance of the Townsville-Bowen region, northern Queensland". Bur. Min. Res. Geol. Geophys. Rec. 1951/25.

PART IV. OUTLINE OF THE GEOMORPHOLOGY OF THE TOWNSVILLE-BOWEN REGION

By G. A. STEWART,* D. M. TRAVES,† and S. J. PATERSON*

I. GENERAL TOPOGRAPHY

The Townsville-Bowen region can be divided into three broad topographic zones differentiated on a basis of range of relief and altitude.

The coastal zone consists of nearly flat alluvial lowlands with scattered high rugged mountainous residuals — "Mendips" (Plate 1, Fig. 2; Plate 7, Fig. 1). The altitude of the alluvia ranges from sea-level to over 300 ft., with the mountain residuals rising to almost 4000 ft.

The central southern zone consists of maturely dissected rugged hills and mountains and extensive undulating country. The highland country of this zone reaches 3500 ft. above sea-level while the undulating country is at altitudes from 100 to 1000 ft. above sea-level.

The western zone, the dissected country of the Leichhardt and Hervey Ranges, ranges in altitude from 300 to 2000 ft. (Plate 1, Fig. 1).

About half the region is drained by the lower Burdekin River and its tributaries. The remainder of the area is drained by short coastal streams which generally flow in a northerly direction. The lower Burdekin River flows in a northerly direction, but the Bogie, Bowen, and middle Burdekin rivers all flow approximately parallel to the general NNW.-SSE. trend of the coastline. The general linearity of the coast is broken by a number of mountain residuals between which there are gently sloping alluvial plains.

II. GEOMORPHOGENY

The history of the land surface can be traced from the end of the Mesozoic Era. During Cretaceous time the main drainage divide must have been in the vicinity of the present coastal mountains, and at the end of the Cretaceous Period, or the beginning of the Tertiary Period, the present main divide was formed by upbowing movements. The NNW.-SSE. trend of the structures produced by these movements was probably responsible for marked parallelism between present major streams and the coast. The upbowing movements ponded the drainage between the two divides and lacustrine sediments were deposited in lakes. Subsequent drainage of the lakes by headward erosion of coastal streams was

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responsible for the "pocket"-shaped catchments of the major rivers of the eastern Queensland coast.

Following the drainage of the lakes there was a long period of erosion and, by the end of the Miocene Epoch, a laterite-capped peneplain had developed over much of the country to the west of the region. However, the area surveyed was probably not peneplained or lateritized but only eroded to late maturity.

During the Pliocene Epoch there may have been slight regional uplift, followed by entrenchment and mature dissection.

In the late Pliocene or early Pleistocene Epochs warping and flexing movements downwarped the Barrier Reef platform along an axis parallel to the present coast. Coincident with this movement the coastal zone was upwarped as far inland as the Leichhardt Range. These movements were gradual and on the landward side the rejuvenated rivers were able to maintain their courses by active degradation. Thus the present high coastal mountains, which apparently were more resistant peaks of the Cretaceous divide, were re-elevated to some degree.

At the end of the last glacial stage a eustatic submergence betrunked coastal streams and brought about extensive alluviation in the bays and estuaries. In Recent time a slight emergence has resulted in much of this alluvium being raised above deposition level to form broad coastal plains, but rejuvenation of streams was only sufficient for entrenchment of stream beds. At present deposition is confined to the river deltas and the low-lying coastal fringe.

The region as a whole has been eroded to late maturity. Dissection of the Miocene lateritic peneplain has not been complete and there are still some extensive areas of laterite-capped residuals to the west of the region.

III. Land Surface Units

Land surfaces within the region may be divided into four units on the basis of their nature and origin.

(i) *Land Surfaces associated with Palaeozoic Rocks*

(1) Rugged Hilly Country. On the steep slopes of the mountains and hills erosion is actively removing the products of rock weathering to give shallow skeletal soils and bare rock outcrops.

(2) Upland Undulating Country. On the undulating country erosion is moderate, weathered rock material has accumulated *in situ,* and pedological processes have produced mature soils.

(ii) *Land Surfaces associated with the Quaternary Alluvia*

(1) Older Alluvia with mature soils, uplifted beyond depositional level—virtually the only dissection is stream-bed entrenchment.

(*a*) Fine-textured sediments, probably of mixed origin, including flood-plain, old deltaic, littoral, offshore, and possibly lacustrine sediments.

(*b*) Medium- to coarse-textured sediments of the major stream levees.

(*c*) Medium to coarse sediments of the alluvial fan deposits.

(2) Younger Alluvia, mostly less than 50 ft. above sea-level, with immature soils — deposition still active.

(*a*) Delta deposits.

(*b*) Littoral deposits (Plate 7, Fig. 1).

The distribution of the two Land Surface Units associated with the Palaeozoic and granitoid rocks has been determined primarily by the relative resistance of the rock types to weathering and erosion. A second influence has operated in the coastal zone where much of the relief may be due to the late Pliocene or early Pleistocene warping movements. The higher mountain residuals of the coastal zone consist dominantly of granitoid rocks, but extensive undulating areas are also associated with these rock types. The pyroclastics, lavas, and sediments have also some resistant types, which form local areas of steep, rugged relief.

PART V. SOILS OF THE TOWNSVILLE-BOWEN REGION AND THEIR AGRICULTURAL CHARACTERISTICS

By G. A. STEWART*

In order that the soil classifications used might conform to that already developed by G. D. Hubble in the Lower Burdekin Valley, the author spent a period with the C.S.I.R.O. soil survey party operating in that section before commencing the regional survey. So far as possible Hubble's† classification into *soil groups* has been used, but it was necessary to describe some additional soils. These include a range of soils similar to that of the soil group but the constituent soil series could not be defined with the limited field work of the regional survey. Some of the additional soils do not occur in the Lower Burdekin Valley and others include soils that are similar to undescribed soils of Hubble's miscellaneous land types. Hubble has also described a number of miscellaneous soil series in the Lower Burdekin Valley, but these soils were of no significance to the regional survey as they occur in very small areas.

I. CLASSIFICATION OF SOILS

The classification in Table 6 is not a pedological classification into Great Soil Groups, but is an attempt to show some of the relationships of the various soils. The soil groups and their constituent soil series are described by Hubble (loc. cit.) and the additional soils are described in the following section of this report.

Solonized soils occur widely spread throughout the area and apparently the region has been a zone of cyclic salt accession in relatively recent time. As well as solonized soils there is a wide range of soils in which the effects of solonization are not evident, e.g. black earths, red-brown earths, red podsolic soils, and some miscellaneous soils.

II. RELATIONSHIP BETWEEN SOILS AND PARENT MATERIAL

In general there is a marked correlation between soils and parent material, particularly for the residual soils.

The acid granites have given deep sandy soils (Granton, Panwood, and Grendal) or solonized soils with sandy surface (Mulgrave).

Sandstones of the Middle Bowen formation are associated with solonized soils with sandy surface (Mungol) and light- to medium-textured soils with clay subsoil (unnamed leached red soil).

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

† Hubble, G. D., and Thompson, C. H. (1953).—Soil survey and land-use potential of the Lower Burdekin Valley, north Queensland. C.S.I.R.O. Aust. Soils Land Use Ser. No. 10.

Intermediate sedimentary and igneous rocks, i.e. Middle Devonian agglomerate, tuffs, and sandstones, Upper Devonian andesites, trachytes, agglomerates, etc., and granodiorites, have given red-brown earths (Dalrymple), solonized soils of medium texture (Ranly and Dowie), and light- to medium-textured soils with clay subsoils (Yalboota).

TABLE 6

A CLASSIFICATION OF THE SOILS OF THE REGION

	Soil Groups Described by Hubble (loc. cit.)	Additional Soils Described in This Report; Comparable with Soil Groups
I. Immature soils, i.e. soils without well-developed horizons		
(*a*) Soils associated with rocks		
(i) Skeletal soils		
(*b*) Soils associated with recent alluvia (coastal)		
(i) Sand dune soils		Undifferentiated dune sand Yellow-brown dune sand Mottled subsoil dune sand
(ii) Saline alluvial soils		Salt-marsh soil Salt meadow soil Swamp soil Salt plain soil
(iii) Deltaic alluvial soils		Sandy delta soil Medium delta soil Heavy delta soil Hardpan delta soil
II. Mature soils with well-developed horizons		
(*a*) Black earths	Koberinga	
	Wygong	Submature black earth
(*b*) Red-brown earths	Dalrymple	Tandale Submature red-brown earth
(*c*) Solonized soils with tough clay subsoils		
(i) Heavy surface texture	Barratta	
(ii) Medium surface texture	Oakey Zandor Ranly Dowie	
(iii) Sandy surface texture	Mulgrave Yoda	
		Mungol

TABLE 6 (*Continued*)

	Soil Groups Described by Hubble (loc. cit.)	Additional Soils Described in This Report; Comparable with Soil Groups
(*d*) Miscellaneous soils		
(i) Heavy texture	Tolgai	
(ii) Light- to medium-textured soils with clay subsoils	Clare	
	Kelona	
	Lancer	
	Tootra	
	Yalboota	
		Unnamed leached red soil
(iii) Deep sandy soils	Burdekin	
	Hylo	
		Granton
	Panwood	
	Wenlee	
	Grendal	

The more basic igneous rocks and the finer, more calcareous sediments, i.e. Lower Bowen volcanics, Upper Bowen shales, limestones, etc., are associated with black earths (Wygong, submature black earth), red-brown earths (Tandale, submature red-brown earth), and solonized soils of medium texture (Ranly).

The correlation between alluvial parent materials and associated soils is less marked. The coarse to medium alluvial fans have deep sandy soils (Hylo, Wenlee, Burdekin), light- to medium-textured soils with clay subsoils (Lancer, Clare, and Tootra) and some solonized soils (Yoda, Oakey, and Mulgrave).

The coarse- to medium-textured levee alluvia have deep sandy soils (Burdekin), light to medium soils with clay subsoils (Lancer, Clare, Kelona), and no solonized soils.

The fine-textured alluvia mostly have solonized soils of heavy texture (Barratta) and medium texture (Oakey) with small areas of black earths, light- to medium-textured soils with clay subsoils, and deep sandy soils.

III. Description of the Additional Soils

The wide range of skeletal soils on steep slopes has not been described. They are stony and shallow and have no possible agricultural use. Hubble (loc. cit.) included them in miscellaneous land type — "Mountainous Land".

(*a*) *Sand Dune Soils*

These include the soils of Hubble's miscellaneous land type — "Beach Ridge Land".

(i) *Undifferentiated Dune Sand* — on fore dunes and well-drained fixed dunes.

0-6 in.	Grey-brown sand.
6-30 in.	Greyish yellow-brown sand (containing white, dull yellow, yellow-brown, and black grains).
30-72 in. +	Yellow-brown sand, moist (also with distinct grains).

(ii) *Yellow-brown Dune Sand* — on well-drained, older, fixed dunes.

0-6 in.	Light grey-brown sand.
6-18 in.	Light brown sand.
18-40 in.	Yellow-brown sand.
40-72 in. +	Orange or yellowish red sand.

(iii) *Mottled Subsoil Dune Sand* — in poorly drained depressions in fixed dunes and on lower areas adjacent to heavy soils.

0-6 in.	Grey-brown sand.
6-12 in.	Yellowish grey-brown sand.
12-20 in.	Yellow-grey sand.
20-33 in.	Light yellow-grey sand with yellow-brown mottling, moist.
33 in.	Water-table.
33-42 in. +	Light yellow-grey with rusty brown mottling, clayey horizon (varies from clayey sand to sandy clay).

(b) *Saline Alluvial Soils*

The lower-lying, near-coastal portions of the younger alluvia are occupied by a group of heavy-textured soils that have fairly high salt contents. Hubble (loc. cit.) has included similar soils in miscellaneous land type — "Saline Land". The four units described are each associated with particular environmental conditions. The first three units have permanently waterlogged subsoils, which are characteristically steel grey with red, yellow, or rusty mottling.

(i) *Salt-marsh Soil* — on the lowest part of the coastal alluvia, and liable to periodic tidal flooding. The soil is so saline that it supports no vegetation except scattered samphire plants or mangroves along the estuary fringes.

0-2 in.	Brownish grey loam with salt crystals.
2-4 in.	Very dark grey heavy clay, tough, very sticky when wet.
4-15 in.	Steel grey with rusty brown mottling, heavy clay, wet, very sticky.
15 in.	Water-table.
15 in. +	Steel grey with rusty brown, red, or yellow mottling, stratified sediments.

(ii) *Salt Meadow Soil* — on areas slightly above high tide level. However, they are liable to flooding by sea-water diluted with fresh flood-water. The soils are not as saline as the salt-marsh and they carry a vegetation of salt-tolerant species.

0-2 in.	Light grey sandy loam with rusty specks.
2-4 in.	Dark grey heavy clay, tough, very sticky when wet.
4-15 in.	Mottled grey, dark grey, rusty brown, yellow and red heavy clay, tough, sticky when wet.

15-24 in.	Grey with rusty yellow mottling, heavy clay, wet and sticky.
24 in.	Water-table.
24 in. +	Steel grey with rusty mottling, stratified sediments.

(iii) *Swamp Soil* — in depressions subject to prolonged freshwater flooding. As they are leached by this flooding they are less saline than other members of the group.

0-1 in.	Very dark grey organic clay with rusty flecking, moist.
1-8 in.	Very dark grey heavy clay with rusty flecking, moist.
8-14 in.	Dark grey, light yellow-grey, heavy clay with rusty yellow-brown inclusions, wet.
14 in.	Water-table.
14 in. +	Steel grey with brownish yellow, reddish brown, and dark grey inclusions, heavy clay, plastic but not very sticky.

(iv) *Salt Plain Soil* — on gently sloping slight rises associated with the previous soil. The period of flooding is much less and the subsoil is very high in soluble salts, e.g. 1.5 per cent. at 20 in.

0-6 in.	Light grey loam.
6-20 in.	Dark grey heavy clay, tough, sticky when wet.
20-30 in.	Dark yellowish grey heavy clay.
30 in. +	Yellowish grey heavy clay with rusty, dark grey inclusions, may have gypsum.

(c) *Deltaic Alluvial Soils*

Four units are described from the very complex group of soils that occur on deltaic deposits at the mouths of most of the larger streams. They have weakly developed shallow profiles overlying stratified yellow-brown to brownish grey sediments. Hubble (loc. cit.) includes these soils in miscellaneous land type — "Delta Land".

(i) *Sandy Delta Soil* — on higher parts of deltas near the stream.

0-6 in.	Brownish grey fine sand.
6-12 in.	Grey-brown fine sand.
12-33 in.	Greyish brown fine sand.
33-39 in.	Mottled greyish-brown, yellow-brown, yellow-grey-brown clayey fine sand.
39-45 in. +	Mottled as above, fine sand.

(ii) *Medium Delta Soil* — on gentle slopes between the anabranches.

0-6 in.	Dark grey fine sandy loam.
6-16 in.	Dark brownish grey fine sandy loam.
16-27 in.	Yellowish grey-brown fine sandy clay loam to fine sandy clay.
27-45 in. +	Yellow-brown clayey fine sand.

(iii) *Heavy Delta Soil* — in depressions or drainage lines within the two previous soils.

0-9 in.	Dark grey heavy loam.
9-18 in.	Dark grey clay loam.
18-30 in.	Very dark grey medium heavy clay, mellow.
30-45 in. +	Brownish grey sandy medium clay, stratified.

(iv) *Hardpan Delta Soils* — in small saucer-shaped areas in the second unit.

0-6 in.	Brownish grey sandy loam.
6-18 in.	Dark brownish grey with brownish grey mottling medium clay, dry, hard.
18-30 in.	Darkish brownish grey light clay.
30-45 in. +	Mottled grey-brown, brownish grey fine sandy clay, stratified.

(d) Black Earths

(i) *Submature Black Earth.*—These soils are related to the Wygong Family but, because they have some characteristic profile features and their occurrence is characteristic of the Havilah Land System, they are described separately. They occur on moderate to gentle slopes on tuffaceous and calcareous Permian sediments to the south of Collinsville.

0-6 in.	Dark grey, sometimes brownish or yellowish, heavy clay with specks of tuffaceous material.
6-12 in.	Dark grey, sometimes brownish or yellowish, heavy clay with carbonate concretions, speckling increasing.
12-18 in.	Mottled, decomposing tuffaceous material.

(e) Red-brown Earths

(i) *Tandale Soil.*—This is related to the Dalrymple soil, but the subsoil is dark brown rather than red-brown, and the profiles are generally shallower. It is formed on Permian basic volcanics on moderate slopes. It does not occur as large unit areas, but as small areas interspersed with Ranly and Wygong Soil Groups and skeletal soils.

0-1 in.	Grey-brown loam, weakly laminated.
1-6 in.	Darker grey-brown clay loam.
6-16 in.	Dark brown, greyish or reddish in some soils, medium heavy clay.
16-24 in.	Grey-brown, grey, yellow-grey, mottled light clay, mealy.
24-30 in.	Decomposing basaltic rock.

(ii) *Submature Red-brown Earth.*—These soils are common on moderate slopes on the freshwater calcareous and tuffaceous Permian sediments to the south of Collinsville.

0-5 in.	Brownish grey clay loam, weakly laminated with stones on surface.
5-10 in.	Reddish brown medium clay with pockets of surface soil.
10-18 in.	Reddish brown medium clay with fragments of speckled tuffaceous material.
18-21 in. max.	Mostly decomposing tuffaceous material with carbonate concretions.

(f) Solonized Soils

(i) *Mungol Soil.*—These sandy solonized soils occur in the south-east corner of the region on moderate to gentle slopes over sandy Permian sediments. They are related to Mulgrave soil group, but the sandy surface soil is not as leached, the general profile is somewhat deeper, the surface of the subsoil is generally not so markedly domed, and carbonate is not always present. The colours of the subsoils vary but, with the limited field work, it was not possible to subdivide the unit. The major morphological features are:

0-4 in.	Brownish grey sand or loamy sand.
4-11 in.	Light yellowish grey loamy sand.
11-15 in.	Predominantly yellow-grey, with yellowish grey, dark grey, and rusty brown mottling, heavy clay. The upper surface is domed in some profiles.
15-24 in.	Yellow-grey with light yellow-grey and rusty brown mottling, heavy clay.
24-30 in.	Yellow-grey with light yellow-grey and rusty brown mottling, heavy clay, with carbonate concretions, some fragments of weathering rock.
30 in. +	Decomposing sandstone, etc.

Colour of the subsoil in some soils is light grey with rusty brown mottling. In others the lower subsoil is yellow-grey without mottling. Carbonate concretions were present in about 60 per cent. of the profiles examined.

(*g*) *Light- to Medium-textured Soils with Clay Subsoil*

(i) *Unnamed Leached Red Soil.*—This soil occurs as small areas in association with the Mungol soils on gentle slopes overlying arenaceous Permian sediments.

0-4 in.	Grey-brown fine sand.
4-10 in.	Light brown to brown fine sand.
10-20 in.	Red-brown medium clay.
20-26 in.	Red-brown light medium clay, with yellow mottling.
26-33 in. max.	Similar with fragments of decomposing sandstone and shaley sandstone.

