QR90003

RESEARCH ESTABLISHMENTS PUBLICATION

RESEARCH ESTABLISHMENTS PUBLICATION

SOILS OF THE BUNDABERG RESEARCH STATION

N. G. Christianos and S. E. Macnish
Land Resources Branch

D. E. Baker
Agricultural Chemistry Branch

Queensland Department of Primary Industries

Queensland Government Technical Report

This report is a scanned copy and some detail may be illegible or lost. Before acting on any information, readers are strongly advised to ensure that numerals, percentages and details are correct.

This report is intended to provide information only on the subject under review. There are limitations inherent in land resource studies, such as accuracy in relation to map scale and assumptions regarding socio-economic factors for land evaluation. Before acting on the information conveyed in this report, readers should ensure that they have received adequate professional information and advice specific to their enquiry.

While all care has been taken in the preparation of this report neither the Queensland Government nor its officers or staff accepts any responsibility for any loss or damage that may result from any inaccuracy or omission in the information contained herein.

For information about this report contact soils@qld.gov.au

Queensland Department of Primary Industries
Research Establishments Publication QR90003

SOILS OF THE BUNDABERG RESEARCH STATION

N.G. Christianos and S.E. Macnish
Land Resources Branch

D.E. Baker
Agricultural Chemistry Branch

Queensland Department of Primary Industries
Brisbane 1990

ISSN 0813-4391
AGDEX 524

This publication was prepared for Queensland Department of Primary Industries officers. It may be distributed to other interested individuals and organisations.

Queensland Department of Primary Industries
GPO Box 46
Brisbane Q 4001

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The Bundaberg Research Station is located approximately six kilometres east of Bundaberg, and occupies 32 ha on gently undulating plains formed on basalt and basalt-derived colluvium.

A 1:2500 soil survey was carried out on a 50 x 75 m grid. Three soil types were described and mapped (See Table 3). Eight representative soil profiles were sampled for detailed chemical analyses. Surface soil fertility was assessed from ninety bulk 0 to 0.1 m samples taken at each grid point.

Soils were classified as euchrozem, xanthozem and prairie soil Great Soil Groups (Stace et al. 1968).

Soils are generally medium acid to neutral throughout the profile.

All soils have adequate levels of phosphorus and potassium. The euchrozem soil has very high levels of copper and zinc.

A compaction layer was found at most sites between 0.05 to 0.3 m, although in some places it was as deep as 0.65 m. Deep ripping in several directions is recommended to break up this layer.

1. INTRODUCTION

In June 1985, the Queensland Department of Primary Industries purchased 32 hectares of land near Bundaberg as the site for a new research station. The site is opposite the Bundaberg Sugar Experiment Station and is approximately six kilometres east of Bundaberg on the Ashfield road (Figure 1.).

The station was established to undertake research into small crops, tree crops and grain crops in the form of glasshouse and field trials.

In February 1986, Research Stations Board approached Land Resources Branch to undertake a soil survey of the station. Soils information is required for planning soil conservation and irrigation layouts, and to ensure that experimental plots are located on uniform areas of soils.

This report details the results of a survey undertaken during March 1986.

2. DESCRIPTION OF THE AREA

2.1 Physiography

The research station site is predominantly flat with a gentle slope (<2%) to the north east. It is drained by a shallow creek which has been excavated to provide a waterhole at the north-eastern corner of the property.

2.2 Geology

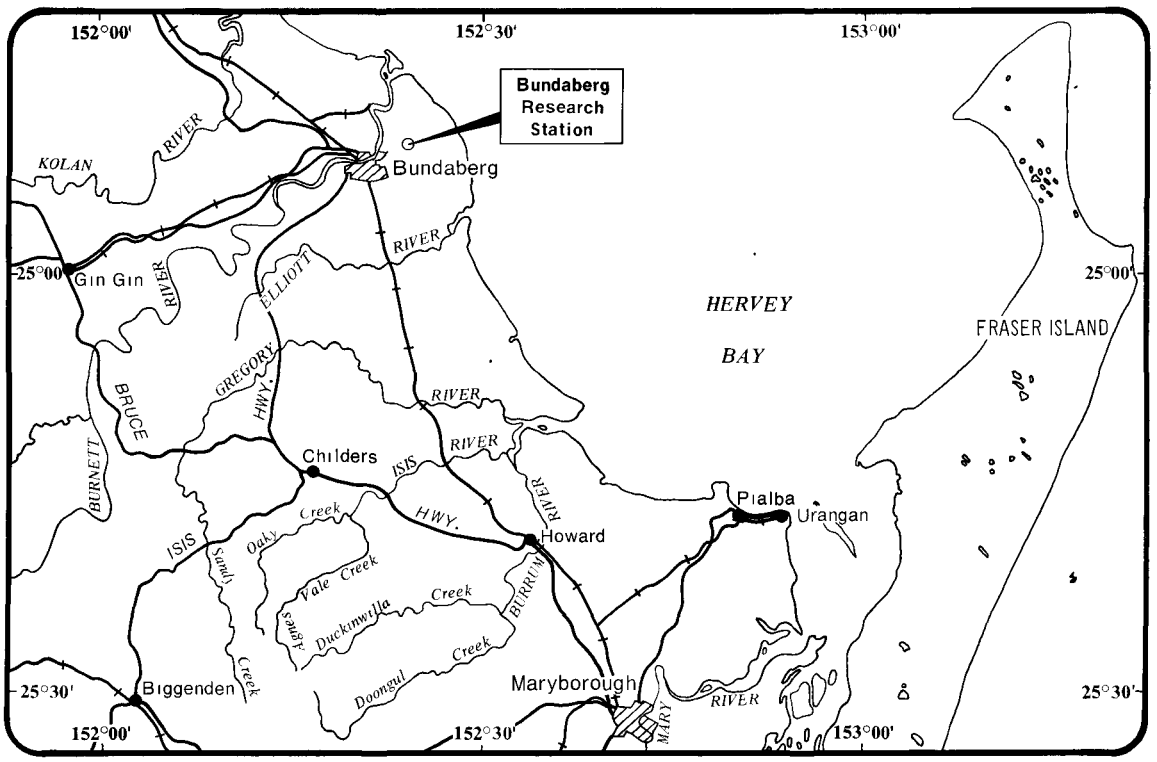
The soils have developed on olivine basalt and basalt-derived colluvium. The basalts are of Quaternary age (0.6 to 0.9 million years) and originated from vents at Sloping Hummock which lies some 3 km to the east (McTaggart 1960).