Samples taken from two deep subsoils have pH values less than 6 and have low total soluble salts and chlorides (0.02 and 0.01 per cent. respectively). This soil is tentatively classified as a red podsolic.

(*h*) *Deep Sandy Soils*

(i) *Granton Soil.*—These sandy soils are formed on moderate to steep slopes on acid granites. They are shallower than Panwood soils and do not have the subsoil mottling characteristic of the Panwood Family.

0-4 in.	Light brownish grey coarse sand with quartz grit.
4-10 in.	Light grey-brown coarse sand with quartz grit.
10-27 in.	Light reddish brown or light yellowish brown coarse sand with quartz grit.
27-48 in. +	Yellow-brown or yellow-grey coarse sand, slightly clayey, with quartz grit and fragments of decomposing granite including felspars, etc.

IV. Agricultural Characteristics of the Soils

In Table 7 the soils are summarized in terms of topography and parent material, generalized profile description, and major agricultural characteristics. The following agricultural characteristics have been considered and are mentioned where pertinent:

Slope and liability to erosion.

Drainage and liability to flooding.

Nature of surface soil including stoniness.
Nature of subsoils.
Water-holding capacity.
Assessment of degree of leaching and chemical fertility.
Nature of occurrence (large or small unit areas) and associated soils.
Salinity.

In general the soils have low phosphate contents ($<$ 0.04 per cent. P_2O_5) and a phosphate fertilizer would be required for maximum crop production. However, samples taken from soils formed on the Lower Bowen volcanics have high phosphate contents (0.1-0.4 per cent. P_2O_5) and phosphatic fertilizer should not be required on these soils.

TABLE 7

SUMMARY OF SOIL GROUPS AND SOIL UNITS

	Soil	Topography and Parent Material	Generalized Description		Agricultural Characteristics
Sand dune soils	Undifferentiated dune sand	Fore dunes or better-drained fixed dunes	0	Brownish grey sand	Deep, excessively drained sands of low fertility
			3-72+	Brownish yellow-grey (most light yellow-brown) sand with grains of white, black, dull yellow, and yellow-brown minerals	
	Yellow-brown dune sand	Rises of older dunes	0-18	Light grey-brown or light brown sands	Deep, well-drained sands of low fertility
			18-72+	Yellow-brown or reddish yellow sand	
	Mottled subsoil dune sand	Lower parts of depressions of fixed dunes	0-6	Grey-brown sand	Sandy, infertile, subsoil liable to waterlogging
			6-20	Yellow-grey or yellow-grey-brown sand	
			20-42+	Light yellow-grey sand with rusty yellow-brown mottling, waterlogged	
Saline alluvial soils	Salt-marsh soil	Lower coastal areas subject to fairly regular tidal inundation	0-2	Brownish grey loam, fluffy when dry	Too saline for agriculture, liable to saline flooding
			2-4	Very dark grey tough heavy clay	
			4-15	Steel grey heavy clay with rusty mottling, wet, sticky	
			15+	Similar colour, stratified sediments, saturated	
	Salt meadow soil	Slightly more elevated, less flooded	0-2	Light grey sandy loam	Too saline for agriculture, liable to saline flooding
			2-4	Very dark grey heavy clay, tough	
			4-24	Light grey tough heavy clay with rusty mottling	
			24+	Steel grey with rusty mottling, stratified sediments	

TABLE 7 (*Continued*)

	Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
	Swamp soil	Slightly elevated coastal alluvia liable to prolonged freshwater flooding	0-2	Very dark grey organic clay	Heavy-textured, low-lying soil subject to prolonged flooding, occurs in irregular patches
			2-8	Very dark grey heavy clay	
			8-14	Dark grey, light grey rusty mottled heavy clay, wet	
			14+	Steel grey heavy clay with rusty mottling, saturated	
	Salt plain soil	Coastal alluvia subject to shorter freshwater flooding	0-6	Light grey loam	Tough saline subsoil, liable to freshwater flooding, occurs in irregular patches
			6-20	Very dark grey tough heavy clay	
			20-30	Dark yellowish grey tough heavy clay	
			30+	Light grey heavy clay with rusty mottling	
Deltaic alluvial soils	Sandy delta soil	Gently sloping higher portions of the deltaic Younger Alluvia	0-12	Brownish grey fine sand	Well-drained but may be flooded rarely; low water-holding capacity, otherwise suitable for agriculture
			12-33	Greyish brown fine sand	
			33+	Mottled yellow-brown and greyish brown fine sand, may be clayey	
	Medium delta soils	Gently sloping higher portions of the deltaic Younger Alluvia	0-16	Dark grey fine sandy loam	Good agricultural soils, liable to occasional flooding
			16-27	Yellowish grey-brown fine sandy clay loam	
			27+	Yellow-brown clayey fine sand	
	Heavy delta soil	Lower slopes and depressions in the deltaic Younger Alluvia	0-18	Dark grey clay loam	Good agricultural soils, liable to more prolonged flooding
			18-30	Very dark grey medium clay, mellow	
			30+	Brownish grey fine sandy clay stratified	
	Hardpan delta soil	Small, shallow depressions in the gently sloping parts of the deltaic Younger Alluvia	0-6	Brownish grey sandy loam	Liable to occasional flooding
			6-18	Dark brownish grey medium clay, tough	Tough clay subsoil makes these soils less attractive for agriculture
			18-30	Brownish grey, light clay	
			30+	Mottled stratified sediments	

TABLE 7 (*Continued*)

	Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
Black earths	Koberinga soil group	Nearly flat plains on fine sediments of Older Alluvia	0-45	Very dark grey heavy clay, with carbonate concretions, self-mulching at surface	Self-mulching heavy clay, high water-holding capacity, internal drainage only fair, may suffer occasional flooding, appears suitable for agriculture
		Gentle slopes on more	45+	Mottled dark grey, yellow-grey, yellow-brown, heavy clay with carbonate concretions	
	Wygong soil group	basic volcanics, tuffaceous sediments	0-30	Dark grey, sometimes brownish heavy clay, self-mulching at surface, generally some carbonate concretions	Self-mulching heavy clay, sometimes stony, large areas only in southern part of region
			30+	Lighter-coloured, mottled, decomposing rock	
	Submature black earth	Moderate slopes on tuffaceous and volcanic rocks	Shallow	(18 in.) dark grey heavy clay with carbonate concretions, stones, and light flecks of tuffaceous material over decomposing tuffaceous rocks	Irregular small areas on moderate slopes, surface generally stony, not suitable for cultivation
Red-brown earths	Dalrymple soil group	Gentle to moderate slopes on granitoid rocks, Devonian volcanic, and sediments	0-8	Grey-brown loam	Well-drained loamy surface, may be stony, permeable clay subsoil, appears well suited for agriculture, steeper slopes may be liable to erosion if cultivated
			8-24	Red-brown medium heavy clay	
			24-33	Mottled clay, transition	
			33+	Lighter-coloured, mealy, decomposing rock, may be stony	
	Tandale soil	Moderate slopes on basic volcanics	0-6	Grey-brown loam	Well-drained, surface may be stony, loam surface over permeable clay, occurs only in small areas with shallow and solonized soils
			6-16	Dark brown medium heavy clay	
			16-24	Mottled clay, transition	
			24+	Light-coloured, mealy decomposing rock	
	Submature red-brown earth	Moderate slopes on Permian tuffaceous and calcareous sediments	0-5	Brownish grey clay loam with stones	Irregular small areas on moderate slopes, surface generally stony, not suitable for cultivation
			5-10	Reddish brown clay with pockets of surface soil	

Table 7 (*Continued*)

Soil		Topography and Parent Material		Generalized Description	Agricultural Characteristics
			10-18	Reddish brown medium clay with fragments of speckled tuffaceous material	
			18-21	Decomposing tuffaceous material with carbonate concretions	
Solonized soils (i) Heavy	Barratta soil group	Lower portions of the Older Alluvia	0-4	Light grey clay loam to medium clay	Very poorly drained, liable to flooding, may have gilgai, shallow, poorly structured surface over tough clay. Appears unsuitable for agriculture
			4-24	Grey to dark grey heavy clay, tough, sticky when wet	
			24-39	Dark grey, may be yellowish, heavy clay with carbonate concretions	
			39+	Yellow-grey, may be brownish, heavy clay with carbonate concretions	
(ii) Medium	Oakey soil group (including the Zandor soils)	Broad banks or gentle slopes of the Older Alluvia	0-8	Light grey sandy loam or loam	Poor drainage, poor surface structure, and tough subsoil clay will limit agricultural possibilities
			8-20	Dark yellowish grey, may have mottling, heavy clay, tough, sticky when wet	
			20-30	Yellow-grey heavy clay, with some carbonate concretions	
			30+	Yellow-grey or yellow-brown clay, friable, with carbonate concretions	
	Ranly soil group	Gentle slopes on variety of intermediate to basic rocks	0-4	Grey loam, compact	Generally occur in small areas, moderately drained but poor surface structure, tough clay subsoil, and presence of some gilgais will limit their use for agriculture
			4-6	Weakly bleached loam or clay loam	
			6-24	Dark grey heavy clay, tough, sticky when wet, some carbonate concretions	

TABLE 7 (*Continued*)

Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
		24-33	Mottled medium clay with carbonate concretions	
		33+	Lighter-coloured, mealy, decomposing rocks	
Dowie soil group	Gently sloping parts of the Older Alluvia, particularly near edge of residuals, also small areas of residual soils	0-2	Light yellowish grey sandy loam	Occur as very small patches. Very shallow surface over tough clay. Appear unsuitable for agriculture
		2-15	Dark brownish grey or mottled heavy clay with carbonate concretions at 10 in.	
		15+	Light yellow-grey with mottling friable light clay with carbonate concretions	
(iii) Sandy Mulgrave soil group	Very gentle to moderate slopes on granitoid rocks or Older Alluvia	0-4	Grey sand	Leached sand over tough clay subsoil, droughty, probably waterlogged after heavy rain, do not appear suitable for agriculture
		4-15	Bleached sand	
		15-24	Light grey with yellow-brown mottling tough clay, columnar	
		24+	Lighter-coloured clay with carbonate concretions	
Yoda soil group	Flat to slightly depressed areas on Older Alluvia near the base of hills	0-4	Brownish grey sandy loam	Poor surface soil and impeded drainage
		4-9	Bleached sandy loam	Appear unsuited for agriculture
		9-12	Mottled grey, yellow-grey clay, tough	
		12-30	Light yellow-grey clay with black inclusions	
		30+	Lighter colour with carbonate concretions	
Mungol soil	Moderate to gentle slopes on Permian arenaceous sediments	0-4	Brownish grey sand	Surface not as leached as Mulgrave Family, but similar in other agricultural characteristics
		4-11	Weakly bleached sand	
		11-24	Mottled, predominantly light yellow-grey, heavy clay, tough	
		24-30	Similar with carbonate concretions	
		30+	Decomposing sandstone	

TABLE 7 (*Continued*)

	Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
Miscel-laneous soils (i) Heavy-textured	Tolgai soil group	Parts of nearly flat fine sediments of the Older Alluvia	0-36+	Grey to light grey heavy clay with carbonate concretions	Heavy clay throughout, gilgai very strongly developed, covered by dense forest of Burdekin gidgee (*Acacia* sp.). Associated with medium and heavy solonized soils, do not appear suitable for agriculture
(ii) Medium- to light-textured surface, clay subsoil	Clare soil group	Back slope of, or minor depressions in, levees of major streams	0-4	Grey fine sandy loam	Drainage slightly impeded, surface soil compact. Otherwise good agricultural soils, suitable for tobacco
			4-18	Bleached fine sandy loam	
			18-30	Yellow-grey, with yellow-brown and grey-brown mottling, medium clay	
			30+	Browner clay with carbonate concretions	
	Kelona soil group	Well-defined depressions in the levees and poorly drained flats of the levee flood-plain transition	0-4	Brownish grey fine sandy loam	Poorly drained, hard clay subsoil. Unsuitable for tobacco and of low agricultural value
			4-14	Bleached fine sandy loam	
			14-30	Mottled grey, dark grey and yellow-grey clay, hard	
			30+	Dull brown sandy clay with carbonate concretions	
	Lancer soil group	Back slope of levee or on banks of old distributary channels	0-4	Grey fine sandy loam, compact	Well-drained, good agricultural soils, but surface generally compact
			4-18	Bleached sandy loam	
			18-36	Red-brown to yellow-grey-brown medium clay, some yellow mottling	
			36+	Variable colour and texture, no carbonate	
	Tootra soil group	On banks of old distributary channels	0-4	Grey sand	Fair drainage, good agricultural soils, but occur mostly as small areas within poorer soils
			4-12	Bleached sand	
			12-24	Mottled light grey, grey-brown, etc., sandy loam increasing to sandy clay loam	

TABLE 7 (*Continued*)

	Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
			24-36	Red-brown with yellow-grey mottling medium clay	
			36+	Mottled red-brown light yellow-grey clay, no carbonate	
	Yalboota soil group	Gentle to moderate slopes on granitoid rocks, Devonian volcanics, and sediments	0-6	Grey loam or sandy loam	Surface may be stony, associated with Dalrymple soils. Appears suited for agriculture
			6-12	Bleached loam or sandy loam	
			12-24	Mottled yellow-grey and yellow-brown medium heavy clay	
			24	Lighter-coloured, mottled, decomposing rock	
	Unnamed leached red soil	Small areas with Mungol soils on Permian arenaceous rocks	0-4	Grey-brown sand	Well-drained, sandy surface over permeable clay, occur as small scattered areas with Mungol soils, not likely to be developed for agriculture
			4-10	Light brown sand	
			10-20	Red-brown medium clay	
			20-26	Red-brown medium clay with yellow mottling	
			26+	Fragments of decomposing sandstone, etc.	
(iii) Deep sandy soils	Burdekin soil group	Crests and gentle slopes of levees of major streams	0-5	Brownish grey loamy fine sand	Well-drained, good agricultural soils suitable for a wide range of crops, including tobacco
			5-30	Greyish yellow-brown fine sand to loamy sand	
			30-42	Dull yellow-brown clayey fine sand to fine sandy clay loam	
			42+	Dull yellow-brown fine sand	
	Hylo soil group	Generally associated with banks of old stream channels in Older Alluvia	0-4	Light grey-brown coarse sand	Well-drained coarse sand, low water-holding capacity, occur mostly in narrow bands; may be suitable for special crops, e.g. tobacco
			4-12	Light yellow-brown coarse sand	
			12+	Yellow-brown coarse sand, may have some water-worn gravel	

TABLE 7 (*Continued*)

Soil	Topography and Parent Material		Generalized Description	Agricultural Characteristics
Granton soil	Moderate to steep slopes on acid granites	0-4	Light brownish grey coarse sand	Leached very coarse sandy soil on moderate to steep slopes, would be liable to erosion if cultivated, not suitable for agriculture
		4-10	Light grey-brown coarse sand	
		10-27	Light reddish brown coarse sand	
		27+	Yellow-grey coarse sand with grit of quartz and granite fragments	
Panwood soil group	Gentle slopes on acid granites	0-9	Light grey coarse sand	Leached coarse sand of low fertility, subsoil probably waterlogged in wet season. Appears unsuitable for agriculture
		9-18	Very light grey coarse sand	
		18-36	Very light grey coarse sand with yellow or rusty brown mottling	
		36+	Variable—may be gritty, clayey, or hardpan	
Wenlee soil group	In old stream channels or on coarse alluvia fans of the Older Alluvia	0-6	Light grey loamy coarse sand	Leached coarse sand, gravelly subsoil probably waterlogged in wet season, occurs mostly as very narrow linear bands through solonized soils, appears generally unsuitable for agriculture, but some areas may be suitable for tobacco
		6-20	Bleached coarse sand	
		20+	Light yellow-grey with rusty mottling clayey coarse sand, may have gravel and grit increasing with depth	
Grendal soil group	In depressions and on lower seepage slopes over acid granites	0-6	Dark grey organic loamy sand	Leached coarse sand, subsoil waterlogged throughout year, occurs in small patches or narrow, linear bands in other leached sandy soils, not suitable for agriculture
		6-12	Grey loamy sand	
		12-30	Very light yellowish grey coarse sand	
		30-42	Light yellow-grey with rusty mottling coarse sand, moist	
		42+	Light greenish or bluish grey with rusty mottling sandy clay loam, saturated	

PART VI. THE VEGETATION COMMUNITIES OF THE TOWNSVILLE-BOWEN REGION

By R. A. PERRY*

I. INTRODUCTION

The Townsville-Bowen region is small and the climate relatively uniform, the whole region having a short wet season and a long dry season. The climatic variations within the region are mainly variations in total annual rainfall and the length of the wet season. These variations have little effect on the native vegetation communities, which show a much stronger correlation with soil factors. The distribution of the vegetation communities is largely determined by the texture of the soil, the depth of the surface soil, the drainage conditions, and the degree of solonization of the soil.

Most of the area carries a eucalypt open forest vegetation in which the trees and ground flora vary considerably in height, density, and floristic composition according to the habitat. Table 8 shows the main vegetation communities in relation to the topography, drainage, and soils and shows their approximate extent.

Much of the region is grazed by cattle and is subject to periodic burning of the pastures. It was not possible from this brief survey to determine to what extent these have modified the ground flora of the main communities. In some parts the ground flora has been modified by Townsville lucerne (*Stylosanthes sundaica*) which has spread naturally and is introduced in an effort to improve the pastures. It is particularly prominent on some of the lighter-textured soils. For a similar reason Mitchell grass (*Astrebla* spp.) has been planted on some of the heavy soils but has not been successful. Some introduced plants have become bad weeds, e.g. Noogoora burr (*Xanthium pungens*) on heavy soils and the cactus *Harrisia* sp. near Collinsville. The introduced red Natal grass (*Rhynchelytrum repens*) is widely spread throughout many of the open forest communities and frequently is co-dominant with the native perennial species. In some parts of the area most of the tree cover has been killed by ringbarking. Selective cutting of narrow-leaved ironbark (*Eucalyptus drepanophylla*), which is extensively used for fence posts, has altered the composition of the narrow-leaved ironbark–red-barked bloodwood association and in consequence there are many parts of this community that appear to be dominated by red-barked bloodwood.

In a few places where the *Ophiuros*-bluegrass association has been overgrazed the community now consists of a low, dense sward of small herbs.

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TABLE 8

MAIN VEGETATION COMMUNITIES, RELATION TO TOPOGRAPHY, DRAINAGE, AND SOIL FACTORS, AND APPROXIMATE EXTENT

Community	Formation	Topography	Drainage	Soils	Range
Ophiuros–bluegrass association	Grassland	Undulating to flat	Fair to poor, some parts liable to short flooding	Black earths or heavy. solonized soils	Mainly on parts of Older Alluvia not far from coast, also on volcanic soils near Strathmore
Sand couch association	Grassland	Very gently sloping	Very poor, liable to flooding	Saline soils	Near coast
Narrow-leaved ironbark–red-barked blood-wood association	Open forest	Undulating to hilly	Good	Medium-textured soils (Dalrymple-Yalboota groups) and loamy skeletal soils	Extensive
Poplar gum–ghost gum association	Open forest	Undulating to hilly	Good	Medium-textured (Dalrymple and Yalboota groups) and loamy skeletal soils	Small areas
Ghost gum association	Woodland	Undulating to flat	Fair to poor	Shallow phases of Oakey and Mulgrave soil groups —hard clay subsoil 3-8 in. below surface	Scattered throughout region, but mostly on alluvial areas
Narrow-leaved ironbark–ghost gum association	Open forest	Undulating to flat	Fair to poor	Deeper phases of Oakey soil group and Ranly group—hard clay subsoil 8 in. below surface	Scattered throughout region, but mostly on alluvial soils
Poplar gum–grey bloodwood association	Open forest	Gently sloping	Good	Major stream levees (Burdekin, Lancer, Clare, and Kelona soil groups) and old streamlines (Wen-lee, Tootra, and Lancer soil groups)	Along major streams and old streamlines
Grey bloodwood association	Open forest	Undulating	Good surface drainage but subsoil drainage impeded	Sandy soils (Panwood and Wenlee groups)	Scattered patches
Reid River box association	Open forest	Gently undulat-ing to undulating	Fair surface drainage but internal drainage impeded	Ranly and Mungol soil groups and better-drained parts of Oakey soil group	Scattered throughout the lower-rainfall parts

TABLE 8 (*Continued*)

Community	Formation	Topography	Drainage	Soils	Range
Poplar gum association	Woodland	Nearly flat to gently undulating	Poor surface drainage, subsoil drainage impeded	Sandier solonized soils with hard clay subsoil 10-16 in. below surface (Mulgrave and Yoda groups)	Mainly in the north-western parts of the area
Moreton Bay ash-grey bloodwood association	Open forest	Low-lying areas broken by distributaries	Internal drainage of soils generally good but liable to flooding	Delta soils	Burdekin and other deltas
Bowen box association	Woodland	Undulating	Good to fair	Black earth soils (Wygong group) and submature black earth soils	Small areas near Collinsville
Moreton Bay ash association	Open forest	Undulating	Good	Stabilized sand dunes	Near coast
Silver-leaved ironbark association	Woodland	Undulating to hilly	Excessive	Stony and skeletal soils on 'acid" rocks	Scattered throughout hilly country
Softwood association	Forest	Steeply undulating to hilly	Excessive	Stony and skeletal soils	Scattered but mainly in higher-rainfall parts
Brigalow association	Forest	Nearly flat to undulating	Fair	Black earth soils (Wygong group)	Small areas near Collinsville
Burdekin gidgee association	Forest	Gently undulating to nearly flat	Poor	Heavy alluvial soils (Tolgai group)	Mainly in area of Older Alluvia
Lancewood association	Forest	Steeply sloping	Excessive	Skeletal	Between Leichhardt Range and Hidden Valley Station
Bulloak association	Woodland	Gently undulating	Poor	Shallow solonized soils (Mulgrave group)	Scattered throughout region—generally only small patches
Tea-tree association	Forest	Undulating or sloping	Surface drainage good but restricted in subsoil	Deep sandy soils (Grendal and Panwood groups).	Scattered small patches often following seepage lines
Budda association	Woodland	Sloping to nearly flat	Poor	Strongly solonized soils (Dowie group)	Scattered small patches throughout region

The following is a brief description of the vegetation communities of the region. A more complete account will be published separately by R. A. Perry and L. S. Smith.*

II. Description of the Main Communities

(i) Ophiuros-*Bluegrass* (Dichanthium *spp.*) *Association* (Plate 4, Fig. 2).—Most of the heavy clay soils of the region have a grassland vegetation with a few trees of poplar gum (*E. alba*), coolabah (*E. microtheca*), or red-barked bloodwood (*E. dichromophloia*) occurring near the edges and along narrow flats.

This grassland is a complex community with many variants in different parts of the region. The tall grasses *Ophiuros exaltatus* and tassel blue grass (*Dichanthium superciliatum*), both of which grow to 6 ft. high, are usually present and are the true dominants. However, their frequency and distribution vary considerably. In the higher-rainfall sections and the less well-drained parts of the lower-rainfall sections these two species are very prominent in dense stands. In drier habitats their frequency is much less and in many places they may be absent.

Medium-height grasses (about 3 ft. high) such as the blue grasses (*Dichanthium fecundum, D. aristatum, D. sericeum, D. annulatum,* and *Bothriochloa ewartiana*), barley grass (*Panicum decompositum*), and early spring grass (*Eriochloa pseudo-acroticha*) are very common. They may be co-dominant with the taller grasses and in the drier habitats are the dominant species in the community.

There is a lower layer composed mostly of small herbs such as Australian bindweed (*Convolvulus erubescens*), *Aeschynomene americana, Rhyncosia minima,* glycine pea (*Glycine tabacina*), *Spilanthes grandiflora,* spider grass (*Brachyachne convergens*), and *Euphorbia* spp. In small, heavily grazed parts a modified community is developed with these and other small species as the main constituents.

On some alluvial soils near the coast cane grass (*Chionachne cyathopoda*), 6 ft. high, forms dense stands.

Gilgais are a common feature of the heavy soil areas. In the small depressions, which are wetter habitats, there is a characteristic vegetation with brown top (*Eulalia fulva*), sedges (*Cyperus retzii, C. concinnus,* and *Eleocharis philippinensis*), nardoo (*Marsilea* sp.), spike grass (*Elytrophorus spicatus*), delicate love grass (*Eragrostis japonica*), swamp rice grass (*Leersia hexandra*), *Leptochloa* sp., Australian rice (*Oryza australiensis*), Sesbania pea (*Sesbania aculeata*), and the herbs *Ludwigea parviflora, Neptunia gracilis* (and var. *major*), *Ammannia multiflora,* and *Limnophila gratioloides.*

(ii) *Sand Couch* (Sporobolus virginicus) *Association* (*Salt Meadow*).—This community occurs in a narrow strip of land slightly

* "Plant ecology of the Townsville-Bowen region" (in course of preparation).

higher than the salt-marshes near the coast. The dominant grass forms a dense sward 6-12 in. high and has very few plants associated with it. The commonest of the associated plants are salt-water paspalum (*Paspalum vaginatum*) and *Fimbristylis polytrichoides*.

(iii) *Narrow-leaved Ironbark* (E. drepanophylla)–*Red-barked Bloodwood* (E. dichromophloia) *Association* (Plate 2, Fig. 2; Plate 3, Fig. 1).— This is a widespread community in which the dominant trees vary from 30 to 50 ft. in height. It is present on freely drained sites such as skeletal soils on hills and slopes and the medium-textured soils of the Dalrymple and Yalboota groups. Bunch spear-grass (*Heteropogon contortus*), forest blue grass (*Bothriochloa intermedia*), kangaroo grass (*Themeda australis*), *Sehima nervosum*, and the naturalized red Natal grass (*Rhynchelytrum repens*) are the common medium-height grasses, with *Themeda* and *Sehima* more prominent on the hills and slopes.

A number of small herbs and grasses such as white heads (*Enneapogon* spp.), indigo (*Indigofera* spp.), glycine pea (*Glycine tabacina*), *Galactia tenuiflora*, and *Tephrosia juncea* are common in this community.

(iv) *Poplar Gum* (E. alba)–*Ghost Gum* (E. papuana) *Association*.— This community occupies only small areas in similar habitats to the previous community. The ground flora is similar to that of the narrow-leaved ironbark–red-barked bloodwood association.

(v) *Ghost Gum* (E. papuana) *Association*.—This community occurs on strongly solonized soils with a hard clay subsoil 3-8 in. below the surface. It is most prominent on the shallower phases of the Oakey and Mulgrave soils, which are waterlogged for periods during the wet season.

The dominant tree is usually only 30-40 ft. high and is widely spaced. Beefwood (*Grevillea striata*) and narrow-leaved beefwood (*G. parallela*) occur very sparsely as a lower tree layer.

A characteristic of the ground flora is the occurrence of patches of short "kerosene" grass interspersed with patches of taller grasses. Annual *Chloris* spp., fairy grass (*Sporobolus caroli*), *Alloteropsis cimicina*, and the small sedge *Fimbristylis dichotoma* are common in the short grass patches.

In the medium-height grass patches bunch spear grass (*Heteropogon contortus*), forest blue grass (*Bothriochloa intermedia*), golden beard grass (*Chrysopogon fallax*), purple-top chloris (*Chloris barbata*), and feather-top chloris (*C. virgata*) are all common.

(vi) *Narrow-leaved Ironbark* (E. drepanophylla)–*Ghost Gum* (E. papuana) *Association*.—This can be considered as a transition between the narrow-leaved ironbark–red-barked bloodwood association and the ghost gum association, but it occupies sufficient area to warrant description. The community occurs on the better-drained Oakey soils and the Ranly soils, which form fairly similar plant habitats. The dominant trees are usually about 40 ft. high. Beefwood (*Grevillea striata*), a tree of about 20 ft., may be present but is never very common.

Like the ghost gum (*E. papuana*) association, short- and medium-height grass patches are characteristic of the ground flora and the same species are prominent.

(vii) *Poplar Gum* (E. alba)–*Grey Bloodwood* (E. polycarpa) *Association* (Plate 3, Fig. 2).—This community occurs on the major stream levees (Burdekin, Lancer, Clare, and Kelona soils) and old stream-lines (Wenlee, Tootra, and Lancer soils) and on the lighter delta soils.

The two dominants attain a height of 60-70 ft. and are spaced at medium density. Moreton Bay ash (*E. tessellaris*) also occurs in some parts. There is generally a lower tree layer, which is often especially prominent on the Wenlee soils. Cockatoo apple (*Planchonia careya*), pandanus (*Pandanus whitei*), narrow- and broad-leaved tea-trees (*Melaleuca* sp. aff. *minor* and *M. viridiflora*), and quinine berry (*Petalostigma pubescens*) all occur as trees 10-20 ft. high.

The dominant grass, 3-4 ft. high, is bunch spear grass (*Heteropogon contortus*) associated with which are kangaroo grass (*Themeda australis*) and pitted blue grass (*Bothriochloa decipiens* var. *cloncurrensis*). The tall grass, *Coelorhachis rottboellioides*, occurs in the community but only as widely scattered plants. The low shrub *Grewia retusifolia* occurs sparsely.

Small herbs such as glycine pea (*Glycine tabacina*), *Galactia tenuiflora*, and *Moghania lineata* are common.

(viii) *Grey Bloodwood* (E. polycarpa) *Association.*—The deeper, sandier soils of the region (Panwood soils) and some deep, gritty sands (Wenlee soils) support a variable open forest dominated by grey bloodwood (*E. polycarpa*). The height and density of the trees vary considerably but they are usually 30-60 ft. high and medium to densely spaced. Poplar gum (*E. alba*) often occurs in the community and may be co-dominant.

Quinine berry (*Petalostigma pubescens*) and narrow-leaved tea-tree (*Melaleuca* sp. aff. *minor*) are usually fairly common low trees 15-20 ft. high. A number of other low tree species may occur sparsely.

The ground flora is dominated by medium-height grasses of which bunch spear grass (*Heteropogon contortus*) and lemon-scented grass (*Elyonurus citreus*) are the most prominent. Other medium-height grasses that occur constantly (and may become dominant in small areas) are *Eriachne rara, Aristida* spp., *Panicum* spp., and golden beard grass (*Chrysopogon fallax*).

The large number of smaller grasses and herbs is a characteristic of the community. These are far too numerous to list but some of the commonest are *Schizachyrium* spp., *Thaumastochloa pubescens, Perotis rara,* and *Setaria brownii.*

(ix) *Reid River Box* (E. brownii) *Association.*—This community occurs in a similar habitat to the narrow-leaved ironbark–ghost gum association but generally in parts of the region with a lower rainfall. It occurs on Ranly, Mungol, and better-drained Oakey soils. The trees, about 50 ft. high, are usually spaced at medium density, but this varies.

In common with many other communities on these solonized soils, short "kerosene" grass patches are common. These short grass patches contain *Chloris* spp., a sedge (*Fimbristylis dichotoma*), *Eriachne* spp., *Eragrostis* spp., and some golden beard grass (*Chrysopogon fallax*).

The medium-height grass patches contain bunch spear grass (*Heteropogon contortus*), forest blue grass (*Bothriochloa intermedia*), and golden beard grass (*Chrysopogon fallax*).

(x) *Poplar Gum* (E. alba) *Association* (Plate 4, Fig. 1).—On the sandier solonized soils where the clay subsoil is 10-16 in. below the surface (Mulgrave and Yoda soils) poplar gum forms a community in which the trees are fairly widely spaced and about 40 ft. high.

Short grass patches are not as common as on the less sandy of the solonized soils but do occur. In addition to the species usually occurring in these patches, such as *Chloris* spp. and *Fimbristylis dichotoma*, small plants such as *Schizachyrium obliquiberbe* and hare's-foot grass (*Ectrosia leporina*) are common.

The medium-height grass patches contain bunch spear grass (*Heteropogon contortus*), golden beard grass (*Chrysopogon fallax*), cockatoo grass (*Alloteropsis semialata*), and *Aristida browniana*.

(xi) *Moreton Bay Ash* (E. tessellaris)-*Grey Bloodwood* (E. polycarpa) *Association*.—This variable community is characteristic of most of the country in the Burdekin and other deltas. The dominant trees and the silver-leaved tea-tree (*Melaleuca* sp. aff. *minor*) attain a height of 60-80 ft. Smaller trees such as cockatoo apple (*Planchonia careya*) may occur.

The ground layer is generally about 4 ft. high and is dominated by bunch spear grass (*Heteropogon contortus*) with which are associated forest blue grass (*Bothriochloa intermedia*), pitted blue grass (*Bothriochloa decipiens* var. *cloncurrensis*), brown sorghum (*Sorghum nitidum*), and flannel weed (*Sida cordifolia*).

(xii) *Bowen Box Association*.—On a small area of black earth (Wygong soil group) and submature black earth soils near Collinsville there is a community dominated by Bowen box (*Eucalyptus* sp.). The dominant is widely spaced and about 50 ft. high.

There is a fairly dense layer of medium-height grasses of which forest and desert blue grasses (*Bothriochloa intermedia* and *B. ewartiana*), Queensland blue grass (*Dichanthium sericeum*), and *Dichanthium fecundum* are the commonest. Some small grasses and herbs such as *Iseilema vaginiflorum* and *Rhyncosia minima* also occur.

(xiii) *Moreton Bay Ash* (E. tessellaris) *Association*.—A variable community generally dominated by Moreton Bay ash (*E. tessellaris*), but with silver-leaved tea-tree (*Melaleuca* sp. aff. *minor*) dominant in wetter parts, occurs on stabilized sand dunes near the coast. Poplar gum (*E. alba*) may occur in some parts.

A number of low trees (10-20 ft. high) including pandanus (*Pandanus whitei*), cockatoo apple (*Planchonia careya*), red ash (*Alphitonia excelsa*), *Acacia aulacocarpa* var. *macrocarpa,* and narrow-leaved tea-tree (*Melaleuca* sp. aff. *minor*) occur irregularly throughout the community and may form dense stands in some parts.

Crotalaria laburnifolia, a shrub 4-6 ft. high, occurs in some parts.

The medium-height grass storey is not very dense and includes lemon-scented grass (*Elyonurus citreus*), red Natal grass (*Rhynchelytrum repens*), bunch spear grass (*Heteropogon contortus*), and pitted blue grass (*Bothriochloa decipiens* var. *cloncurrensis*).

Smaller grasses and herbs are fairly common, *Perotis rara* and *Setaria brownii* being the most constant.

(xiv) *Silver-leaved Ironbark* (E. shirleyi) *Association.*—On some very stony or skeletal soils on "acid" rocks silver-leaved ironbark (*E. shirleyi*) forms a community of rather regularly, fairly widely spaced trees of 15-20 ft. high. The low trees with rounded crowns give the community the appearance of an orchard.

In some parts spinifex (*Plectrachne pungens*) dominates the lower storey but generally there is a sparse layer of *Sehima nervosum,* bunch spear grass (*Heteropogon contortus*), *Aristida browniana,* and kangaroo grass (*Themeda australis*).

Small grasses such as white heads (*Enneapogon* spp.), *Schizachyrium* spp., and *Tripogon loliiformis* are very common and there are a number of small herbs present.

(xv) *Softwood Communities* (Plate 2, Fig. 1).—These "softwood scrubs" or "monsoon forests" occur in relatively small patches on steep, rocky slopes of hills, on stabilized old sand dunes, in parts of the delta, and in and near watercourses. The total area occupied by the communities is small.

There is a large variation in height, density, and floristic composition, but generally there are several storeys of trees and shrubs, a sparse ground flora, and a number of vines and climbing plants. The communities are usually fairly dense.

(xvi) *Brigalow* (Acacia harpophylla) *Association* (Plate 6, Fig. 2).—Brigalow occurs on heavy clay soils (Wygong soil group) mainly near Strathmore and Collinsville. In some places the community occurs in long, rather narrow patches that probably correspond with certain beds of rock.

The trees grow close together, generally to a height of about 40 ft. A number of lower trees (15 ft.) are sometimes present. *Carissa ovata* and *Plumbago zeylandicum,* small shrubs 3-4 ft. high, are fairly constant, but generally sparse. The ground flora is very variable because of the very marked microtopography of the soil, which is a feature of the brigalow community. Medium-height grasses, which occur mostly on the higher parts of the microtopography, are forest blue grass (*Bothriochloa intermedia*), Queensland blue grass (*Dichanthium sericeum*), *Dichanthium fecundum,* brigalow grass (*Paspalidium caespitosum*), cotton panic grass (*Digitaria brownii*), fairy grass (*Sporobolus caroli*), and *S. scabridus.*

There is a fairly dense layer of small grasses and herbs of which spider grass (*Brachyachne convergens*) is the commonest. A few plants of bull Mitchell grass (*Astrebla squarrosa*) were noticed but were probably introduced.

(xvii) *Burdekin Gidgee* (Acacia *sp.*) *Association* (Plate 6, Fig. 1).—The Burdekin gidgee community has a very similar structure and appearance to the brigalow community described above but is dominated by a different species of *Acacia.* It occurs between Bowen and Ayr on a heavy alluvial soil (Tolgai soil group) with a very pronounced microtopography.

The dominant occurs in dense, pure stands 25-30 ft. high. Shrubs are not common but *Carissa ovata,* which grows 4-6 ft. in height, is usually present in some parts.

The grass layer is not very dense, the commonest plants being cane grass (*Leptochloa* sp.), *Thellungia* sp., panic grass (*Panicum* sp.), brigalow grass (*Paspalidium caespitosa*), and delicate love grass (*Eragrostis japonica*). *Cyperus concinnus* also occurs.

(xviii) *Lancewood* (Acacia shirleyi *vel aff.*) *Association.*—Only one small patch of lancewood was seen. This was on the steep slope to a flat-topped lateritic hill between the Leichhardt Range and Hidden Valley station.

Lancewood occurs in fairly pure, dense stands about 30 ft. high with few smaller trees and shrubs. A complete list of the associated plants was not made but the dominant grasses were *Aristida* spp.

(xix) *Bulloak* (Casuarina leuhmannii) *Association* (Plate 5, Fig. 1).—A very distinctive community dominated by bulloak occurs on patches of shallow solonized soils (Mulgrave group). Bulloak occurs in fairly dense, pure stands 15-25 ft. high generally with no lower trees or shrubs associated with it.