The flows were vesicular and scoriaceous and have been subjected to deep weathering. The basalts flowed over the flat-lying Tertiary Elliott surface which was dissected in this area by coastal drainage patterns.

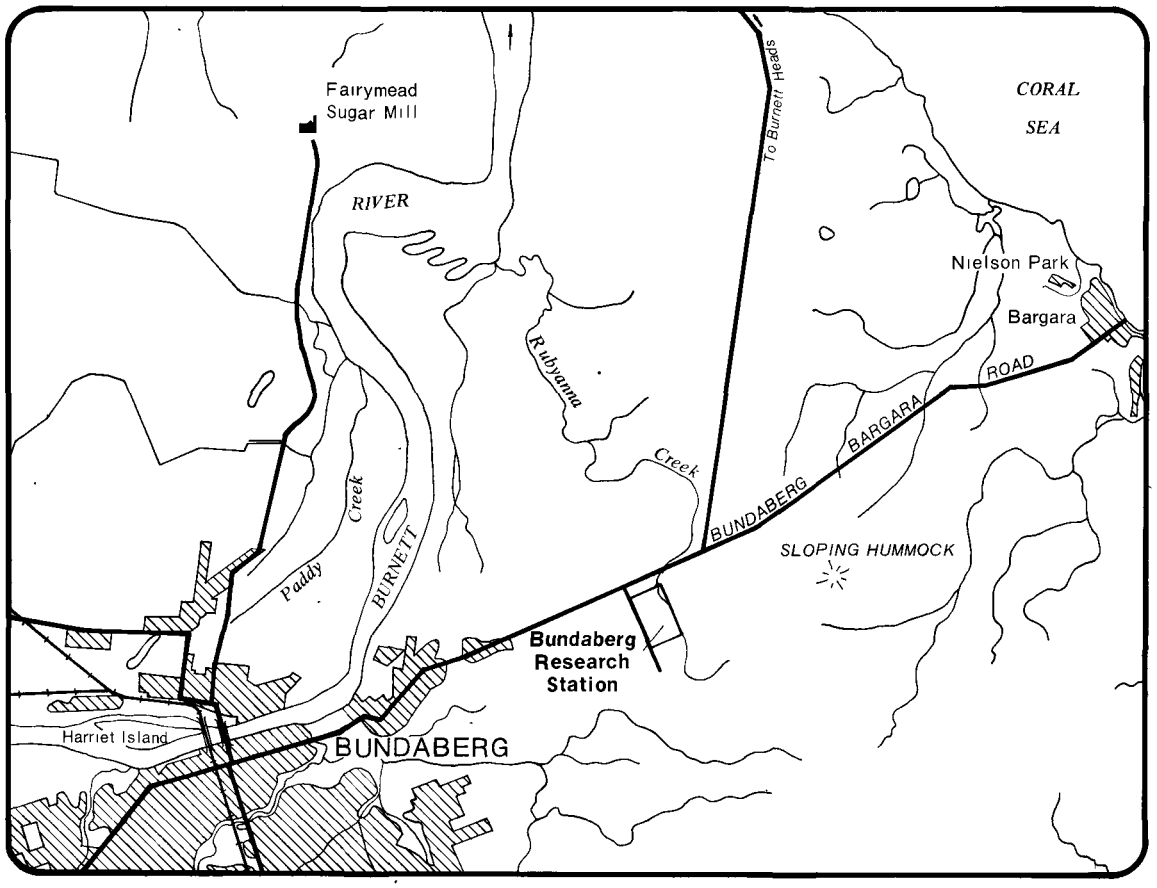
2.3 Climate

The climate of the area is subtropical with summer dominant rainfall. January and February are the highest rainfall months and some 46% of total average rainfall is received from December to March.

Cyclones have a significant effect on rainfall with a return frequency of about 1 in 10 years. In addition, summer rainfall is strongly influenced by cyclonic weather patterns which develop off the tropical Queensland coast. Mean monthly rainfall and the number of rain days for Bundaberg are given in Table 1.



(a) Regional locality map



(b) Detailed locality map

Figure 1. Locality maps

Rainfall is the major limiting factor to crop production (Leverington, 1986). Evaporation exceeds rainfall from May to December inclusive (Figure 2). This highlights the importance of irrigation for optimal crop production in the Bundaberg district.

Table 1. Mean monthly rainfall and number of rain days for Bundaberg (Bureau of Meteorology - Rainfall Statistics, Queensland 1966)

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
Mean monthly rainfall (mm)	219	179	140	82	66	69	54	32	38	61	81	132	1 153
Number of rain days	12	12	12	8	7	6	5	4	5	7	8	9	95

Mean monthly maximum and minimum temperatures for Bundaberg are given in Table 2. Maximum temperatures do not vary greatly throughout the year and the district is considered to have a very equitable climate. Frosts are rare in the district.

Table 2. Mean monthly maximum and minimum temperatures for Bundaberg

Month	J	F	M	A	M	J	J	A	S	O	N	D
Mean maximum temp. °C	29.8	29.7	29.0	27.4	24.5	22.4	21.6	23.2	25.0	27.0	28.4	29.3
Mean minimum temp. °C	21.4	21.3	20.0	17.7	14.2	11.9	10.1	11.4	13.8	17.0	19.3	20.5

2.4 Vegetation

All of the original vegetation has been cleared for sugar-cane production. Vegetation type boundaries in the Bundaberg area generally followed the boundaries of the major soil series (King 1949).