The ground flora varies considerably but generally contains scattered plants of *Aristida browniana,* cockatoo grass (*Alloteropsis semialata*), and golden beard grass (*Chrysopogon fallax*). Lower grasses and herbs that commonly occur are *Chloris scariosa, C. pectinata, Eriachne mucronata, Schizachyrium obliquiberbe,* and *Fimbristylis dichotoma.*

(xx) *Tea-tree* (Melaleuca *sp. aff.* minor) *Association.*—Dense stands of narrow-leaved tea-tree (*Melaleuca* sp. aff. *minor*) and sometimes broad-leaved tea-tree (*M. viridiflora*), about 20 ft. high, occur on Grendal and Panwood soils. These are deep sandy soils with a restricted drainage and are consequently a very wet habitat.

The medium-height grass layer is not very dense but lemon-scented grass (*Elyonurus citreus*) and *Eriachne rara* are present. As with the grey bloodwood community small grasses and herbs are very common and numerous. A few of the commonest of these are hare's-foot grass (*Ectrosia leporina*), *Setaria brownii, Schizachyrium obliquiberbe,* and *Thaumastochloa pubescens.*

(xxi) *Budda* (Eremophila mitchellii) *Association* (Plate 5, Fig. 2).—Budda forms a very distinctive community on strong, solonized soils (Dowie group). The patches are of irregular occurrence and are generally only of small extent. The community is rather dense but the dominant rarely grows higher than 10-15 ft. The shrub *Carissa ovata* may be present but never densely.

The ground cover is never very dense, and bare, scalded areas are a common feature. *Chloris* spp. are characteristic of the community.

Although budda generally forms a well-defined community, a number of transitions between the budda community and the brigalow, Burdekin gidgee, Reid River box, and bulloak communities were noticed.

(xxii) *Fringing Forests.*—These occur along permanent and seasonal watercourses and near lagoons. There are a number of communities within the fringing forests but they have all been grouped for convenience.

The following tall trees may occur: she-oak (*Casuarina cunninghamiana*), paperbarks (*Melaleuca mimosoides* and *M. saligna*), Leichhardt tree (*Nauclea orientalis*), box-barked swamp mahogany (*Tristania grandiflora*), *Eucalyptus raveretiana, E. camaldulensis, E. tereticornis, E. tessellaris,* and pandanus (*Pandanus whitei*).

Reed grass (*Arundinella nepalensis*), river grass (*Chionachne cyathopoda*), and *Vetiveria filipes* are all tall grasses that occur in this community.

(xxiii) *Mangrove Communities.*—Mangroves occur in and near estuaries. The following were noticed: *Avicennia marina* var. *resinifera, Ceriops tagal, Rhizophora mucronata, Bruguiera gymnorrhiza, B. sexangula, Aegiceras corniculatum, Excoecaria agallocha, Osbornia octodonta, Aegialitis annulata, Lumnitzera racemosa,* and *Xylocarpus australasica.*

(xxiv) *Communities of Miscellaneous Habitats.*—There are several communities that occur in such places as salt flats and sand dunes.

(1) Salt-Marsh. This is a rather open community with bare, salty areas occurring frequently. Samphires (*Arthrocnemum leiostachyum, A. holocnemoides* var. *pergranulatum, Salicornia australis*) are the dominant and often almost the only plants present. Other plants that occur are *Suaeda australis, Statice australis, Sesuvium portulacastrum, Cressa australis,* and *Epaltes australis.*

(2) Dunes. The fore dunes have a sparse cover of *Spinifex hirsutus, Ipomoea pes-caprae,* and *Canavalia rosea.* The crests of unstable dunes behind fore dunes carry trees of *Casuarina equisetifolius* with the following associated plants: beach grass, *Thuarea sarmentosa,* bark grass

(*Lepturus repens*), Mossman River grass (*Cenchrus echinatus*), tridax (*Tridax procumbens*), *Romeria maritima,* and *Eragrostis pubescens.*

(3) Lagoons. The commonest water plants growing in the lagoons are blue water-lily (*Nymphaea gigantea*), red water-lily (*Nelumbo nucifera*), water hyacinth (*Eichornia crassipes*), and *Ottelia ovalifolia.* The grass *Pseudoraphis spinescens* grows near the water's edge both in and out of the water. Rice grass (*Leersia hexandra*) may grow into the water. Around the edges of the lagoons, sedges (*Cyperus* spp., *Eleocharis* sp., and *Fuirera* spp.) and rice grass (*Leersia hexandra*) are very common. In some places sedges (*Eleocharis* spp.) are dominant in swamps.

The permanent swamps of the delta areas carry a forest community dominated by silver-leaved tea-tree (*Melaleuca* sp. aff. *minor*) which grows to a height of 70-80 ft. Other trees that may be present are Leichhardt tree (*Nauclea orientalis*) and cabbage palm (*Livistona decipiens*?). The dominant grass in these swamps is rice grass (*Leersia hexandra*).

PART VII. THE LAND SYSTEMS OF THE TOWNSVILLE-BOWEN REGION

By G. A. STEWART* and R. A. PERRY*

I. INTRODUCTION

Although the soil and vegetation units described in the two previous parts of this report are readily recognized in the field they occur in such complex patterns that they could not be mapped over the very large areas without a considerable amount of detailed work. The unit used for describing and mapping the nature of country is the *Land System* as developed by Christian and Stewart (1953).† A Land System is "an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation".

The topography and soils are dependent on the nature of the underlying rocks (i.e. geology), the erosional and depositional processes that have produced the present topography (i.e. geomorphology), and the climate under which these processes have operated. Thus the land system is a scientific classification of country based on topography, soils, and vegetation correlated with geology, geomorphology, and climate.

This region was surveyed in more detail than the previous regions. The greater detail was necessary as one of the objectives of the survey was to assess the possibilities of land utilization under irrigation. The more detailed approach was possible as the area was relatively small and previous investigations had provided considerable data.

The land systems are described in groups associated with each of the four geomorphological Land Surface Units. The characteristics that differentiate the land systems within a land surface unit are summarized in the text and tables.

The description of the land systems and their constituent land units has been condensed and simplified into figures with diagrammatic cross sections (see Figures 1-19). The cross sections are not drawn to scale, but the relative area of each unit is given.

The data given for climate are average figures for different parts of the land system. They indicate the range of conditions within the land system, and not the variation from year to year at a particular locality.

The description of vegetation communities has been simplified by listing together the plant communities and their formation names, e.g.

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

† 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.

the narrow-leaved ironbark–red-barked bloodwood association is an open forest and is referred to as narrow-leaved ironbark–red-barked bloodwood open forest.

II. Land Systems of the Rugged Hilly Country

The regional topography is one of late maturity. There are large areas of steeply sloping hills and ranges where erosion is active and soils are very stony and shallow. The hilly country has all been included in one Land System—the Leichhardt Land System. The vegetation can be grouped into two major communities although there is a diversity of rock types. The Leichhardt Land System is described in Figure 1.

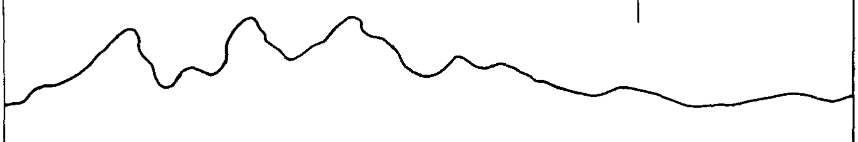
TOPOGRAPHY	Rugged ranges to low hills		Undulating
CROSS SECTION AND RELATIVE AREAS	 Small	Large	Very small
DISTRIBUTION OF UNITS	Generally small patches on steepest slopes and crests	Extensive areas occupying most of land system	Small irregular areas of other land systems which are too small to be mapped separately Kilbogie Land System Strathmore Land System Heidelberg Land System Dalbeg Land System
VEGETATION	Softwood Forest	Narrow-leaved ironbark - red-barked bloodwood Open Forest with small areas of silver-leaved ironbark Woodland	
SOILS	Shallow very stony soils with many rock outcrops		
DRAINAGE	Good to excessive. Intensive pattern of small streamlines		

Fig. 1.—Leichhardt Land System (1,227,000 acres).

Location and General Description.—Rugged ranges and hills which are widespread throughout the region. There are extensive areas in the west and isolated ranges in the east.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Steeply sloping parts of the late mature topography on a wide range of Palaeozoic rocks including Devonian volcanics and sedimentaries, Permian volcanics, and granitoid rocks.

III. Land Systems of the Upland Undulating Country

All of these land systems have undulating topography with mostly mature soils formed by weathering of consolidated rocks. However, a wide range of rock types has given rise to differences in the soils and vegetation. Table 9 shows the land systems and the broad relationship between their soils and vegetation and the underlying rock. The eight land systems are described in Figures 2-9.

IV. Land Systems of the Older Alluvia

The topography is gently undulating to nearly flat and elevations vary from 15 to 300 ft. above sea-level. The nature of the soils and vegetation is related to the nature and origin of the alluvia. It has not

Table 9

Land systems of the undulating upland country showing the relationship of soils and vegetation to underlying rock

	Underlying Rock	Nature of Major Soils	Major Vegetation Community	Land System
More acidic	Most acidic granitoid rocks (acid granites)	Deep sandy soils	Grey bloodwood Open Forest	Dalbeg
		Deep sandy soils (less mature)	Grey bloodwood Open Forest	Heidelberg
	Acidic granitoid rocks	Sandy surface, clay subsoil	Bulloak Woodland *or* ghost gum Woodland *or* poplar gum Woodland	Mookara
	Sandstone	Sandy surface, clay subsoil	Reid River box Open Forest	Macedon
			Reid River box Open Forest *or* narrow-leaved ironbark–red-barked bloodwood Open Forest	Collinsville
More basic	More basic granitoid rocks (granodiorites etc.), volcanics (andesites), and some sediments	Loam surface, clay subsoil	Narrow-leaved ironbark–red-barked bloodwood Open Forest	Kilbogie
	Tuffaceous sediments	Loam or clay surface, clay subsoil	Bowen box Woodland and *Ophiuros*-bluegrass Grassland	Havilah
	Mainly basic volcanics (basic tuffs, agglomerates, andesites, and basalts)	Loam or clay surface, clay subsoil	Narrow-leaved ironbark–red-barked bloodwood Open Forest and *Ophiuros*-bluegrass Grassland	Strathmore

always been possible to define accurately the origin of the alluvia, but Table 10 shows the broad correlations between the alluvia and soils of the various land systems. In general, vegetation communities are closely correlated with the nature of the soils. The land systems are described in Figures 10-16.

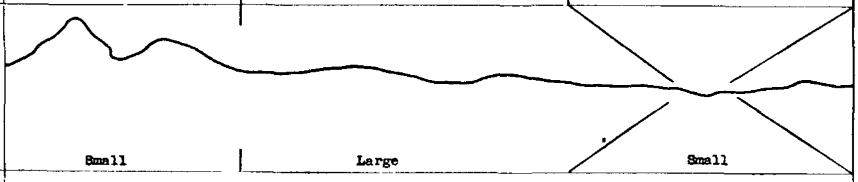
TOPOGRAPHY	Crests or steeper slopes	Undulating to gently undulating	Localized seepage areas mostly at heads of small streams
CROSS SECTION AND RELATIVE AREAS			
	Small	Large	Small
DISTRIBUTION OF UNITS	The undulating country occurs as broad areas with the crests and steeper slopes irregularly distributed through them and with the seepage areas as narrow bands near the heads of streams		
VEGETATION	Narrow-leaved ironbark - red-barked bloodwood Open Forest	Grey bloodwood Open Forest	Teatree Forest
SOILS	Boulders or sandy skeletal soil	Panwood Soil Group - deep, sandy soil, waterlogged in wet season	Grendal Soil Group - deep, sandy waterlogged soil
DRAINAGE	Good surface drainage by small streams with a well-defined dendritic pattern of moderate intensity		

Fig. 2.—Dalbeg Land System (74,000 acres).

Location and General Description.—Forested, gently undulating country with deep sandy soils which occur in many small areas in three localities: near Townsville, west of the Lower Burdekin River, and near Bowen.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Undulating portions of the late mature topography where the most acidic granitoid rocks are exposed.

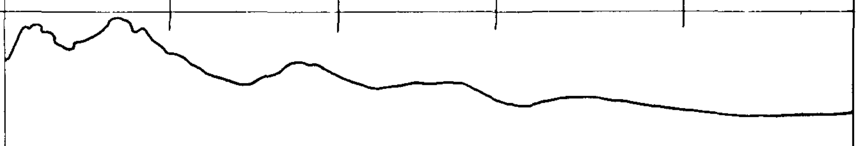
TOPOGRAPHY	Boulder areas on crests of hills	Steep slopes with some boulders	Undulating	Small localized areas in previous unit	Small areas on gentle slopes
CROSS SECTION AND RELATIVE AREAS					
	Small	Small	Large	Small	Small
DISTRIBUTION OF UNITS	The undulating portions occur as extensive areas with irregular small areas of the other units				
VEGETATION	Softwood Forest	Narrow-leaved ironbark - red-barked bloodwood Open Forest	Grey bloodwood Open Forest	Teatree Forest	Narrow-leaved ironbark - red-barked bloodwood Open Forest
SOILS	Rock outcrops	Sandy skeletal soil with some rock outcrops	Granton soil - deep, sandy with moderate internal drainage	Grendal Soil Group - waterlogged sandy soil	Dalrymple and Yalboota Soil Groups - loams with permeable clay subsoil
DRAINAGE	Well drained by small streams with a well-defined dendritic pattern of moderate intensity				

Fig. 3.—Heidelberg Land System (120,000 acres).

Location and General Description.—The two major localities of this undulating or steeply undulating forested country with deep sandy soils are north of Collinsville and near Heidelberg.

Climate.—Wettest locality:—mean annual rainfall 30 in., estimated useful agricultural period exceeds 12 weeks in 75 per cent. of years, 14 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Undulating portions of the late mature topography where the most acidic granitoid rocks are exposed. Rainfall is lower, topography steeper, and the major soils less mature than those of the Dalbeg Land System.

TOPOGRAPHY	Steeper slopes or crests	Undulating to gently undulating	Moderate upper slopes or crests	Gentle slopes
CROSS SECTION AND RELATIVE AREAS	 Small	Large	Only small areas south of Mt. Woodhouse	Small
DISTRIBUTION OF UNITS	Broad areas of undulating country with irregularly distributed patches of the minor units			
VEGETATION	Narrow-leaved ironbark - red-barked bloodwood Open Forest	Bulloak Woodland, poplar gum Woodland ghost gum Woodland or teatree Forest	Teatree Forest	Narrow-leaved ironbark - red-barked bloodwood Open Forest
SOILS	Rock outcrops	Mulgrave Soil Group - sandy surface with tough clay subsoil	Panwood Soil Group - deep, sandy, waterlogged in wet season	Dalrymple and Yalboota Soil Groups - loams with permeable clay subsoil
DRAINAGE	Well-defined small streamlines, dendritic pattern			

Fig. 4.—Mookara Land System (48,000 acres).

Location and General Description.—Several small areas of undulating country with sandy surface soils and variable vegetation which occur near Mt. Dalrymple, Reid River, and Townsville.

Climate.—Wettest locality:—mean annual rainfall 40 in., estimated useful agricultural period exceeds 14 weeks in 75 per cent. of years, 15 weeks in 50 per cent. of years. Corresponding values for driest locality:—30 in., 12 and 14 weeks.

Geology and Geomorphology.—Undulating portions of the late mature topography where acidic granitoid rocks are exposed.

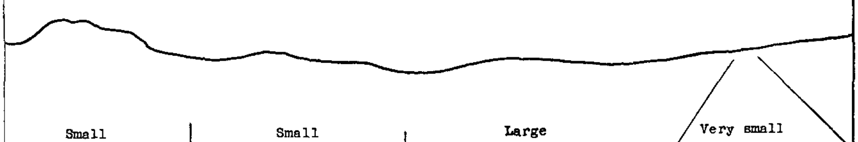
TOPOGRAPHY	Low hills	Undulating to gently undulating		
CROSS SECTION AND RELATIVE AREAS	 Small	Small	Large	Very small
DISTRIBUTION OF UNITS	The minor units occupy small local areas.			
VEGETATION	← Narrow-leaved ironbark - red-barked bloodwood Open Forest →		← Reid River box Open Forest →	Budda Woodland
SOILS	Skeletal	Un-named leached red soils	Mungol soil - sandy surface with clay subsoil	Dowie Soil Group - very shallow sandy loam over very tough clay
DRAINAGE	Areas are too small to show definite drainage patterns			

Fig. 5.—Macedon Land System (43,000 acres).

Location and General Description.—Several small areas in the south-eastern corner of the region, i.e. near Collinsville. Forested undulating country with sandy-surfaced soils.

Climate.—Wettest locality:—mean annual rainfall 28 in., estimated useful agricultural period exceeds 12 weeks in 75 per cent. of years, 14 weeks in 50 per cent. of years. *Corresponding values for driest locality:—25 in., 11 and 13 weeks.*

Geology and Geomorphology.—Undulating portions of the late mature topography where erosion has exposed sediments (principally sandstones) of the Permian marine (Middle Bowen) deposits and similar sediments interbedded with the Lower Bowen volcanics.

TOPOGRAPHY	Low hills and steeper slopes	Undulating
CROSS SECTION AND RELATIVE AREAS	 Large	Large
DISTRIBUTION OF UNITS	The two units occur in an intricate pattern of small irregular areas	
VEGETATION	← Narrow-leaved ironbark - red-barked bloodwood Open Forest →	← Reid River Box Open Forest →
SOILS	Skeletal or shallow sand over rock	Mungol soils - sandy surface soils with tough mottled clay sub-soil
DRAINAGE	Well drained by an irregular pattern of small streams	

Fig. 6.—Collinsville Land System (24,000 acres).

Location and General Description.—A number of small areas near Collinsville. Low hilly or undulating country with forested sandy surface soils.

Climate.—Mean annual rainfall 26 in., estimated useful agricultural period exceeds 11 weeks in 75 per cent. of years, 13 weeks in 50 per cent. of years.

Geology and Geomorphology.—Undulating portions of the late mature topography where rocks of the Permian (Middle Bowen) coal measures are exposed.

TOPOGRAPHY	Low stony rises or steeper slopes	Undulating to gently undulating			Small localized areas in undulating or gently undulating units
CROSS SECTION AND RELATIVE AREAS	 Small	Large	Medium	Very small	Very small
DISTRIBUTION OF UNITS	Predominantly a mixture of the second and third units with localized small areas of other units				
VEGETATION	← Narrow-leaved ironbark - red-barked bloodwood Open Forest →		← Poplar gum - ghost gum Open Forest →	← Bulloak Woodland →	Various Open Forest or Woodland communities or budda Woodland
SOILS	Stony shallow soils	Dalrymple Soil Group - brown loam over permeable red clay	Yalboota Soil Group - sandy loam over yellow clay subsoil	Mulgrave Soil Group sandy surface, tough clay subsoil	Ranly, Dowie and Wygong Soil Groups
DRAINAGE	Well drained by clearly defined pattern of modern intensity				

Fig. 7.—Kilbogie Land System (825,000 acres).

Location and General Description.—Forested undulating country with medium-textured soils, widely spread throughout the region, extending from Townsville to east of Bowen and south beyond the Bowen River.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Undulating portions of the late mature topography where erosion has exposed a wide range of "intermediate" Palaeozoic rocks—Devonian volcanics and sediments, some Lower Bowen volcanics, e.g. andesites, and the more basic rocks of the granitoid complex

TOPOGRAPHY	Undulating	Low crest or steeper slope	Undulating	Gently undulating or lower gentle slope	Nearly flat lower parts
CROSS SECTION AND RELATIVE AREAS					
	Medium	Small	Medium	Medium	Medium
DISTRIBUTION OF UNITS	Complex pattern of mixed small areas		Narrow bands restricted to certain rock beds with some small irregular areas	Mostly in complex pattern with previous 3 units	Mainly in large separate areas
VEGETATION	Narrow-leaved ironbark - red-barked bloodwood Open Forest		Brigalow Forest	Bowen box Woodland with small areas of Ophiuros-bluegrass Grassland	Ophiuros-bluegrass Grassland with patches of brigalow Forest
SOILS	Submature red-brown earth	Shallow stony soils	Wygong Soil Group or Submature black earth soil with irregular surface	Wygong Soil Group or Submature black earth -dark grey clay soils	Koberinga Soil Group - dark grey clay soils
DRAINAGE	Well drained by an irregular pattern of small streams				

Fig. 8.—Havilah Land System (28,000 acres).

Location and General Description.—A single area of undulating country near the south-eastern corner of the region. It has a complex mixture of calcareous soils carrying a range of vegetation communities.

Climate.—Mean annual rainfall 26 in., estimated useful agricultural period exceeds 11 weeks in 75 per cent. of years, 13 weeks in 50 per cent. of years.

Geology and Geomorphology.—Undulating portions of the late mature topography where Permian (Upper Bowen) freshwater sediments (sandstones, tuffs, shales, etc.) are exposed.

TOPOGRAPHY	Low stony hills	Undulating	Gently undulating or gentle lower slopes	Gently undulating	Lower gentle slopes	Nearly flat near streams
CROSS SECTION AND RELATIVE AREAS						
	Medium	Medium	Medium	Small	Medium	Small
DISTRIBUTION OF UNITS	Complex, intermixed pattern of well-defined units					
VEGETATION	Narrow-leaved ironbark - red-barked bloodwood Open Forest		Narrow-leaved ironbark - ghost gum Open Forest or Reid River box Open Forest	Ophiuros - bluegrass Grassland, some trees		
SOILS	Shallow, stony soils	Tandale soil - brown loam over dark brown clay	Ranly Soil Group - loam over tough clay subsoil	Brown members of Wygong Soil Group	Wygong Soil Group - dark grey clay soils	Koberinga Soil Group - dark grey clay soils
DRAINAGE	Widely spaced dendritic drainage pattern					

Fig. 9.—Strathmore Land System (256,000 acres).

Location and General Description.—Undulating country with a range of soils and vegetation communities. The major area is centred on Strathmore but there are some very small areas in the eastern, near-coastal areas.

Climate.—Wettest locality:—mean annual rainfall 28 in., estimated useful agricultural period exceeds 12 weeks in 75 per cent. of years, 14 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Undulating portions of the late mature topography where basic igneous rocks are exposed, e.g. the Permian (Lower Bowen) volcanics. The main rock types are basic tuffs, agglomerates, and basalts.

TOPOGRAPHY	Nearly flat	Very slight rises	Nearly flat
CROSS SECTION AND RELATIVE AREAS	Large	Very small	Very small
DISTRIBUTION OF UNITS	Relatively large areas of the first unit traversed by linear bands of the second and third units		
VEGETATION	Ophiuros - bluegrass Grassland	Ghost gum Woodland	Ophiuros - bluegrass Grassland
SOILS	Koberinga Soil Group - dark grey heavy clay	Oakey Soil Group - sandy loam surface, very tough clay subsoil	Barratta Soil Group - very shallow clay loam surface over tough clay, gilgais common
DRAINAGE	Traversed and drained by widely spaced streams which rise in other land systems. Occasional flooding		

Fig. 10.—Kyburra Land System (42,000 acres).

Location and General Description.—These nearly flat black-soil grasslands occur in one major area south of Home Hill and several smaller ones to the south along the Burdekin River and east along the coast.

Climate.—Wettest locality:—mean annual rainfall 38 in., estimated useful agricultural period exceeds 14 weeks in 75 per cent. of years, 15 weeks in 50 per cent. of years. Corresponding values for driest locality:—25 in., 11 and 13 weeks.

Geology and Geomorphology.—Fine-textured deposits of the Older Alluvia — littoral, offshore, or lacustrine sediments.

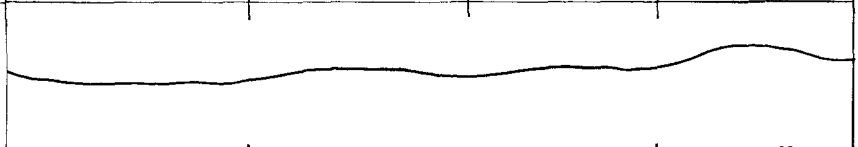
TOPOGRAPHY	Nearly flat	Nearly flat	Broad shallow depressions	Nearly flat
CROSS SECTION AND RELATIVE AREAS	Large	Large	Small	Very small
DISTRIBUTION OF UNITS	Simple pattern with large occurrences of each unit except the fourth, which occurs as small patches only			
VEGETATION	Burdekin gidgee Forest	Narrow-leaved ironbark - ghost gum Open Forest or ghost gum Woodland	Ophiuros - bluegrass Grassland with scattered trees of poplar gum	Budda Woodland
SOILS	Tolgai Soil Group - grey, calcareous clay with gilgai	Oakey Soil Group - sandy loam surface over tough clay subsoil	Barratta Soil Group - shallow clay loam with tough clay subsoil, gilgais common	Dowie Soil Group - shallow, sandy loam over tough clay subsoil
DRAINAGE	Small, poorly defined and widely spaced streamlines which receive drainage from the broad shallow depressions. Occasional flooding			

Fig. 11.—Woontonvale Land System (84,000 acres).

Location and General Description.—Nearly flat forested plains, with areas of dense Burdekin gidgee, near Guthalungra and on the lower Bogie River.

Climate.—Wettest locality:—mean annual rainfall 38 in., estimated useful agricultural period exceeds 14 weeks in 75 per cent. of years, 15 weeks in 50 per cent. of years. Corresponding values for driest locality:—28 in., 12 and 14 weeks.

Geology and Geomorphology.—Fine-textured deposits of the Older Alluvia — littoral, offshore, or lacustrine sediments.



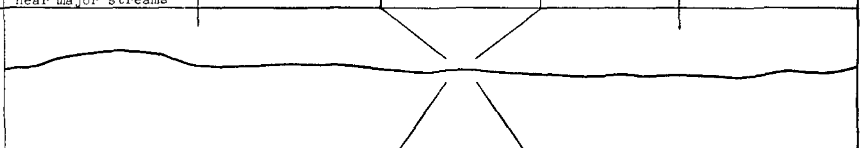
TOPOGRAPHY	Broad flats or linear depressions	Very gently sloping low rises	Small patches on very low rises	Small linear rises - old stream lines
CROSS SECTION AND RELATIVE AREAS	Medium	Medium	Very small	Very small
DISTRIBUTION OF UNITS	The proportion of first and second units vary greatly in different areas. The third unit occurs in small local areas and the fourth unit in long narrow bands			
VEGETATION	Ophiuros - bluegrass Grassland with scattered trees of poplar gum in some parts	Ghost gum Woodland or narrow-leaved ironbark - ghost gum Open Forest	Budda Woodland	Poplar gum - grey bloodwood Open Forest
SOILS	Barratta Soil Group - very shallow clay loam over tough clay, gilgais common	Oakey Soil Group - sandy loam surface, tough clay subsoil .	Dowie Soil Group - shallow sandy loam over tough clay	Soils of the Lancer, Tootra or Wenlee Soil Groups
DRAINAGE	Broadly spaced, irregularly patterned, small streams receive drainage from the depressions of the first unit. Drainage is slow and lower parts are liable to flooding			

Fig. 12.—Northcote Land System (376,000 acres).

Location and General Description.—Nearly flat forested plains extending from Townsville south-east to the Burdekin River with smaller areas along the Burdekin Valley.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—27 in., 12 and 14 weeks.

Geology and Geomorphology.—Fine-textured Older Alluvia — flood-plain and littoral deposits with some old streamlines.



TOPOGRAPHY	Lower linear rises or gentle levee slopes near major streams	Gentle slope	Small patches on gentle slopes	Lower gentle slopes or flats	Linear depressions
CROSS SECTION AND RELATIVE AREAS	Small	Large	Very small	Medium	Very small
DISTRIBUTION OF UNITS	The units occur in a complex pattern in which the gentle slopes and flats are broken by streamlines, linear low rises of old streamlines, linear depressions and irregular patches of Dowie Soil Group				Only in the Don River area
VEGETATION	Poplar gum - grey bloodwood Open Forest	Narrow-leaved ironbark - ghost gum Open Forest or ghost gum Woodland	Budda Woodland	Ophiuros - bluegrass Grassland with scattered poplar gum in some parts	Ophiuros - bluegrass Grassland with coolabah trees
SOILS	Soils of Wenlee, Lancer and Tootra Soil Groups	Oakey Soil Group - sandy loam over tough clay	Dowie Soil Group - shallow sandy loam over tough clay	Barratta Soil Group - shallow clay loam over tough clay, gilgais common	Dark grey heavy clay soils
DRAINAGE	Drained by an irregular pattern of linear depressions and small creek lines. Low-lying parts liable to occasional flooding				

Fig. 13.—Rocky Ponds Land System (138,000 acres).

Location and General Description.—Gently undulating forested plains near the Don River, in the vicinity of Gumlu, north of Mt. Woodhouse, and to the west of Townsville.

Climate.—Wettest locality:—annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—32 in., 12 and 14 weeks.

Geology and Geomorphology.—Fine-textured Older Alluvia — old deltaic deposits with many old streamlines.

TOPOGRAPHY	Nearly flat	Linear slight rises	Nearly flat	Gentle slopes adjacent to small creeks
CROSS SECTION AND RELATIVE AREAS	Large	Very small	Small	Small
DISTRIBUTION OF UNITS	Wenley soils occur as linear bands on the old streamlines while the truncated Mulgrave soils are adjacent to small dissecting creeks			
VEGETATION	Poplar gum Woodland or Reid River box Open Forest	Teatree Forest or grey bloodwood Open Forest	Bulloak Woodland	Bulloak Woodland
SOILS	Yoda Soil Group - sandy surface over tough clay	Wenlee Soil Group - sandy soils with gritty or gravelly subsoil	Mulgrave Soil Group - sandy surface over tough clay	Truncated soils of Mulgrave Soil Group
DRAINAGE	Well-defined drainage lines in an irregular pattern			

Fig. 14.—Manton Land System (67,000 acres).

Location and General Description.—These small areas of nearly flat, forested plains with sandy surface soils are found from Townsville to beyond Mt. Dalrymple and on two small areas south of Abbott's Bay.

Climate.—Wettest locality: mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality: 28 in., 12 and 14 weeks.

Geology and Geomorphology.—Medium- to fine-textured Older Alluvia — flood-plain deposits near the base of hills, some old streamlines.

TOPOGRAPHY	River	Crest and gentle slope of levee	Gentle slope	Nearly flat or slight depression	Gently sloping low rise	Deep depressions in levee or levee - flood-plain transition
CROSS SECTION AND RELATIVE AREAS		Medium	Medium	Medium		Medium
DISTRIBUTION OF UNITS	The units tend to occur in linear bands parallel to the river bank					
VEGETATION	Fringing community	Poplar gum - grey bloodwood Open Forest				
SOILS		Burdekin Soil Group - brown deep sands	Lancer Soil Group - sandy loam over yellow-brown or red clay	Clare Soil Group - sandy loam or loam over mottled clay	Lancer Soil Group - sandy loam over yellow-brown or red clay	Kelora Soil Group - sandy loam or loam over mottled hard clay
DRAINAGE	Occasional depression lines, no drainage system but generally well drained by the adjacent streams. Lower parts liable to flooding. Some sections are deeply dissected					

Fig. 15.—Clare Land System (87,000 acres).

Location and General Description.—Forested, gently sloping levee country fringing the major rivers.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality: 25 in., 11 and 13 weeks.

Geology and Geomorphology.—Bands of levee sediments of the Older Alluvia adjacent to the major streams.

TOPOGRAPHY	The general topography is gently sloping with a complex pattern of irregular linear rises and depressions with many small streamlines
CROSS SECTION AND RELATIVE AREAS	Too complex to be illustrated by diagrammatic cross section
DISTRIBUTION OF UNITS	Very complex pattern of topographic and soil units, but the vegetation is fairly uniform throughout
VEGETATION	Generally poplar gum - grey bloodwood Open Forest with poplar gum Woodland on Yoda and Oakey soils
SOILS	Very complex pattern dominated by coarse sandy soils (Hylo and Wenlee Soil Groups) but with small areas of good agricultural soils (Burdekin, Lancer, Clare, and Tootra Soil Groups) and some solonized soils (Mulgrave, Yoda, and Oakey Soil Groups)
DRAINAGE	Drained by many small streams flowing through the land system from neighbouring land systems

Fig. 16.—Milleroo Land System (130,000 acres).

Location and General Description.—Numerous small areas of gently sloping forest country with sandy soils occur irregularly at the foot of the lower slopes of the Leichhardt and Hervey Ranges, Mt. Elliot, and Mt. Aberdeen.

Climate.—Wettest locality: mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality: 27 in., 12 and 14 weeks.

Geology and Geomorphology.—Coarser-textured fans of the Older Alluvia deposited near the mountain scarps.

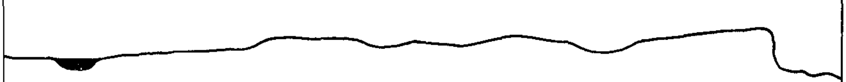
TOPOGRAPHY	Lagoon	Lower slope near lagoons or stream lines	Gently sloping high country	Small shallow depressions in previous unit	Lower depressions of drain lines	Gently sloping high country	River
CROSS SECTION AND RELATIVE AREAS							
	Very small	Small	Large	Small	Medium	Large	
DISTRIBUTION OF UNITS	Very intricate pattern, tending to be in linear band parallel to stream channels						
VEGETATION	Waterplants	Silver-leaved teatree Forest	Moreton Bay ash - grey bloodwood Open Forest	Beefwood	Fringing Forest	Moreton Bay ash-grey bloodwood Open Forest or softwood Forest	Fringing Forest
SOILS		Heavy delta soil with mottled subsoil	Medium delta soil	Hardpan delta soil	Heavy delta soil	Sandy delta soil	
DRAINAGE	Liable to flooding	Cut by the anabranches of the deltaic stream pattern					

Fig. 17.—Ayr Land System (169,000 acres).

Location and General Description.—The major occurrence of this delta country is in the Burdekin Delta near Ayr and Home Hill. Smaller areas of similar country occur on the Houghton River at Giru, the Don River at Bowen, and in a number of smaller isolated areas.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—33 in., 12 and 15 weeks.

Geology and Geomorphology.—Deltaic deposits of variable texture of the Younger Alluvia.

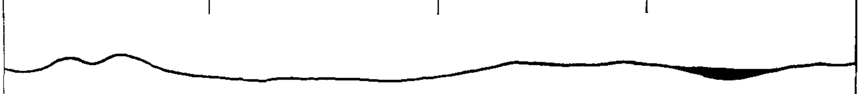
TOPOGRAPHY	Low rises - long and narrow	Broad, irregular, swampy depressions	Gently sloping plain	Shallow lagoons
CROSS SECTION AND RELATIVE AREAS	 Small	Medium	Medium	Small
DISTRIBUTION OF UNITS	Rather complex pattern of plains and depressions with scattered areas of the small units			
VEGETATION	Moreton Bay ash Open Forest	Sedges	Sand couch Grassland with bunch spear grass	Waterplants
SOILS	Yellow-brown dune sand	Swamp soils - wet heavy clays	Salt plain soils - loam over tough clay subsoil	---
DRAINAGE	No defined stream lines, but drained by broad irregular depressions			

Fig. 18.—Bowling Green Land System (38,000 acres).

Location and General Description.—Nearly flat swampy plains which occur in three localities — north of Ayr, near Giru, and west of Townsville.

Climate.—Wettest locality:—mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—42 in., 14 and 16 weeks.

Geology and Geomorphology.—Parts of the littoral deposits of the Younger Alluvia where the saline influence has been partly removed by freshwater flooding.

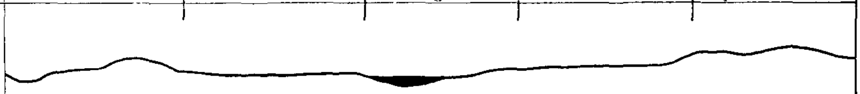
TOPOGRAPHY	Undulating foredunes	Low lying flats, liable to periodic tidal flooding	Flats fringing estuaries, liable to regular tidal flooding	Flats liable to occasional saline flooding	Undulating stabilised dunes with narrow linear depressions
CROSS SECTION AND RELATIVE AREAS	 Very small	Medium	Small	Large	Small
DISTRIBUTION OF UNITS	The dunes and saline flats occur as distinct areas within which there are complex patterns of the various units				
VEGETATION	Ipomoea - Spinifex community	Bare or scattered samphire plants	Mangrove communities	Sand couch Grassland	Softwood Forest or Moreton Bay ash Open Forest
SOILS	Undifferentiated dune sand	Salt marsh soil - highly saline clays	Salt marsh soil - highly saline clays	Salt meadow soil - shallow sandy loam surface, tough clay subsoil	Undifferentiated dune sand, some Mottled subsoil dune sand
DRAINAGE	No well-defined drainage pattern, but cut by many estuaries and salt stringers				

Fig. 19.—Littoral Land System (250,000 acres).

Location and General Description.—Salt flats and sand dunes in an irregular narrow strip along the coast.

Climate.—Wettest locality: mean annual rainfall 47 in., estimated useful agricultural period exceeds 16 weeks in 75 per cent. of years, 17 weeks in 50 per cent. of years. Corresponding values for driest locality:—35 in., 13 and 15 weeks.

Geology and Geomorphology.—Littoral deposits of the Younger Alluvia adjacent to the coast. The low-lying parts are markedly saline owing to the tidal influence.

V. Land Systems of the Younger Alluvia

This land surface unit is liable to flooding, and deposition is still active. The soils are immature and the vegetation is very variable.

Ayr Land System consists of deltaic deposits, which are cut by many anabranches. In general they are not saline. Flooding is by fresh water and is less severe and of shorter duration than in Bowling Green Land System.