The vegetation on the Woongarra soil type (Table 3) was described as closed forest or monsoon forest. Composition was very complex with more than 90 tree species identified (King 1949). Vegetation for this soil was described as vine scrub in Stace et al. 1968, P305. Species included crows ash (Flindersia australis), leopard ash (F. collina), silver ash (F. schottiana), tulipwood (Harpullia pendula), Moreton Bay fig (Ficus macrophylla), Burdekin plum (Pleiogynium cerasiferum) and yellow hollywood (Vitex lignum-vitae). It is also suggested by Stace et al (1968) that a grassy forest of Moreton Bay ash or carbeen (Eucalyptus tessellaris), Queensland blue gum (E. tereticornis) and patches of closed forest known as 'softwood scrub' were probably

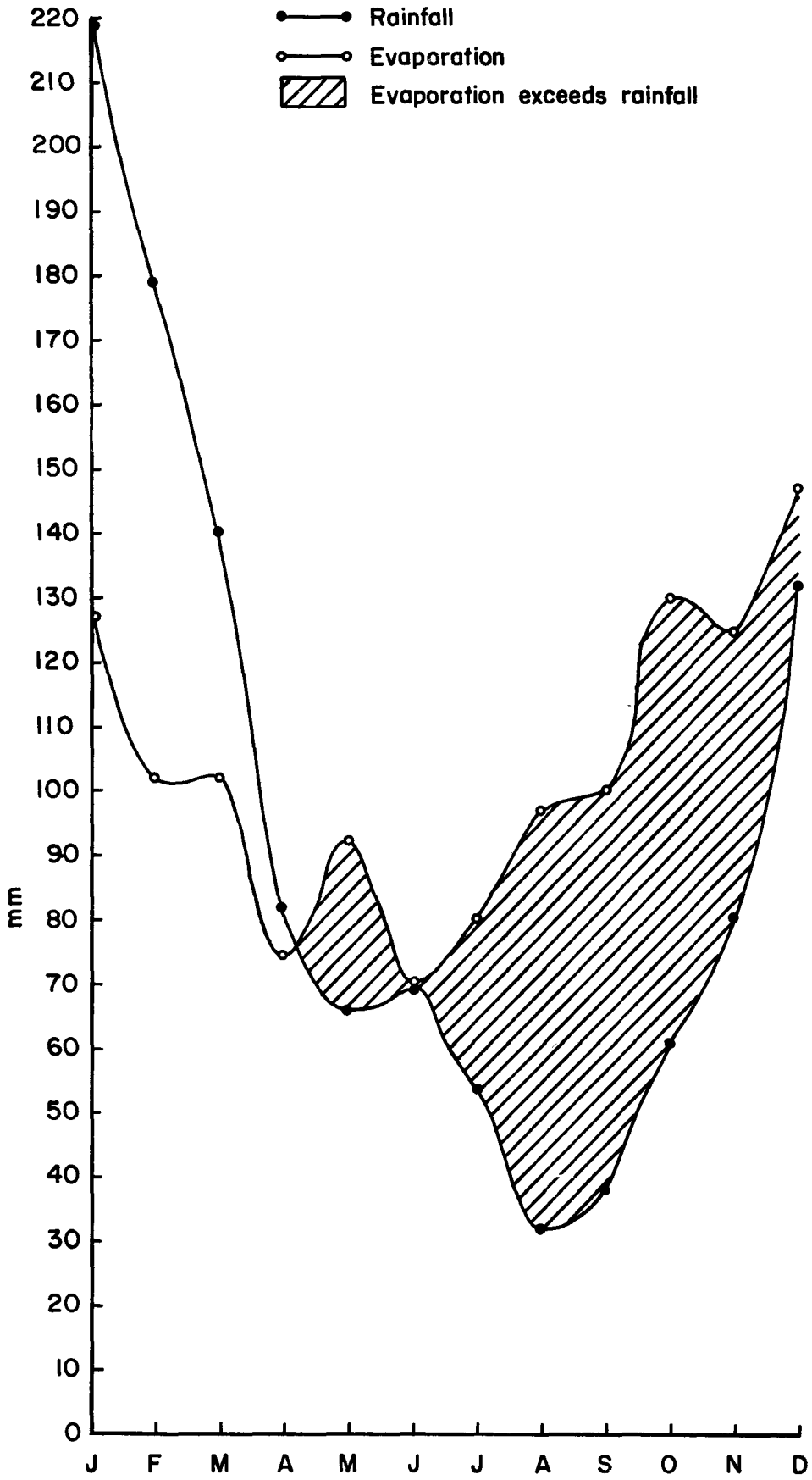


Figure 2. Mean monthly rainfall and evaporation for Bundaberg. Source: Leverington (1986)

growing on the prairie soil. Former vegetation on the xanthozem is unknown.

3. SOIL SURVEY METHOD

Soils on the research station were described and classified at 90 sites located on a 50 m x 75 m grid. Several grid lines which crossed established sugar-cane blocks were relocated to suit existing laneways for easier access. Additional sites were examined where necessary to assist in soil boundary delineation.

Soil types were mapped at a scale of 1:2 500, and were given names of local significance. Eight representative soil profiles were sampled at standard depths for detailed laboratory analysis. Surface soil fertility was assessed from bulk 0 to 0.1 m samples taken at each grid point.

4. SOILS - MORPHOLOGY AND CLASSIFICATION

4.1 Morphology

From the field survey, three soil types (Table 3) were identified and mapped. These soils are similar to soils already described for the area (Leverington 1986), and the Woongarra soil closely matches the Woongarra Type 1 soil described by King (1949). Detailed soil morphological descriptions are tabulated in Appendix 1.

Table 3. Major distinguishing attributes of the soils

Soil type	Major distinguishing attributes	Great Soil Group	PPF
Woongarra (Wg)	Dark reddish brown light clay to 0.85 - 0.9 m over dark red neutral to alkaline light clay to 1.50 m. Occasional yellow weathered basalt gravel.	Euchrozem	Uf6.31
Telegraph (Tg)	Dark brown light clay to 0.15 - 0.2 m over brown to yellow brown, occasionally mottled, light clay to 0.65 - 1.40 m abruptly underlain by grey (gleyed) mottled acid medium heavy clay. Occasional weathered basalt gravel or stone.	Xanthozem	Uf6.31 Uf6.4
Ashgrove (Ag)	Brownish black clay loam to light clay to 0.10 - 0.25 m overlying ferromanganiferous nodular pan to 0.15 - 0.70 m, abruptly underlain by grey (gleyed) mottled acid medium heavy clay. Occasional yellow brown, mottled, medium clay B horizon to 0.55 m. Occasional weathered basalt gravel.	Prairie soil	Gn3.92 Uf6.4

The three soils can be easily identified by surface soil colour and by their position in the landscape (Figure 3). The euchrozem occurs on the mid to upper slopes, the xanthozem in the mid to lower slope position with the prairie soil at the base of the slope. Soil distribution strongly reflects the poorer drainage that is found downslope.