Table 10

LAND SYSTEMS OF THE OLDER ALLUVIA AND THEIR SOILS AND VEGETATION IN RELATION TO THE NATURE AND ORIGIN OF THE ALLUVIA

Origin of Alluvia	Approximate Proportions of Various Soils*	Land System
Fine-textured alluvia with no old streamlines—offshore, littoral, or lacustrine deposits	4/5 H_1 1/5 M	Kyburra
Fine-textured alluvia with no old streamlines—offshore, littoral, or lacustrine deposits	3/5 H_2 2/5 M	Woontonvale
Fine-textured alluvia of the flood plain and littoral deposits with some old streamlines	1/2 H_3 0.3 M 1/5 L or DS	Northcote
Fine-textured alluvia of the old deltaic deposits with many old streamlines	0.3 H_3 1/2 M 1/5 L or DS	Rocky Ponds
Medium- to fine-textured alluvia of the flood plains, near the base of hills, some old streamlines	4/5 SS 1/5 DS	Manton
Medium- to coarse-textured levee alluvia of major streams, coarser sediments near stream	3/5 L 2/5 DS	Clare
Medium to coarse sediments of the alluvial fans deposited where streams emerge from hill country into their plain tracts	Mostly L and DS minor areas of SS and M	Milleroo

* H_1 = Heavy soil—Koberinga soil group—*Ophiuros*-bluegrass Grassland.

H_2 = Heavy soil—Tolgai soil group—Burdekin gidgee Forest.

H_3 = Heavy soil—Barratta soil group—*Ophiuros*-bluegrass Grassland and very scattered poplar gum.

M = Medium-textured soils—Oakey and Dowie soil groups—Ghost gum or poplar gum Woodland or narrow-leaved ironbark–ghost gum Open Forest and budda Woodland.

SS = Sandy-surface solonized soils—Mulgrave and Yoda soil groups—poplar gum Woodland or Reid River box Open Forest or bulloak Woodland.

L = Lighter-textured alluvial soils—Clare, Lancer, Kelona soil groups—poplar gum–grey bloodwood Open Forest.

DS = Deep sandy alluvial soils—Burdekin, Wenlee, Hylo soil group—poplar gum–grey bloodwood Open Forest.

Bowling Green Land System is part of the littoral deposits where the saline influence has been partly lost by drainage and leaching. Present flooding is largely by fresh water.

Littoral Land System consists of near-coastal littoral deposits which, except for the sand dunes, are liable to saline flooding. The lowest parts are flooded by high tides and the slightly elevated areas are flooded by saline water when the high tides are diluted with flood waters.

These land systems are described in Figures 17-19.

PART VIII. LAND-USE GROUPS OF THE TOWNSVILLE-BOWEN REGION AND THEIR POTENTIALITIES

By C. S. CHRISTIAN* and G. A. STEWART*

The methods adopted by the Land Research and Regional Survey Section for defining land-use potentialities of a region include a comprehensive description of its inherent land characteristics and the subdivision of the region according to differences in these characteristics and hence in land-use potentialities.

I. LAND-USE GROUPS

The Townsville-Bowen Region has been subdivided by this survey into 19 land systems, which are described in Part VII of this report. As some land systems are similar in some land-use characteristics, it has been possible to group them into seven land-use groups. This grouping facilitates the discussion of present land use and the assessment of broad regional potentialities.

The distribution of the land-use groups is indicated in the Land-use Group map, which accompanies this report. Areas of the groups and individual land systems are shown in Table 11. The areas for the Lower Burdekin Valley refer to that portion of the region enclosed within the heavy dashed line shown on the map.

II. PRESENT LAND USE

The main features of present land use are indicated in Figure 20. The most widespread form of land use is beef-cattle breeding and fattening. Agriculture is confined almost entirely to intensive farming under irrigation on the better alluvial soils near the coast. Dairying is restricted to production of milk for local consumption.

(a) *Beef-cattle Industry*

The beef-cattle industry is based on grazing of natural pastures. The pastures of the region may be broadly classified as follows:

(1) Pastures dominated by *Themeda australis* and *Sehima nervosum* on stony hillsides occupy about 20 per cent. of the region. These are relatively poor pastures with a short growing season.

(2) Pastures dominated by *Heteropogon contortus* (bunch spear) and *Bothriochloa intermedia* (forest blue) on moderately and well-drained soils of medium texture. These pastures, which cover about half of the region, are of moderate value but vary according to location and soil. They are most valuable on the undulating country with well-drained soils.

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(3) Sparse pastures dominated by various short annual species or poorer perennials on sandy-surfaced soils. These pastures, which cover 10 per cent. of the region, have a very low carrying capacity in their native state.

(4) Pastures dominated by *Ophiuros exaltatus* (locally called cane grass) or species of *Dichanthium* and *Bothriochloa* (blue grass), or all three, on heavy soils occur over about 10 per cent. of the region. These vary considerably. In the higher-rainfall zones or in poorly drained places the perennials are dense and 4-6 ft. high, and the pastures are

TABLE 11

AREAS OF LAND-USE GROUPS AND LAND SYSTEMS

Land-use Group	Area: Lower Burdekin Valley (1000 ac.)	Area: Whole Region (1000 ac.)	Land Systems	Area: Lower Burdekin Valley (1000 ac.)	Area: Whole Region (1000 ac.)
1. Levee group	87	217	Clare	52	87
			Milleroo	35	130
2. Delta group	141	169	Ayr	141	169
3. Sandy group	71	376	Macedon	—	43
			Collinsville	—	24
			Heidelberg	7	120
			Dalbeg	28	74
			Mookara	3	48
			Manton	33	67
4. Flood plain group	286	640	Northcote	220	376
			Woontonvale	15	84
			Kyburra	20	42
			Rocky Ponds	31	138
5. Better uplands group	272	1109	Strathmore	22	256
			Kilbogie	250	825
6. Hilly country group	138	1227	Havilah	—	28
			Leichhardt	138	1227
7. Saline lands group	142	288	Bowling Green	30	38
			Littoral	112	250

rank and of moderate value only. In better-drained locations or in the lower-rainfall sections the perennial species are shorter and less dense, and the pastures have a higher dry season value. Also there is a greater variety and proportion of more nutritious annual species which tend to increase in frequency where the pastures are heavily grazed. These pastures are particularly valuable on the residual soils formed from volcanic rocks.

(5) Pastures dominated by *Sporobolus virginicus* or *Xerochloa barbata* on the saline coastal lowlands occupying 5-10 per cent. of the region. These pastures are of relatively high value, especially for dry-season grazing.

Apart from minor native pasture communities such as those of lagoons and swamps, sand dunes, and dense forests, there are also many areas

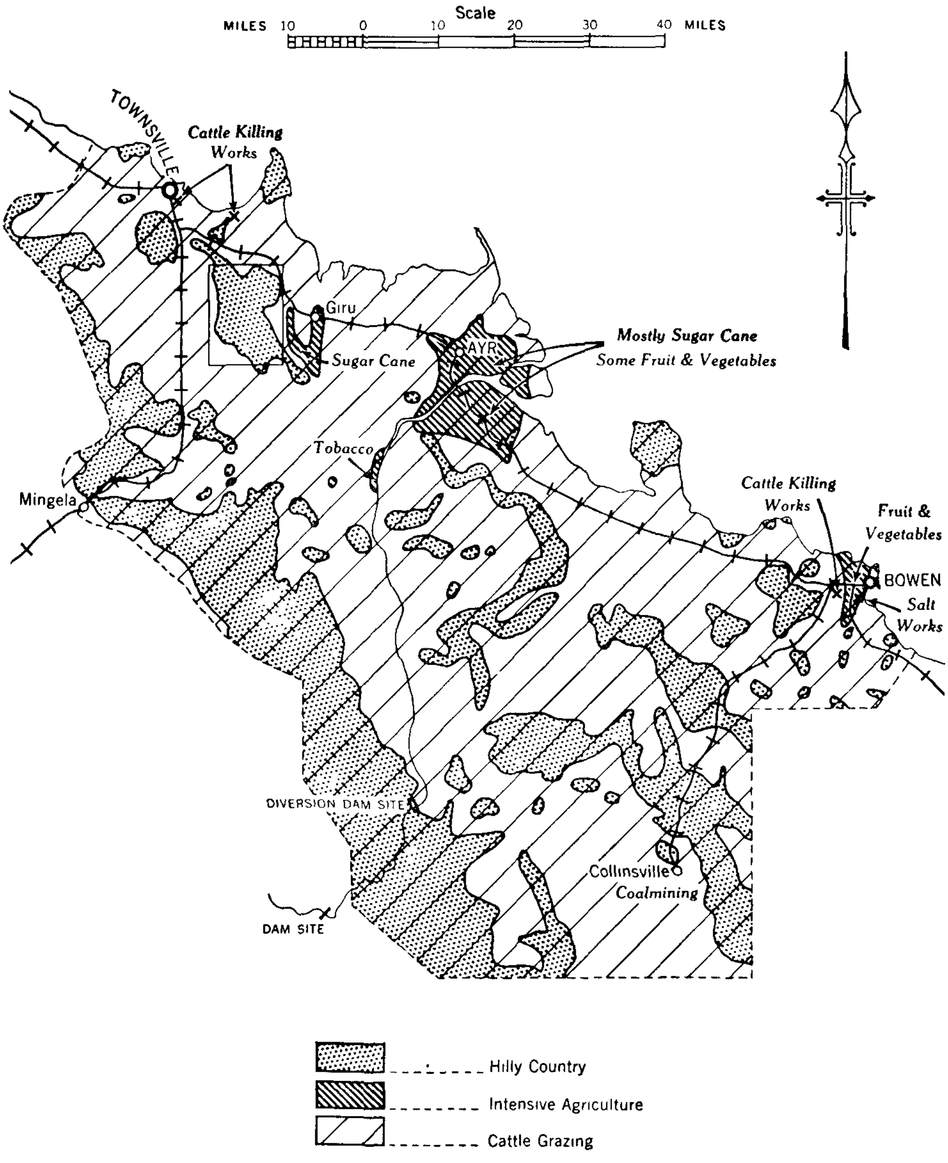

Fig. 20.—Sketch map of Townsville-Bowen region showing major forms of present land use.

occupied by mixtures or intergrading communities of the main pastures described above.

The rate of stocking varies considerably and, excluding the most rugged country, ranges from 1 beast to 15 acres to 1 to 40 acres.

In general, properties are not highly improved. The main forms of property improvement are the construction of buildings and yards, a limited amount of fencing, some ringbarking to encourage pasture growth, and the establishment of a small number of watering points. The introduced annual legume Townsville lucerne (*Stylosanthes sundaica*) is fairly widespread in the north-western half of the region. It occurs mainly on sandy-surfaced soils, but in places has become established on some of the heavier and wetter soils. Mainly the species has spread naturally, but efforts have also been made to introduce it to some properties. This legume is reported to raise the stock-carrying capacity by at least 50 per cent. in some places because of its value as standby hay in the dry season. However, winter rains spoil this carry-over feed and it is said to be of little value in wet winters. Townsville lucerne is a useful species as it is tolerant of low phosphate levels in the soil. It is known to respond to applications of superphosphate under certain conditions, but top-dressing is not practised in this region and it is not known if this would give economic returns.

Minor attempts have been made on some properties to produce fodder crops on cultivated land in specially selected areas, but this is not generally practised and cattle depend almost entirely on natural pastures.

Killing works within the region provide an easily accessible outlet for fat stock. Cattle are bred and fattened within the region, but additional store cattle are obtained from inland breeding areas for fattening.

(*b*) *Agriculture*

The main agricultural developments have taken place near the mouths of the Burdekin, Houghton, and Don Rivers, with a smaller development on the colluvial soils on Major Creek.

Sugar-cane is the most important crop on the deltaic soils of the Burdekin and Houghton Rivers. In 1949 the Lower Burdekin Valley produced 881,262 tons of cane at an average yield of 31.74 tons per acre, or 4.67 tons of sugar (94 N.T.) per acre.* The three mills on the Burdekin River delta, Pioneer, Kalamia, and Inkerman, crushed 232,863, 236,133, and 302,295 tons of cane respectively. The Invicta mill at Giru on the smaller delta of the Houghton River crushed 104,971 tons.

Most of the sugar-cane production in this region is grown with irrigation, although small areas of cane are grown under rainfall alone, particularly near Giru. Irrigation water is obtained from underground supplies at shallow depths, each farm having its own well and pump. Intrusion of salt water into these aquifers in dry seasons suggests that their irrigation capacity is being fully used. Areas of land for sugar-cane production are assigned and limits are imposed on the area harvested each season. Most farms include more than the assigned area, but the excess

* Australian Sugar Year Book 1951.

is mostly undeveloped. There is some rotation of cultivation on cane land, but relatively little alternative cropping is practised. Minor areas of other crops, such as fruits, vegetables, and tobacco, are grown.

A recent agricultural development in the Lower Burdekin Valley is the production of tobacco on the levees of the Burdekin River at Clare, where farmers are being settled under the terms of the War Service Land Settlement Agreement (Plate 8, Fig. 2). At present about 50 farms are operating or in the course of establishment. It is planned to increase this to 200. Experience has shown that, on the average, yields of at least 1000 lb. cured leaf per acre may be expected. Quality of the leaf has been satisfactory. About 400 acres of tobacco were to be sown in this area during 1951.

Vegetable and fruit growing under irrigation has been developed on the delta of the Don River near Bowen, water being pumped from shallow wells. The main exports, which are sold on southern markets, are tomatoes, mangoes, and pineapples.

The Major Creek area produces vegetables and fruits primarily to supply the needs of Townsville. Smaller agricultural areas have been established on some of the smaller coastal streams between Ayr and Bowen, but these are only of minor importance.

III. Land Use in Relation to Climate

The Townsville-Bowen region is a relatively dry section of the Queensland coast. At the coastal centres of Townsville and Bowen the average annual rainfall is 42 and 37 in. respectively, and at the inland centres of Mingela and Strathmore, 24 and 28 in. respectively. The rain falls mostly during the summer months and the period with adequate moisture for plant growth is relatively short in all parts of the region. The criterion based on the period of adequate rainfall used in Part II of the report shows that in the coastal sections the estimated useful agricultural period is of the order of 17 weeks. The estimated length of growing season diminishes with increasing distance from the coast, and at Woodstock and Woodhouse, which are about 20 and 30 miles inland respectively, the season is 15 weeks. At Mingela, on the top of the Leichhardt Range at the western edge of the region, the period is only 13 weeks. At Strathmore, which is as far from the coast as Mingela but in lower country in the southern corner of the region, the season is of the order of 14 weeks. These periods are based on the estimated requirements of cultivated crops. It is to be expected that the period during which conditions are satisfactory for the growth of natural pastures would be slightly longer, but a large part of the year would still have inadequate rainfall.

The short summer growing season and the long dry season are major factors limiting the productivity of natural pastures and the development of agriculture.

In consequence of these seasonal characteristics pastures make their main growth during a relatively short period of high temperatures, tending to produce bulky pastures of low nutritive value at maturity. In most of the summer-rainfall section of Australia, stock depend largely on this mature pasturage to carry them through the dry season, and carrying capacity is determined by the quality and quantity of feed at the end of the dry season rather than by the productivity of the pastures during the wet season. Further, the length of the fattening period is limited by the rapid deterioration in the quality of the maturing pasturage. Winter rains occur erratically and where the pastures are well grazed and open, a sparse growth of winter annual species may result. If winter temperatures are high following such wet periods some growth of summer pasture species occurs and the rains are valuable, but if temperatures are low there is little response from these species and the rains may be detrimental by damaging carry-over feed.

The restriction of agriculture by climate to one season of the year limits the variety of staple crops that might be grown and hence the diversity of agriculture that might be practised. These limitations are more marked in the section farthest away from the coast where the estimated useful agricultural period is shortest. Under comparably short growing conditions in the winter-rainfall zones of Australia large-scale production of a single staple crop such as wheat makes agriculture possible. Such staple crops for short-season, summer-rainfall zones have not been developed to the same stage in Australia. However, grain sorghums are now widely grown and the Queensland-British Food Corporation project at Peak Downs is a large-scale attempt at this type of agriculture in a marginal area. If this type of agriculture can be still further developed, it is possible that portions of the region surveyed, which now appear to have little agricultural potentiality, could be put to some agricultural use.

The present agricultural development of the region is based mainly on irrigation by water pumped from streams or underground supplies. These sources are now exploited almost to full capacity and any further large-scale development under irrigation must depend upon the provision of alternative water supplies.

The possibility of obtaining a large source of water for irrigation was a major factor leading to the investigation of the possibilities of damming the Burdekin River.

IV. The Burdekin River Irrigation, Hydro-electric, and Flood Mitigation Project

Investigations to examine the possibility of damming the Burdekin River with the triple objectives of providing water for irrigation and for generation of hydro-electric power, and of giving some measure of flood mitigation in the lower section of the Burdekin Valley were initiated in

1945 by the Queensland Co-ordinator-General of Public Works and the Queensland Bureau of Investigation.

The main feature of the proposal is the construction of a dam about 99 miles from the mouth of the Burdekin River. The dam would conserve about 6.58 million acre-feet and provide about 900,000 acre-feet annually for irrigation. A diversion dam would direct water into reticulation channels, which could command a large proportion of the lands in the Lower Burdekin Valley. If agricultural problems can be overcome, 325,360 acres of land could be developed by irrigation. In addition, the scheme could produce continuously 80,000 kW. of electricity at 50 per cent. load factor.

This regional survey was not concerned with engineering features of the scheme, but with its irrigation aspects in relation to possible agricultural development. For this reason it paid special attention to the nature, extent, and distribution of lands that might be considered for irrigation in the area commanded by the scheme.

V. The Land-use Groups in Relation to Irrigation

(a) *Levee Group*

This land-use group is of major agricultural importance as it contains worth-while areas of soils suitable for a wide range of intensive crops, satisfactory for irrigation, and in situations where irrigation water might be supplied.

The group contains the Clare and Milleroo Land Systems, which are characterized by light- and medium-textured soils. It should be emphasized, however, that the development of the Milleroo Land System would not be so straightforward and could not be so complete as the development of the Clare Land System.

The Clare Land System has been formed as long, narrow bands on levees adjacent to the major streams, the beds of which have a fall of 2-3 ft. per mile. On the other hand the Milleroo Land System includes numerous irregular alluvial fans and smaller levee deposits, mostly situated near the base of the ranges to the west of the Lower Burdekin Valley, and such areas have surface gradients of 15-30 ft. per mile.

The various soils in the Clare Land System occur in a more or less regular linear pattern parallel to the streams, generally increasing in texture and liability to flooding with distance from the streams. A typical sequence of soil groups from the crest of the levees to the flood plain is Burdekin (brown fine sand), Lancer (fine sandy loam over red-brown or yellow-brown clay), Clare, and Kelona (sandy loam or loam over mottled yellow clay subsoil). A certain amount of agricultural experience has already been gained on these soils by the Queensland Department of Agriculture and Stock at Clare where an irrigation settlement, mainly producing tobacco, was commenced in 1949. These investigations have shown that a wide range of crops can be produced on these soils, the fine, sandy soils of the Burdekin soil group being particularly suitable for tobacco. Other crops that have been grown include sugar-cane, peanuts, potatoes, cotton, introduced pasture and fodder crop species, various fruits, and vegetables, and there is adequate variety for a stable agriculture. In seasons of heavy rains and major floods the lower levee soils are subject to flooding in spite of normal drainage provision and this imposes some limitations on their agricultural utilization.