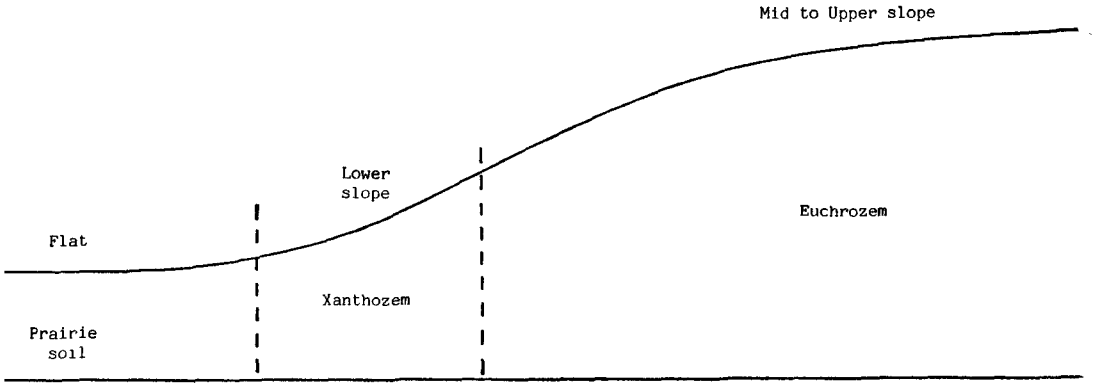


Figure 3. Topographic soil sequence of Bundaberg Research Station (not to scale)

The euchrozem is the major soil on the station and occupies 77% of the total area. The xanthozem and prairie soil occupy 15% and 8% respectively.

Large amounts of rock fill have been dumped on the prairie soil in the north eastern corner of the property making characterisation of the prairie soil difficult. This material has come from excavation of the waterhole in the creek or from 'floaters' (basalt corestones) removed from elsewhere on the station. Floaters occur in profiles of both the xanthozem and prairie soil and rise to the surface through time.

4.1.1 Euchrozem (Woongarra)

These soils have previously been classified as Krasnozems (Stace et al. 1968, p.305). However, laboratory analysis shows a pH (1:5) range of 6.8 to 7.1 at 0.9 m in the sampled profiles and the soils have thus been reclassified as euchrozems.

The Woongarra euchrozem is deep (>1.5 m), strongly-structured, with uniform clay textures throughout. Years of continuous cultivation have generally destroyed the structure of the top 0.2 to 0.3 m. In addition, a hard, dense compaction layer has developed between 0.05 and 0.3 m possibly as a result of the frequent use of rotary hoes. One profile exposure showed compaction to a depth of 0.65 m.

This soil shows remarkable uniformity throughout the station in having the compaction layer and a characteristic colour change from very dark reddish brown to dark red at 0.85 to 0.9 m.

4.1.2 Xanthozem (Telegraph)

This soil has greater profile variability than the euchrozem and its depth ranges from shallow to moderately deep. It overlies a grey, mottled, heavy clay at depths ranging from 0.6 to 1.4 m.

The xanthozem has slightly impeded external drainage associated with its position on the slope and the impermeable nature of the underlying clay. The presence of manganiferous and ferromanganiferous nodules in the profile is indicative of slow drainage and the occurrence of seasonally perched watertables.

Long term cultivation has also generally destroyed surface structure, but the compaction layer is not as dense as that found in the euchrozem. A red variant, identified at some sites, is considered to be a transitional soil which intergrades between the euchrozem and the xanthozem.

4.1.3 Prairie soil (Ashgrove)

This soil type is shallow and abruptly overlies a manganiferous pan indicative of prolonged periods of wetness or a fluctuating watertable. The pan in turn abruptly overlies a heavy, mottled and gleyed clay subsoil similar to that underlying the xanthozem and may be a continuous layer underlying both soils.

Long term cultivation has also generally destroyed surface structure, however no compaction layer was evident.

4.2 Classification

Table 4 shows the soils classified into Great Soil Groups (Stace et al. 1968), Principal Profile Forms (Northcote 1979) and Soil Taxonomy subgroups (Soil Survey Staff 1975).

Table 4. Classification of the Bundaberg Research Station soils

Soil type	Great Soil Group	Principal Profile Form	Soil Taxonomy Subgroup
Woongarra	Euchrozem	Uf6.31	Tropeptic eutrustox
Telegraph	Xanthozem	Uf6.31, Uf6.4	Tropudult
Ashgrove	Prairie soil	Gn3.92, Uf6.4	Aquic dystropept

5. SOILS - CHEMICAL AND PHYSICAL PROPERTIES

5.1 General

Eight representative soil profiles were described and sampled for detailed laboratory analysis. In addition, bulked 0 to 0.1 m samples were taken at each of 90 grid points to assess surface fertility. Analytical methods are described in Bruce and Rayment (1982).

As the Woongarra euchrozem represented the major area of the station, five profiles were sampled for analysis. Two profiles of the Telegraph xanthozem were sampled, one being a red variant, and one profile of the Ashgrove prairie soil was sampled.

Table 5. Soil fertility related measurements in the surface 0 to 0.1 m of the Bundaberg Research Station soils

		pH (1:5)	Bicarb P ppm P	Extr. K m. equiv.%	ppm cu	DTPA Extractable ppm Zn	ppm Mn	Total Nitrogen%	Organic Carbon%
WOONGARRA									
	Range	5.7-7.1*	35-200	0.38-2.0	6-24	6.1-16	215-345*	0.15-0.20	1.4-1.9
	Mean	6.3	67	0.94	15	8.5	302	0.18	1.6
Standard	Deviation	0.28	23	0.34	4	1.5	28	0.01	0.14
	Rating	medium acid to neutral	medium to very high	medium to very high	high to very high	high to very high	high	medium	low to medium
TELEGRAPH									
	Range	5.8-7.1	41-165	0.26-0.91	3.9-6.5	5.4-11*	220-310	0.15-0.20	1.3-1.8
	Mean	6.4	73	0.65	5.3	6.8	274	0.17	1.6
Standard	Deviation	0.35	35	0.19	0.87	1.7	26	0.01	0.16
	Rating	medium acid to neutral	medium to very high	medium to high	medium to high	high	high	medium	low to medium
ASHGROVE									
	Range	6.0-6.8	61-130	0.39-1.0	4.0-5.2	7.5-15*	153-300	0.13-0.25	1.1-2.8
	Mean	6.3	91	0.64	4.5	9.8	238	0.19	1.8
Standard	Deviation	0.30	20	0.19	0.47	2.4	55	0.04	0.62
	Rating	slightly acid to neutral	medium to very high	medium to high	medium	high	high	medium	low to high

Note: Values are on 40°C air dry basis

* One atypical value excluded from the general range

Profile morphology and analytical results for the sampled profiles are given in Appendix II.