In contrast to the Clare Land System the various soils of the Milleroo Land System are intermixed in a very complicated, irregular pattern. The soils themselves are more variable and the individual areas of the better soils are small. The soils are mostly deep coarse sands (Hylo and Wenlee Groups) with small areas of good agricultural soils (Burdekin, Lancer, Tootra, and Clare Soil Groups) and some solonized soils (Yoda, Mulgrave, and Oakey Soil Groups). The coarse, sandy soils are not as good as the Burdekin soils and, although they may be satisfactory for tobacco under spray irrigation, they are much less satisfactory for alternative crops. The solonized soils are sands or sandy loams with tough clay subsoils and are not suitable for intensive agriculture.

The Milleroo Land System therefore is far more complex than the Clare Land System, and farm layout and efficient water reticulation would be much more difficult.

The irrigation development of each land system can be considered in two sections.

(i) *Clare Land System*

(1) *The Levees of the Lower Burdekin River.*—The total area is approximately 49,000 acres, of which 30,000-35,000 acres might be cultivated, the remainder being unusable because of gullying, isolation of small areas, and narrow width of the levees. A detailed soil survey would be necessary to demarcate usable areas. These levees could be supplied with water by pumping from the river if the dry season flow is augmented from the diversion weir, or by gravity reticulation.

(2) *The Levees of the Bowen River.*—These levees are narrow in most places and of the total of 26,000 acres it is estimated that only 10,000 acres would be available for actual cultivation. The water from the proposed diversion weir on the Burdekin River could not be reticulated to these levees and their use would depend upon an alternative supply of water. The Bowen River is non-permanent and only small areas could be irrigated by pumping from large waterholes. If half the available land was irrigated each year, 10,000-15,000 acre-feet delivered to the farms would be required annually.

(ii) *Milleroo Land System*

(1) *Portions in the Lower Burdekin Valley.*—Three major areas occur to the west of the lower Burdekin River, totalling 32,000 acres.

From existing information it is not possible to estimate how much of this is suitable for irrigation, but the greater complexity of soils and topography indicates that the proportion would be very much less than for the river levees. A detailed soil survey would be even more necessary in this section than on the levees. As the areas are situated at the foot of the mountain ranges, mostly well above the main river levees, water could be supplied only by a major gravity reticulation channel traversing the broken country at the western edge of the valley.

(2) *Portions outside the Lower Burdekin Valley.*—Large areas of the Milleroo Land System occur along the upper Houghton River, on Major Creek at the foot of Mount Elliot, on the upper Ross River, and on the upper Black and Bohle Rivers east of Townsville. These areas are not commandable from the Burdekin diversion weir and there are no apparent large-scale alternative sources of water.

(*b*) *Delta Group*

Most of the region's agriculture is within this land-use group, which has already reached a high degree of agricultural development. The one land system, Ayr, has good but variable agricultural soils formed on deltaic deposits. Of the total area of 169,000 acres, over 80 per cent. occurs in the Burdekin delta. This section and a smaller one at Giru on the Houghton River are used mainly for the production of sugar-cane with irrigation from underground water. On a small area on the Don River near Bowen fruit and vegetable growing are the major forms of production. The remaining sections are small and largely underdeveloped.

The Ayr-Home Hill and Giru sections are the only ones that might be served by the Burdekin River storage and the other areas must remain dependent upon local pumping plants.

The major scope for development is in the Ayr-Home Hill area, but this will be influenced by the present form of land utilization. There is scope for agricultural development in:

(1) Alternative and rotation crops on cane lands. The Queensland authorities are investigating these possibilities at the Regional Experiment Station at Ayr and at the Sugar Experiment Station at Pioneer.

(2) The utilization of unallotted and undeveloped lands interspersed between the cane fields for additional cane production and for other crops.

(3) The utilization of soils too sandy for sugar-cane, but suitable for tobacco, pineapples, etc., under spray irrigation.

However, the underground water supply has set a limit to the extension of irrigation, especially during periods of low rainfall when salt water encroaches into the aquifers. Because wells and pumps have already been established on the allotted cane lands, and because there are numerous distributary channels and depressions traversing the delta, it would not be practicable to supply water to the scattered undeveloped areas by gravity reticulation, and a change from the present system of irrigation to complete reticulation would be very costly. The possibility of replenishing the aquifers with water from the Burdekin storage has been mooted, but this is obviously not a simple, straightforward problem and would require careful engineering investigation before any plans might be adopted.

Thus it appears that, except for areas near the inland edge of the delta, which might be served by gravity reticulation from the Burdekin scheme, further agricultural development must depend largely on rainfall.

The possibility of serving areas of sandy soils in the Brandon-Pioneer section and also other soils suitable for cane production near the inland margin of the delta is worth examination.

(c) *Sandy Group*

The six land systems that form this land-use group, Macedon, Collinsville, Mookara, Manton, Heidelberg, and Dalbeg, occur as small, widely distributed areas, many of them at the foot of the mountain ranges at the west of the valley. They are all characterized by sandy-surfaced soils. With the exception of the soils of the Manton Land System, which have formed on alluvial deposits, these are residual soils formed on granites and sandstones. They are all of low fertility and at present are used only for pastoral purposes at a low rate of stocking on the rather sparse natural pastures.

There are two subgroups:

(1) Macedon, Collinsville, Mookara, and Manton, which mainly have sandy soils with tough, impermeable clay subsoils.

(2) Heidelberg and Dalbeg, which have mostly deep sandy soils.

In the first subgroup the tough clay subsoil of the major soils is a most undesirable agricultural feature in that it would be a barrier to root development, and, by preventing water penetration, would cause temporary waterlogging following rains or irrigation. The very leached, sandy surface horizon, in addition to being of very low fertility, dries out rapidly and produces droughty conditions in the root zone.

Most of this subgroup is in the south-east and east of the region and could not be commanded by the diversion weir. Small areas occur within the Lower Burdekin Valley, and although they might be commanded by water, it is considered that their agricultural potential is too low to warrant any special efforts being made to include them in a reticulation system. Extensive agronomic investigations would be necessary to determine the practicability of an irrigated agriculture on these soils.

The deeper sandy soils of the two land systems of the second subgroup occur on undulating to steeply undulating topography. Very little of the Heidelberg Land System could be commanded by the proposed diversion weir. Several areas of the Dalbeg Land System occur in the Lower

Burdekin Valley, and portions might be commanded, although the undulating topography would complicate water distribution and increase the erosion hazard. In this land system the crests of the rises usually have very shallow soils not satisfactory for cultivation. The bottoms of the undulations are frequently perennially waterlogged by seepage. The profile characteristics of the soils on the slopes indicate that they are subject to waterlogging in the wet season, and the application of irrigation water would tend to extend this period, especially on the lower slopes. It is evident that only relatively narrow bands along the upper slopes could be satisfactorily irrigated. Because of this and the poor nature of the soils, the development of this land system by irrigation is not worth consideration except where it adjoins better soils or where distribution channels serving other areas necessarily traverse it. As with the first subgroup, successful use of land with irrigation would be dependent upon prior agronomic investigations.

(*d*) *Flood-plain Group*

This land-use group, which covers a total area of 640,000 acres, is of particular significance in the Lower Burdekin Valley where it occupies 286,000 acres, i.e. over one-quarter of the valley area (see map). The land-use group is composed of four land systems, Northcote, Woontonvale, Kyburra, and Rocky Ponds. All of these are practically flat and are characterized by heavy and medium-textured soils. These have formed on fine-textured alluvia of flood plain and similar formations associated with all the major streams in the region. They are generally low-lying and in consequence are poorly drained and subject to waterlogging. Extensive areas are liable to flooding, both from local rainfall and overflow from the streams. The agricultural use of these plains would necessitate the provision of an extensive drainage system and this need would be accentuated if rainfall was augmented by irrigation. The history of floods on portions of this land-use group and the slow internal drainage characteristics of the soils raise a doubt as to whether any practicable form of drainage would be sufficient to remove the hazard of periodical destruction by major floods in certain areas.

The large areas along and between the lower Burdekin and Houghton Rivers are commandable from the proposed diversion weir. The nearly flat terrain would make water reticulation and farm lay-out relatively straightforward, but the provision of sites for buildings may be difficult on some farms. It is doubtful if the areas on the Ross and Bohle Rivers, or those beyond the eastern margin of the Burdekin Valley, could be commanded by the Burdekin Scheme.

The land-use group includes a range of soils, including some with profile characteristics or microtopography that make extensive areas unsuitable for cultivation and irrigation.

The two land systems, Northcote and Rocky Ponds, are somewhat similar in the soils that compose them, but they differ in their proportion of the various soils. The main soil groups are the heavy-textured Barratta and the medium-textured Oakey, both of which carry a *Eucalyptus* parkland or open forest. The minor soils are the solonized Dowie and the lighter-textured Lancer, Tootra, and Wenlee groups.

The Northcote Land System is mostly nearly flat and is dominated by the soils of the Barratta and Oakey groups, with a very small proportion of the lighter-textured soils. The topography of the Rocky Ponds Land System is slightly more undulating, and the Oakey soils predominate. The lighter-textured soils are more extensive than in the Northcote Land System, but form only a small proportion of the total area. Soils of the Dowie group occur in numerous small areas and are prominent by virtue of their characteristic sandalwood (*Eremophila mitchellii*) vegetation, but actually occupy a small total area in each land system.

The soils of the Barratta group have limited agricultural potentialities. Their shallow surface and tough, heavy clay subsoil horizons and their variable gilgai microtopography would make cultivation, land preparation, and maintenance of efficient irrigation difficult and costly. These soils occupy the lowest portions of any cross section of the flood plain and main drainage channels from any irrigation system must traverse them. Surface drainage is slow, internal drainage poor, and flooding is more common and more severe than on other soils of this land-use group. Two ways in which these soils might be used with supplementary irrigation are the growing of rice and the production of pastures adapted to very wet conditions, such as para grass (*Brachiaria mutica*). The possibilities of various *Paspalum* species and other grasses and of taller types of fodder grasses are also worth examination. However, the boggy nature of these soils when wet would restrict the duration of the grazing period of such pastures. Further, unless very strict control of irrigation and drainage can be maintained, less desirable plants adapted to wet conditions, e.g. reeds and sedges, and poorer native grasses such as *Ophiuros exaltatus*, are likely to become major weeds and reduce the production of the sown pasture species. These factors will set a limit to the economic return from animal products and should be carefully examined before embarking upon the expense of preparing these particular soil areas for irrigation. However, if a successful method of pasture production and management can be developed for these soils, it would constitute a very desirable form of land use to alternate with rice production in areas where flooding can be controlled.

Soils of the Oakey group are better drained and less flooded than those of the Barratta. Their surface soil is deeper (8 in.) and gilgais are uncommon. However, the surface soil is poorly structured and the subsoil is as intractable as the subsoil of the Barratta group. They cannot be classed as good agricultural soils, but their agricultural potentialities are probably wider than those of the Barratta group. The establishment and growth of crop species would be influenced by the possibility of waterlogging during the wet season and by poor surface structure, and maintenance of productivity would be dependent upon satisfactory rotation practices to prevent the deterioration of this initially poor surface structure. Investigations of their agricultural use under irrigation should include not only the possibilities of rice growing and pasture production, but also a wide range of summer- and winter-growing annual crops in order to determine if any are suitable. Some of the crops that should be examined are cotton, grain sorghums, maize, fodder crops, sunflowers, peanuts, sugar-cane, and linseed.

With supplementary irrigation a wider range of pasture species is likely to prove suitable on these soils than on the wetter Barratta soils. The possibility of satisfactory mixed pastures appears greater and the growth of winter-growing pasture and fodder crops for special purposes is worth examination.

The Dowie soils do not occur in sufficiently large patches to warrant special consideration. These soils have a very shallow surface and an extremely tough clay subsoil. They have no obvious agricultural potentialities.

The minor lighter-textured soils, of which the potentialities have been discussed in the Levee land-use group, occur mainly in small, very narrow, linear areas. These are not of sufficient size to significantly affect major decisions concerning the irrigation of these two land systems, although their occurrence may be of value to individual farms, either as sites for building or for more varied cropping.

The Woontonvale Land System has, in addition to soils of the Oakey, Barratta, and Dowie groups already described, another soil group, the Tolgai. This and the Oakey group constitute the greater part of the land system. The Tolgai soils are heavy clays that carry dense forests of Burdekin gidgee (*Acacia* sp.). Gilgai development on these soils is so strong that it would seriously interfere with grading, levelling, and efficient irrigation, and the dense forests would make clearing more difficult than on the Oakey and Barratta areas. This land system occurs mainly outside the area commandable from the Burdekin dam. The areas within the Burdekin Valley are on the east side of the river and are not likely to be concerned with initial irrigation development.

The Kyburra Land System consists mainly of Koberinga soils, a group occurring only in this land system, but also contains minor areas of Oakey and Barratta soils. The Koberinga soils are dark, calcareous, heavy clays that have neither the poorly structured leached surface soil nor the difficult subsoils of the Oakey and Barratta groups. Fertility appears to be fair, but the heavy surface texture may impose some agricultural limitations. Its general agricultural potentialities would appear to be wider than those of the Oakey and Barratta soils, with cotton and possibly sugar as likely crops. There is some doubt as to how much of this land system can be commanded by the Burdekin Scheme. The land system consists of numerous small areas in the coastal strip between Home Hill and Bowen with other small areas to the east of the Burdekin River. The latter are probably easily commandable, but all the first group are well removed from the source of irrigation waters and possibly only the area south of Home Hill could be utilized for irrigation. This area, which is the largest single area of the land system, is known to drain rapidly after normal rains but local reports indicate that deep flooding, which might be damaging to agriculture, occurs on occasions.

(*e*) *Better Upland Group*

The three land systems that compose this group, Strathmore, Kilbogie, and Havilah, all have soils formed on undulating topography at higher levels than adjacent river levees and flood plains. In general this land-use group is not likely to be commanded by irrigation water from the Burdekin dam.

The Havilah Land System is in the south-east of the region far removed from the Burdekin River. The Strathmore Land System is mostly to the south-east of the Lower Burdekin Valley. The small areas within the valley are at the foot of the Bogie Range and would be difficult to command.

It may be possible to gravitate waters to small areas of the Kilbogie Land System and additional areas might be served by pumping if agricultural investigations indicate that this is justified. However, the undulating topography would make water reticulation more difficult, and the possibilities of soil erosion on cultivated land would be an additional agricultural problem.

The major soil groups of the Kilbogie Land System are Dalrymple and Yalboota. Both are sandy loams with permeable clay subsoils. The Dalrymple group belongs to the red-brown earths, which are widely used for agricultural purposes in southern and eastern Australia. The Yalboota group is somewhat similar, but the clay subsoil is not so well drained and the agricultural value would be somewhat less. On commandable moderate and gentle slopes with little surface stone, it should be possible to grow a wide range of crops on these soils, including sugar-cane, cotton, fodder crops, summer cereals, peanuts, and sown pastures.

Minor soils are Mulgrave, Dowie, and Wygong groups. The first two, which are unsatisfactory agricultural soils, have been discussed in previous land-use groups. The soils of the Wygong group, which are black earths with good agricultural characteristics, occur in very small areas and are not likely to influence general planning.

(*f*) *Hilly Country Group*

All the hilly country of this region has been included in one complex land system, the Leichhardt, which is the only one in this land-use group. The steep slopes have stony, shallow soils with extensive rock outcrops. Irrigation is not practicable and the land-use group has no agricultural value.

(*g*) *Saline Lands Group*

These low-lying lands adjacent to the coast have been mapped in two land systems, Littoral and Bowling Green.

The Littoral Land System includes recently stabilized fore dunes, older fixed sand dunes, and the associated coastal country subject to salt water inundations, such as the salt meadows, salt-marshes, and mangrove fringes. The dunes consist of deep sands unsatisfactory for irrigation. The other units are unsuitable for agriculture because of the salinity of the soils and the likelihood of further saline flooding. Most of their soils have sticky heavy clay subsoils, and reclamation by flood prevention, draining, and leaching would not only be difficult but would probably merely result in soils similar to those of the Barratta and Oakey groups. Areas of coarser sediments, as on Rita Island, may be suitable for reclamation if irrigation water can be provided, but it is doubtful if development of this kind could be justified at present.

The Bowling Green Land System occurs on three small areas adjacent to the littoral near Townsville, Giru, and Ayr. The topography is very gently undulating with low rises intermixed with irregular, broad, swampy depressions and some lagoons. Old dunes occupy minor areas. These land units occur in a complicated pattern and the whole land system is low-lying and liable to flooding by fresh water. The native vegetation of the rises, which ranges from the bunch spear grass ground flora typical of the river flood plains to sand couch and other salt-tolerant plants of the littoral, indicates a strong saline influence in the soils. This, together with the intricate pattern of land units and liability to flooding, makes the land system unsuitable for irrigated agriculture.

VI. Land-use Groups in Relation to Development without Irrigation

Only about one-quarter of the region surveyed lies within the area marked as the Lower Burdekin Valley and only part of this would be directly influenced by an irrigation scheme. It is necessary therefore to consider the possibility of land developments over a big proportion of the region by the use of rainfall alone.

(*a*) *Agricultural Development*

The field survey and the study of the climate of the region indicate that there are prospects for the production of non-irrigated crops in some sections. By comparison with other northern areas in which agriculture is practised, it is considered that the length of growing period on the coastal section is adequate for the growth of various summer annual species and that even at some inland centres there are possibilities that some short-season fodder crops could be grown. It is of interest to note that the estimated length of growing season at Clermont, near the Queensland-British Food Corporation project, is only 12 weeks as compared with 12-17 weeks for various parts of this region.

It is likely that the greatest scope for the development of dry-land agriculture will be in the production of fodder and forage crops as supplements to the beef-cattle industry, rather than the establishment of self-contained agricultural units.

The nature of the soils will impose some restrictions on the development of agriculture. The most promising areas for dry-land agriculture are in the Kyburra Land System of the Flood Plain group and the Kilbogie and Strathmore Land Systems of the Better Upland group. In the Kyburra Land System the Koberinga heavy black earth soils appear to be very suitable. These heavy soils have good water-holding capacity, seem to be relatively fertile, are treeless, and occur in areas of usable size, mostly near the coast.

The two dominant soils of the Kilbogie Land System, Dalrymple and Yalboota, are widely and irregularly distributed. Some extensive areas with suitable topography for cultivation occur within sections of the region having an estimated useful agricultural period exceeding 15 weeks. These soils, which carry a *Eucalyptus* open forest vegetation, have a loamy surface and permeable clay subsoil. In some places the surface is stony but otherwise they are attractive agricultural soils. Erosion of cultivated land would be a serious problem on steeper slopes. The associated solonized soils are not suitable for agriculture.

In the Strathmore Land System cultivation is likely to be restricted to Wygong and Koberinga soils. These black earths are good agricultural soils and the former, which is formed from volcanic rocks, is high in phosphate (0.1-0.4 per cent. P_2O_5). Considerable areas of these soils occur inland where rainfall incidence appears to be marginal for the growth of crop species. There may be scope for the production of short-season fodder crops for use by the cattle industry. These soils carry a sparse tree vegetation, which would be easily cleared. In general they occur on gentle slopes not conducive to soil erosion, but the soil itself would erode freely once erosion commenced.