The results of the laboratory analyses and soil test interpretations are applicable to the Bundaberg Research Station only and should not be extrapolated to similar soils in the Bundaberg district without further investigation.

5.2 Fertility

Soil fertility data for the surface 0 to 0.1 m for the three soil types are given in Table 5. Mean, range and standard deviation values provide a clear indication of the variability in fertility.

5.2.1 pH

Surface pH ranges from medium acid (5.7) to neutral (7.1) with a mean of 6.3 $\pm$ 0.3 for all soils. Surface (0-0.1 m) pH was found to be unrelated to soil type. The highest pH recorded was sampled near the site of the old Ashgrove Sugar Mill and it is assumed that this high pH (8.0) is a result of past activities at the mill.

Woongarra and Ashgrove have neutral soil reaction trends (field pH), in comparison to Telegraph which has an acid soil reaction trend.

5.2.2 Phosphorus and potassium

Medium to very high levels of bicarbonate phosphorus (bicarb-P) and extractable potassium (extr-K) are found in the surface 0 to 0.1 m. Ranges for these properties are from 35 to 200 ppm P and 0.26 to 2.0 m.eq.100g^{-1}K. These levels are adequate for plant growth though fertiliser may be required for maximum production of some vegetable and horticultural crops. The variability in surface soil results may reflect inherent soil variability, past management practices or past uneven application of fertiliser.

5.2.3 DTPA extractable copper, zinc and manganese

Medium to very high levels of DTPA extractable copper (Cu), zinc (Zn) and manganese (Mn) were found and their distribution across the station is shown in Figures 4.1, 4.2 and 4.3.

DTPA (Mn) levels are consistently high with values ranging from 238 to 302 ppm Mn. The exception is site AO, Ashgrove Sugar Mill site, (Figure 4) where a level of 75 ppm was recorded. This is probably a result of the mill activity and may be associated with the high surface pH of 8.0.

DTPA (Cu) ranges from 3.9 ppm to 24 ppm with results indicating that soil type relates to micronutrient levels (Table 5). The Woongarra soil shows a range for copper of 6 ppm to 24 ppm, with 73% of sites greater than 15 ppm which is very high. The remaining 27% range from 7.3 ppm to 14 ppm and encompass the southern corner (Figure 4). Mean copper levels for the Telegraph and Ashgrove soils are lower than the Woongarra soil and range from 3.9 ppm to 6.5 ppm (medium to high rating).

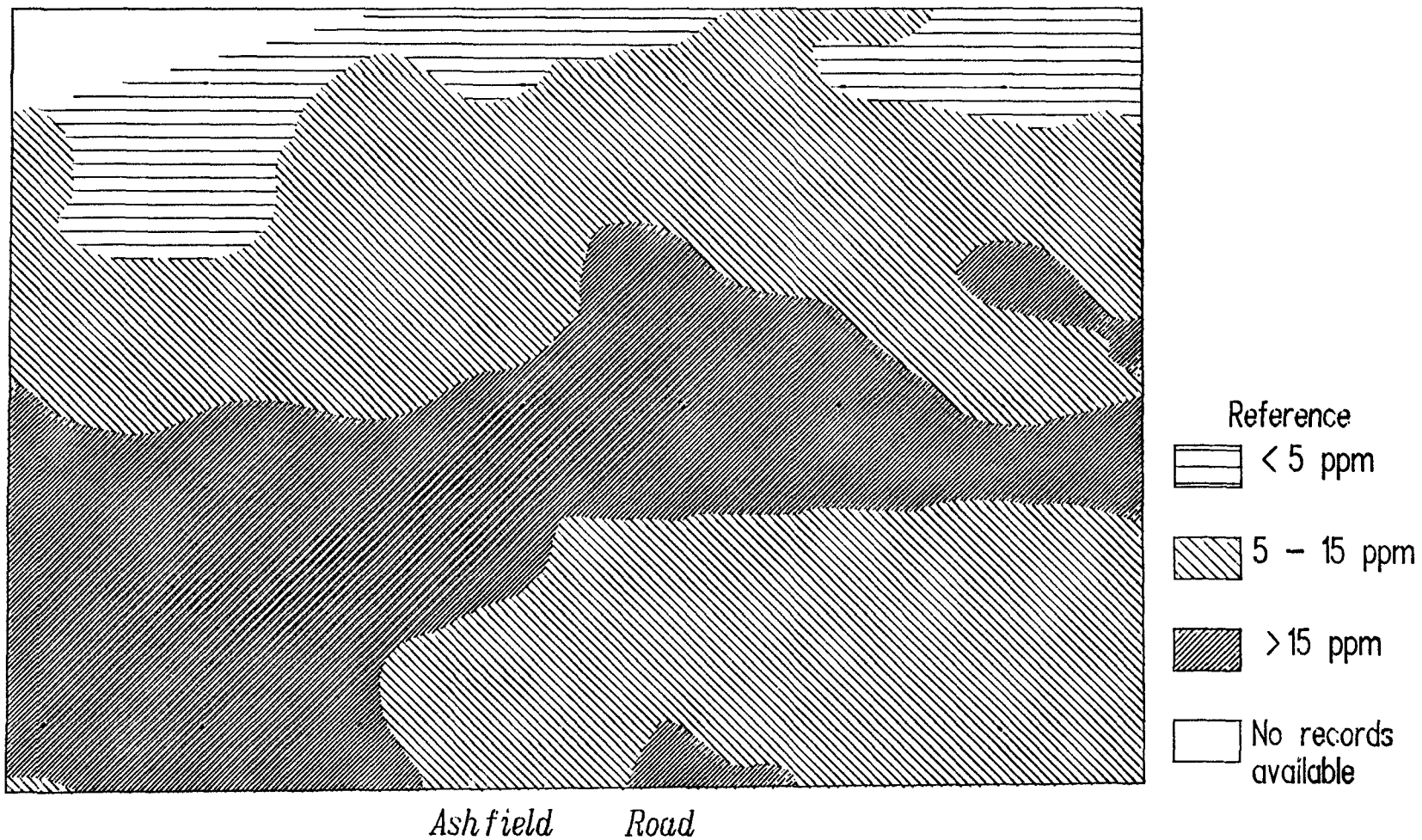


Figure 4.1 Soil DTPA Copper (ppm) levels for the soil depth 0 to 0.1m at the Bundaberg Research Station.

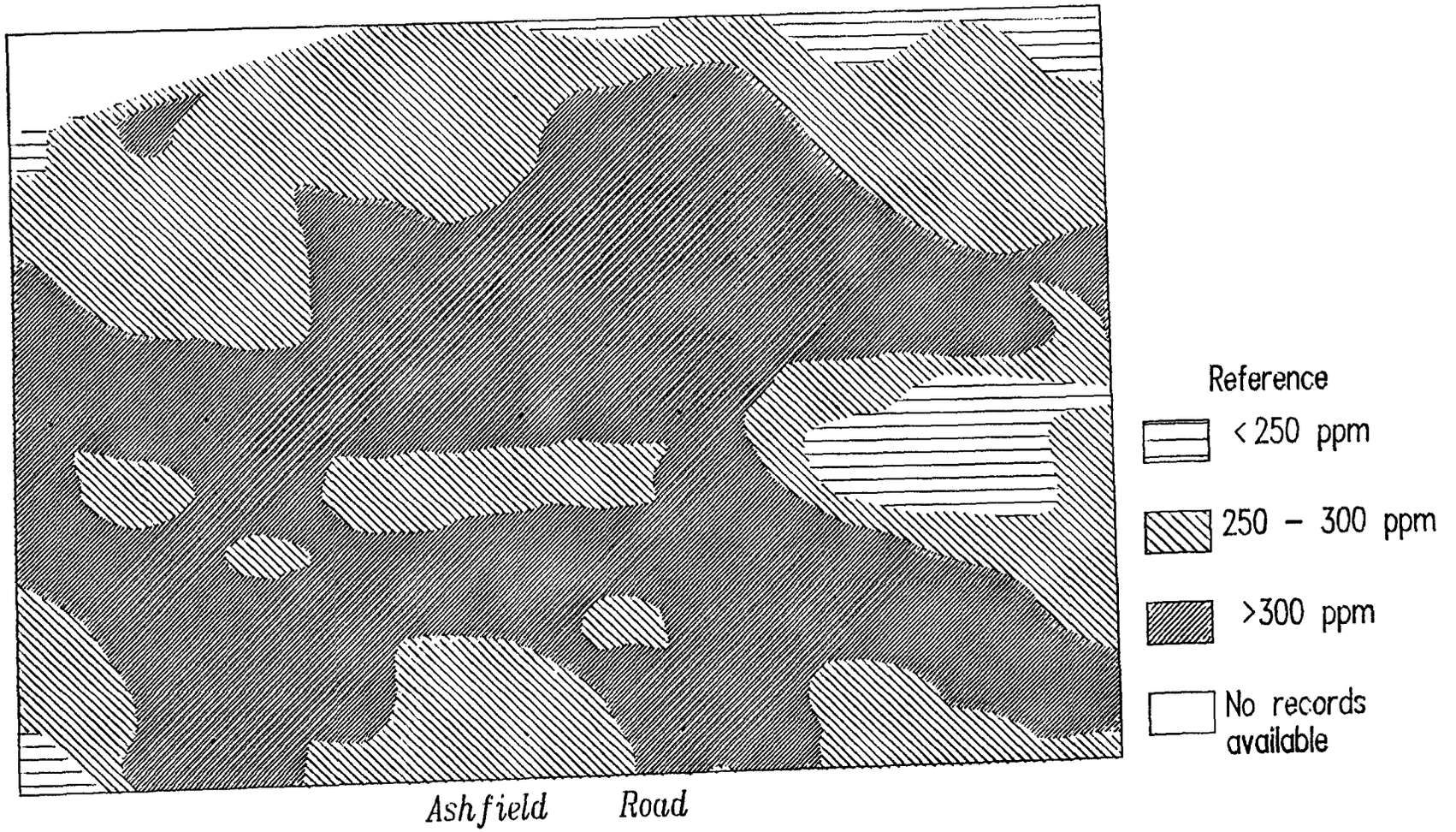


Figure 4.2 Soil DTPA Manganese (ppm) levels for the soil depth 0 to 0.1m at the Bundaberg Research Station.