Apart from the soils mentioned, all those of the Levee and Delta land-use groups except the coarse sandy soils would be suitable for crop production. However, their future development may be mainly by irrigation, and dry-land cropping is likely to be restricted to small areas in association with irrigation farming. Areas of Levee group in the southern portion of and outside the Lower Burdekin Valley are mainly in sections with a shorter growing season and their use for dry-land agriculture would therefore be limited.

(b) *Pastoral Development*

At present the pastoral industry occupies most of the region. The standards of stock and pasture husbandry are in keeping with the climatic limitations but could be influenced considerably by a major irrigation development in the region if that included stock fattening. The efficient use of irrigated pastures would make a demand for stock within the region for fattening purposes which may not be supplied by normal seasonal stock movements. In order that stock might be available in the irrigation areas whenever pastures are suitable for grazing it may be necessary to hold large numbers on the adjacent dry-land areas throughout the wet season, when pastures on the low-lying irrigable country may be too wet to graze. This in turn would encourage improved husbandry on the dry-land areas, partly by this increased demand for stock, and partly by relieving the areas during the dry season, which at present is a limiting factor because of the low level of nutrition of the native pastures at that time.

Irrespective of the influence of irrigated pastures in the region there is the scope for the use of fodder crop production in the cattle industry referred to above.

A further possible aid to development of the unirrigated areas is pasture improvement. There are two methods of improvement for restricted areas already available. One is the spread of Townsville lucerne on sandy-surfaced soils, the other is the establishment of para grass in wet areas. A third species available that may prove of value on lighter-textured soils is buffel grass (*Cenchrus ciliaris*).

These methods apply only to specific land types. Before pasture improvements can be more generally practised in such summer-rainfall regions, further investigation of methods is necessary, including the introduction of other pasture species and the economic possibilities of top-dressing with both minor and major fertilizing elements.

VII. Conclusions

The main conclusions drawn from this survey are:

(i) In portions of the Kyburra, Kilbogie, and Strathmore Land Systems, where agriculture is not practised at present, both soil and climatic conditions are considered to be satisfactory for the growth of short-season annual summer crop species. The production of fodder crops for use in the cattle industry should be possible in many sections, and, at least in areas more favoured climatically, agriculture could include a proportion of cash crops. Although this extensive type of agriculture would be of considerable significance to the areas concerned it would not constitute a major regional development.

(ii) A small contribution to the development in the cattle industry is possible at present by pasture improvement, such as the further spread of Townsville lucerne on sandy-surfaced soils, and of para grass in wet sites. Further investigations in this field will be necessary before pasture improvement can be applied widely.

(iii) Some expansion of present irrigation practices in the region is possible, but these will be of a minor nature because the available water is already nearly fully exploited. In these areas there is scope for much greater production of non-irrigated crops in rotation with sugar-cane, or on unassigned land.

(iv) Any major expansion of agriculture or development in the cattle industry in this region will be dependent upon the production of additional water supplies for irrigation.

(v) Concerning the proposal to conserve water for irrigation by damming the Burdekin River, it is considered that:

(1) The intensive irrigation development of the Levee Group in the Lower Burdekin Valley is agriculturally sound.

(2) In this land-use group the greatest and most straightforward development is possible on the levees of the Burdekin River, which form part of the Clare Land System and have a total area of about 49,000 acres. Of this area portions will not be usable because of narrowness of the levee or the occurrence of erosion gullies. As these levees occur in narrow bands along the river bank, careful design will be necessary to ensure that the maximum amount of arable land is retained for agricultural use.

(3) Additional development may be possible in this land-use group in the areas of the Milleroo Land System in the south-west of the Lower Burdekin Valley, which total about 32,000 acres. The proportion suitable for irrigation would be much less than in the Burdekin levees. A detailed soil survey would be required before the exact size of the suitable areas could be indicated and final plans determined for farm layout and water reticulation. The information obtained from such a survey should influence decisions concerning the placement of major water reticulation channels in the valley.

(4) The irrigation of the Flood Plain group is not agriculturally sound at this stage, but, because of the large areas that might be commanded by the Burdekin Scheme, there is every justification for intensive field experimentation to determine the possibilities and economics of production.

(5) As it may be some years before a final answer is available concerning the agricultural possibilities of the Flood Plain group, the initial development of the levees might well proceed independently of this group.

(6) The Sandy group does not warrant special attention, but where portions of this group lie close to planned water channels serving other

sections their possibilities for development should be examined. A detailed soil survey and agronomic investigations would be necessary preliminaries to any plans for this group.

(7) There is scope for the utilization of much additional water for irrigation in the Delta group, but it may not be practicable to reticulate water beyond the inland margins of this group. The possibility of augmenting the underground water supplies is an engineering aspect not examined by this survey.

(8) Portions of the Better Upland group have satisfactory soils and topography for irrigation, but only small areas could be commanded from the Burdekin Scheme by gravitation. Limited additional areas could be commanded by pumping. Accurate information concerning areas and height of water lift will not be available until accurate topographic plans are completed.

(9) The soils of the Saline Lands and Hilly Country groups are unsatisfactory for agriculture and will not have any bearing on the agricultural aspects of the Burdekin Irrigation Scheme.

(vi) Apart from the lands that might be commanded by the Burdekin Scheme there is little prospect of expansion of irrigation in the region. The most important area worthy of attention is the portion of the Clare Land System along the Bowen River. This totals 26,000 acres, of which it is estimated that about 10,000 acres could be utilized for intensive agriculture if a source of water can be provided. Most other areas of suitable soils occur in headwater sections or on non-perennial streams with little prospect for water storage.

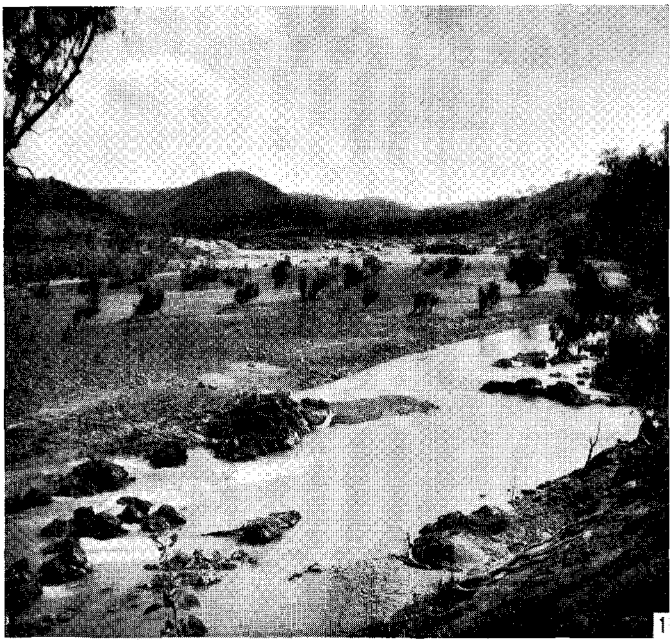

Fig. 1.—The bed of the Burdekin River in the gorge, about four miles downstream from the dam site. The surrounding country is rugged and the bed of the river has many small rock bars.

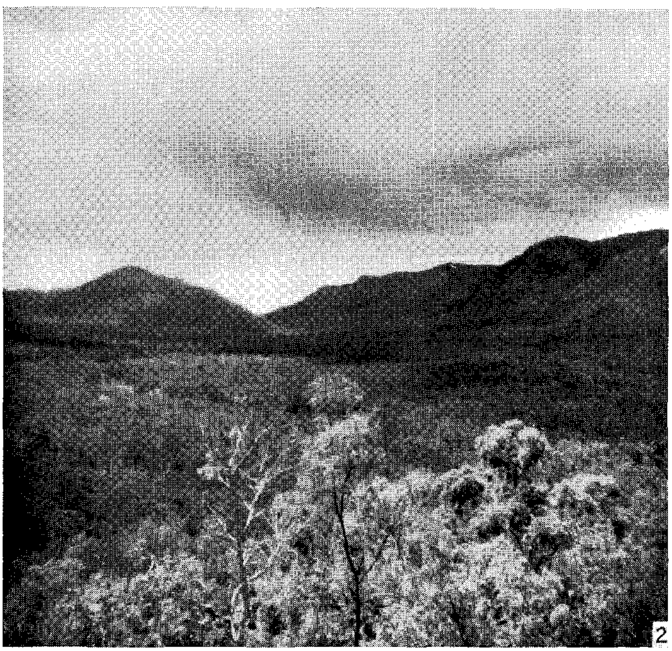

Fig. 2.—Rugged hilly country and nearly flat alluvial plain south of Townsville. About one-third of the region surveyed is rough, hilly country.

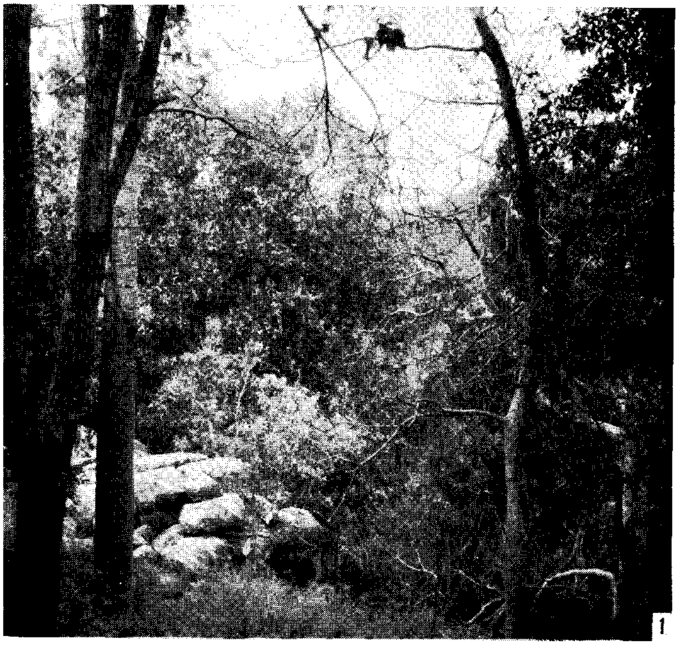

Fig. 1.—Patches of softwood Forest occur on some of the steeper, more rocky slopes.

Fig. 2.—Narrow-leaved ironbark–red-barked bloodwood Open Forest is characteristic of most of the hilly country.

Fig. 1.—Narrow-leaved ironbark–red-barked bloodwood Open Forest covers large areas of undulating country with well-drained soils. The medium-height grasses are dominated by *Heteropogon contortus*.

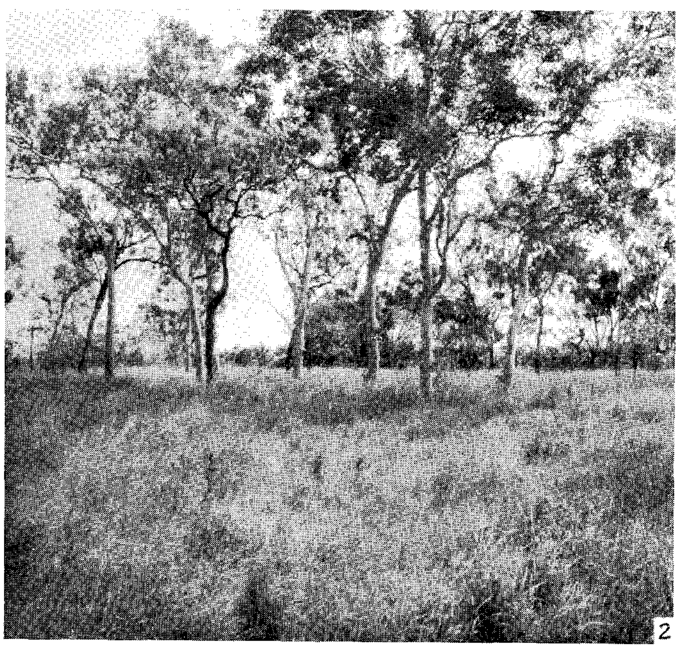

Fig. 2.—The levee soils associated with major rivers have a poplar gum–grey bloodwood Open Forest. *Heteropogon contortus* is the dominant grass.

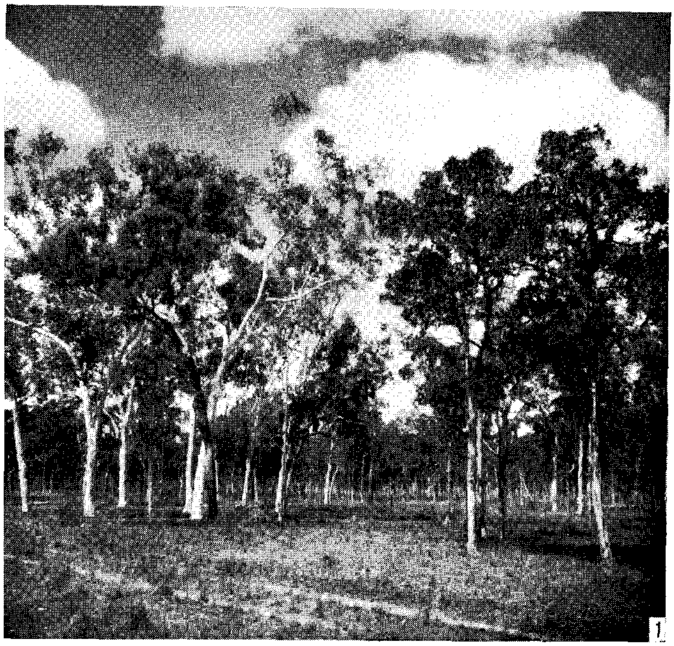

Fig. 1.—Poplar gum Woodland with short grasses occurs on sandy-surfaced solonized soils (Yoda soil group).

Fig. 2.—*Ophiuros*-bluegrass Grassland on black earth soil with Mt. Pollux, a residual of Lower Bowen volcanics, in the background. The grassland community also occurs on heavy solonized soils.

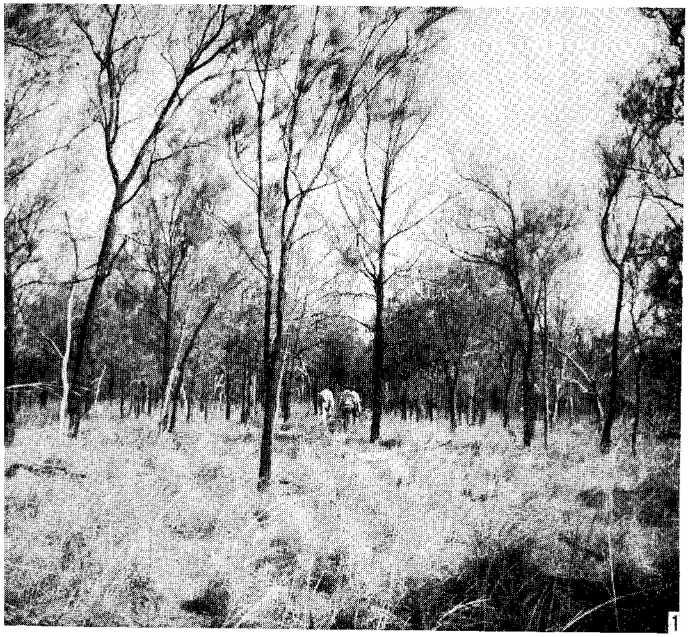

Fig. 1.—Bulloak Woodland on the more droughty sandy-surfaced solonized soils (Mulgrave soil group).

Fig. 2.—Budda Woodland with sparse annual grasses is the characteristic vegetation of the shallow solonized soils of the Dowie group.

Fig. 1.—A small patch of Burdekin gidgee Forest on heavy clay soils with marked gilgai (Tolgai soil group).

Fig. 2.—Brigalow Forest occurs on some black earth soils, and in many places is associated with particular geological strata.

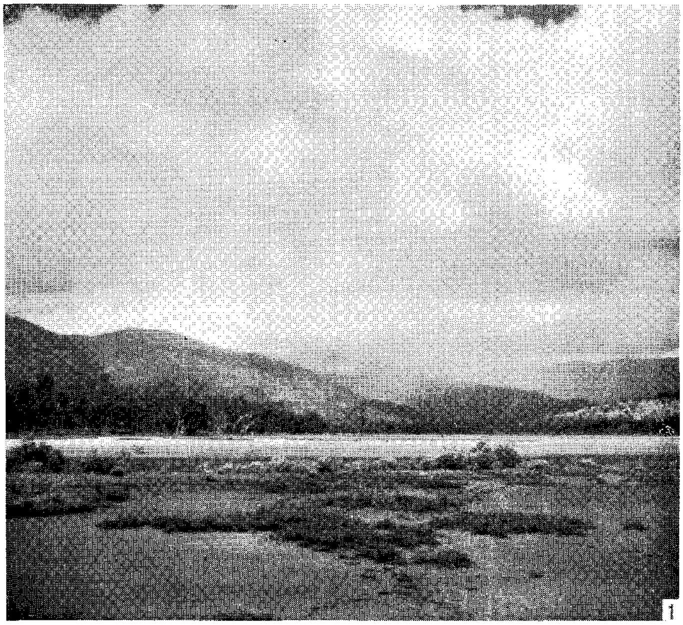

Fig. 1.- The salt marsh of the coastal fringe is bare or has scattered halophytic plants. Mt. Elliot, in the background, is typical of the coastal mountain residuals, which are the highest mountains in the region.

Fig. 2.- -Breeding and fattening of cattle on natural pastures is the most widespread industry in the region. Production is limited by the low nutritive value of the pastures in the dry season. Three meatworks within the region provide a ready outlet for fat stock.

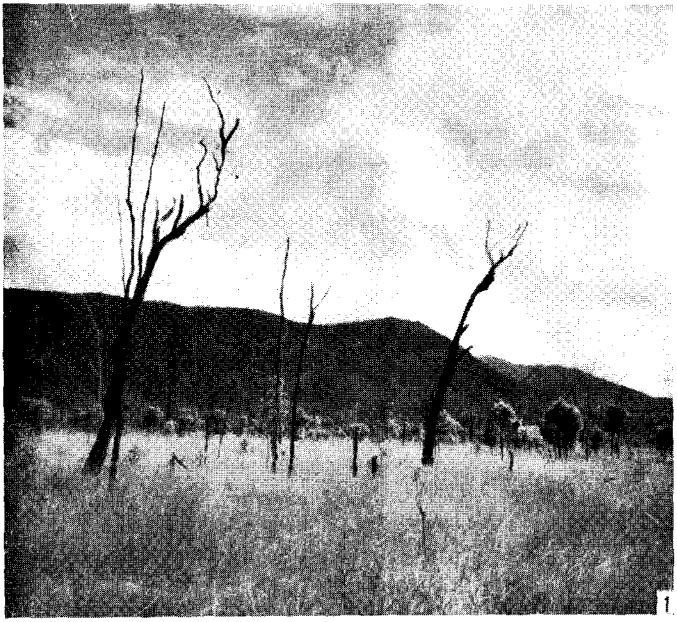

Fig. 1. Ringbarking on better-drained soils is reputed to increase the value of natural pastures but it has not been practised widely.

Fig. 2.—Tobacco growing under irrigation on levee soils of the Burdekin River near Clare is a recent agricultural development.