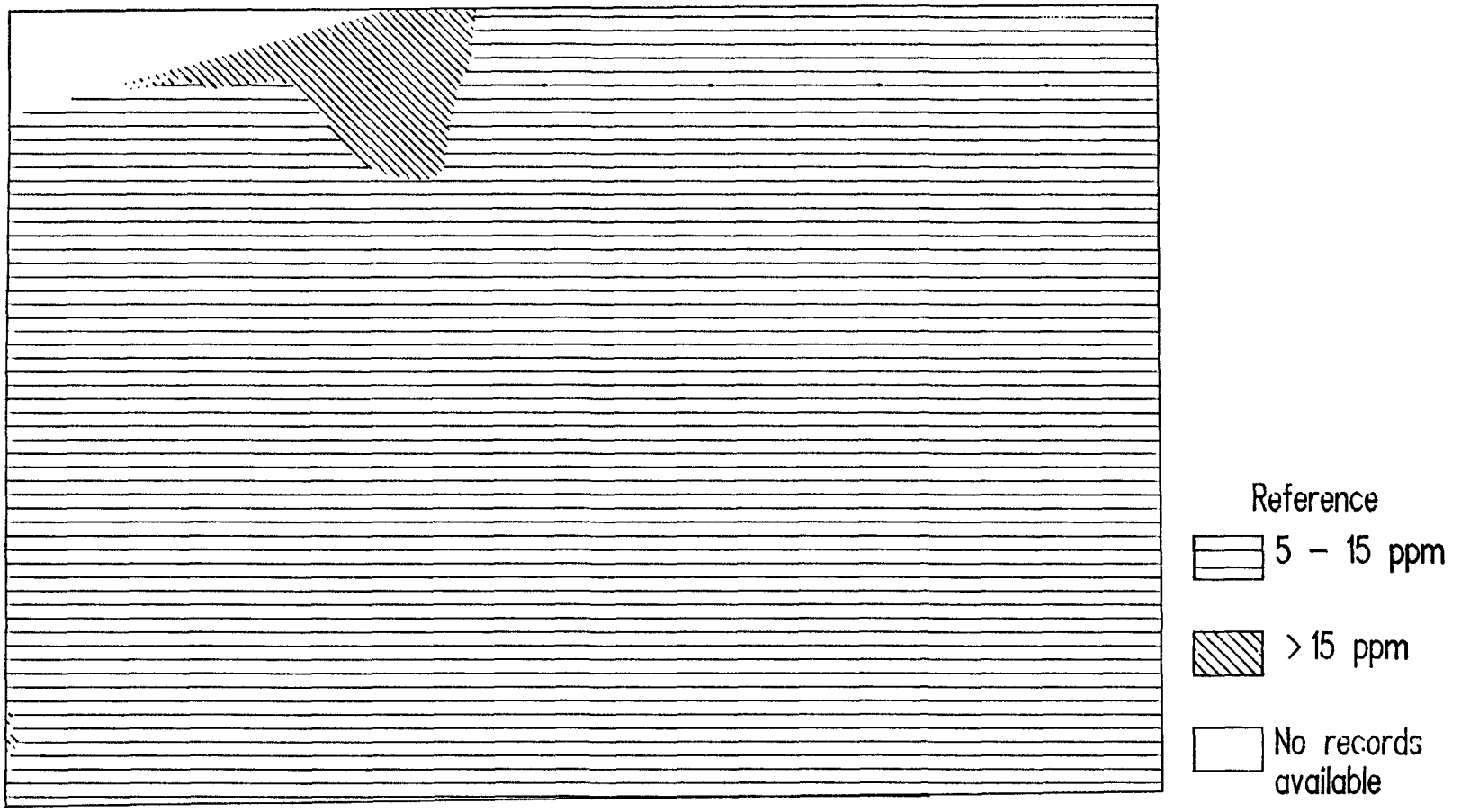


Figure 4.3 Soil DTPA Zinc (ppm) levels for the soil depth 0 to 0.1m at the Bundaberg Research Station.

R. Ridge (pers. comm.) measured levels of DTPA extractable copper, zinc and manganese in the profiles of krasnozems, as part of a Bureau of Sugar Experiment Station (BSES) soil monitoring programme in the Bundaberg area. The ranges and means of these elements based on analysis at three sites are given in Table 6.

Table 6. Trace element levels at BSES soil monitoring stations

Depth (m)	DTPA extractable Cu (ppm)		Zn (ppm)		Mn (ppm	
	range	mean	range	mean	range	mean
0 to 0.25	6.2-7.5	6.7	8.2-11	10.1	28-60	49
0.25 to 0.5	3.6-5.5	4.4	6.2-7.8	7.2	11-39	23
0.5 to 0.75	1.84-2.7	2.3	2.3-4.6	3.5	1.5-11	5.2

Source: (R. Ridge pers. comm.)

Extractable Cu levels below 0.25 m in Table 6 are comparable to those found in the Woongarra soil below 0.2 m (Table 7), although levels in the surface 0 to 0.1 m layer of the Woongarra soil are considerably higher than those reported by Ridge.

Extractable Zn levels to 0.3 m in the Woongarra soil, although lower than those found by Ridge, are rated as medium to high (Bruce and Rayment 1982).

The levels recorded from this survey and the BSES soil monitoring programme suggest that the krasnozems and euchrozems in the Bundaberg district are naturally high in copper and zinc.

Table 7. Mean DTPA trace element levels in sampled profiles

Depth (m)	Cu (ppm)			Zn (ppm)			Mn (ppm)		
	Wg	Tg	Ag	Wg	Tg	Ag	Wg	Tg	Ag
0 to 0.1	14.0	5.7	4.4	8.3	6.0	8.8	314	303	245
0.2 to 0.3	4.2	2.2	4.5	4.1	2.1	20.0	169	75	178
0.5 to 0.6	1.2	0.9	0.6	1.1	0.7	0.7	54	80	59

5.2.4 Total nitrogen and organic carbon

Data in Table 5 show total nitrogen (N) ranges from 0.13% to 0.25% while organic carbon ranges from 1.1% to 2.8%. Sites J7 and J9 have the highest organic carbon levels (2.2% and 2.8%), which may be the result of being under grass pasture for longer periods than the other soils.

5.2.5 Sulphate - sulphur

Sulphate - sulphur values in the surface 0 to 0.1 m are rated high for all profiles (>20 ppm), except for profile I8 which rated medium (18 ppm). These values are considered to be adequate for plant growth.

5.2.6 Exchangeable cations and effective CEC

Effective cation exchange capacity (CEC) was determined by summation of exchange acidity, and exchangeable calcium, magnesium, sodium and potassium. Methods of extraction are those outlined in Bruce and Rayment (1982).

CEC values in the surface 0 to 0.1 m for Woongarra and Telegraph profiles range from 4 to 11 m. equiv. $100g^{-1}$ with 20 m. equiv. $100g^{-1}$ being recorded for the Ashgrove profile. These values are indicative of soils with a low exchange capacity and which are probably dominated by kaolinitic clay minerals.

Profiles on the upper slopes (B_2, B_7 and F_2) are magnesium dominant with calcium/magnesium ratios of 0.5 to 0.6, while the remaining profiles downslope become more calcium dominant with calcium/magnesium ratios of 1.0 to 1.6.

5.3 Chloride and sodicity

All profiles have very low to low levels of chloride at the analysed profile depths (Table 8).

Table 8. Chloride and sodicity levels in sampled profiles

Soil type	% Chloride		Sodicity (ESP)*	
	0-0.1 m	0.8-0.9 m	0-0.1 m	0.8-0.9 m
Wg (B2)	0.002	0.003	1.1	2.8
Wg (B7)	0.003	0.008	2.6	13.0
Wg (F2)	0.003	0.004	2.4	2.8
Wg (G6)	0.001	0.012	2.7	2.2
Wg (I6)	0.001	0.012	4.3	6.7
Tg (I4)	0.002	0.008	1.8	6.8
Tg (I8)	0.001	0.029	2.9	12.6
Ag (J8)	0.016	0.013	4.8	7.0

* Non-sodic = <6 <after Northcote and Skene 1972)
sodic = 6-14

The Woongarra profiles are generally non-sodic to 0.9 m, although profiles B7 and I6 are sodic <ESP 13 and 6.7) at this depth. The high ESP for profile B7 is considered atypical for this soil. The Telegraph and Ashgrove profiles are non-sodic at the surface but are sodic at 0.8 to 0.9 m. These profiles and Woongarra profile I6 are situated in lower slope positions (toeslope). Data from the survey indicates that a seepage salting outbreak is developing in this area. Electrical conductivity measurements from the fluctuating watertable showed values of 4.8 to 7.6 dS/m.

5.4 Particle size distribution and clay activity

Clay percentages of Woongarra profiles range from 71 to 76% in the surface 0 to 0.1 m, to 68-79% at 1.1 to 1.2 m. The measured clay percentages are considerably higher than indicated by field textures

which were consistently recorded as light clay. The discrepancy is believed to be due to high subplasticity (Northcote 1979), or problems of dispersion which occur with iron-rich, fine grained, kaolinitic clays. King (1949) made similar observations in a survey of the Bundaberg area in which mechanical analysis showed an average of 75.2% clay to a depth of 1.22 m, yet textures were recorded as loamy.

The Telegraph soil showed similar discrepancies between field texture and laboratory clay percentage while the field texture of the Ashgrove soil more accurately reflected laboratory clay percentage.

Clay activity values as measured by CEC/clay for Woongarra and Telegraph profiles are <0.2 suggesting that these profiles are dominantly kaolinitic clays. Clay mineralogy is available for only one profile which was described as a krasnozem (Profile B) in Stace et al. (1968). Mineralogical analysis of the clay fraction of this site which is less than 500 m west of the present study area showed 80% Kaolin at a depth of 0.2 to 0.3 m with 65 to 80% kaolin at 1.5 to 1.8 m.

6. SOIL MANAGEMENT

6.1 Land capability classification

The limitations for long-term agricultural use under dryland farming at the research station using the Land Capability Classification of Rosser et al. (1974) are given in Table 9. The description of the limiting factors and the degree of limitation of each, together with the subclass symbols are given in Appendix IV. Descriptions of the land capability classes applicable to the station are shown in Appendix V.

Table 9. Land capability classification of the Bundaberg Research Station soils

Soil type	Class	Limitations
Woongarra	III	c2 m2 p3 n2 k3 e2
Telegraph	III	c2 m2 d3 p3 n2 w3 e2
Ashgrove	IV-VI	c2 m2 d4-6 p4 n2 s4 k2-3 r2 w3 e2 f2

6.2 Morphological limitations

As irrigation supplies are available on the station, the limitations of plant available water capacity of the soils are of less concern than under dryland farming conditions. The major limitations of the soils which will affect crop growth and management are as follows:

6.2.1 Woongarra

Long-term cultivation particularly with a rotary hoe, and harvesting under wet conditions have developed a distinct compaction layer between 0.05 and 0.3 m although in places it may be as deep as 0.65 m. This compaction layer, unless broken up, will severely restrict root growth and water infiltration, and depress crop production. Deep-ripping in

several directions and the incorporation of green manure crops are recommended to reduce this limitation.

6.2.2 Telegraph

The major limitation to crop growth on this soil is the presence at shallow depth (0.20 to 0.65 m) of a yellow, poorly permeable clay which overlies mottled and gleyed clays from as shallow as 0.65 m. Large amounts of manganese and ferromanganiferous nodules in the profile also indicate the presence of seasonal watertables.

With prolonged irrigation, this soil may require drainage to ensure continued crop growth. This soil is not suited to tree crops which require free drainage below 0.2 to 0.65 m.

6.2.3 Ashgrove

The major limitations of this soil are its shallow soil depth (often less than 0.25 m), shallow watertable and the presence of rock and a ferromanganiferous hardpan which occurs from 0.25 to 0.45 m depth. This hardpan is semi-continuous, cannot be easily penetrated by a backhoe and is a severe physical restriction to root growth. The pan is porous and filled with water-saturated, gleyed clay. Water quality measurements from the perched watertable in August 1986 showed electrical conductivity values of 4.8 to 7.6 dS/m. These levels are sufficiently high to affect growth of most crops grown in the Bundaberg district.

Monitoring of watertable depth and quality and the implementation of an effective drainage system are required in this soil as this watertable is likely to rise in response to irrigation.

This soil is considered marginal for long-term cultivation and intensive management will be required to maintain productivity.

6.3 Chemical limitations

Laboratory analyses reported high levels of copper, and to a lesser extent zinc in the surface 0 to 0.1 m.

Rayment and Brooks (1974) found that in citrus orchards in southern Queensland, soil copper and zinc levels in the surface 0 to 0.15 m increased with orchard age. A similar trend was also found for copper (Rayment and Brooks 1974) in a survey of banana plantations on podzolic and red basaltic soils in north Queensland. No evidence was found of zinc accumulation in either of these soils growing bananas.

Rayment and Brooks (1974) concluded that the increase in soil levels of copper and zinc was probably due to excessive drip from foliar applications of copper and zinc-based fungicides. It is possible that a similar development could occur in soils on the station.

The use of copper and zinc-based fungicides needs to be moderated as high application rates may cause copper and zinc to reach toxic levels. A soil monitoring programme is recommended to establish the levels of DTPA extractable copper and zinc where toxicity to the common crops occur.

7. ACKNOWLEDGEMENTS

The authors would like to thank the following people for their assistance in the successful completion of this work:

. Mr G. MacGregor, Farm Manager, Bundaberg Research Station;

. Messrs J. Klein and P. Hayes, Soil Conservation Services Branch for locating the sampling grid;

. Drafting Section of the Division of Land Utilisation for drafting the map and preparation of figures;

. Soils laboratory staff of the Agricultural Chemistry Branch for undertaking the soil chemical and physical analysis;

. Messrs B. Powell and R. Reid for editing the manuscript;

. The very patient typists Miss J. Collett, Mrs C. Payne and Miss D. Hanfling for preparing the manuscript and the earlier drafts.

8. REFERENCES

Bruce, R.C. and Rayment, G.E. (1982), Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys, Queensland Department of Primary Industries, Bulletin QB82004.

King, N.J. (1949), Soil investigations in the sugar-cane producing areas of Bundaberg, Queensland Journal of Agricultural Science **6**, 141-176.

Leverington, A.R. (1986), Evaluation of agricultural land: Woongarra Shire, Queensland Department of Primary Industries, Project Report Q086005.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1984), Australian Soil and Land Survey Field Handbook, (Inkata Press, Melbourne).

McDonald, R.C. (1986), Soil Classification Workshop Maryborough-Bundaberg, 6-9 November 1984, Queensland Department of Primary Industries, Conference and Workshop Series QC86008.

McTaggart, N. (1960), Lower Cainozoic; Bundaberg-Gin Gin, Journal Geological Society, Australia, **7**, 351.

Northcote, K.H. (1979), A Factual Key for the Recognition of Australian Soils, 4th Edition (Rellim Technical Publications: Glenside, South Australia).

Northcote, K.H. and Skene, D.J.M. (1972), Australian soils with saline and sodic properties, CSIRO Australia, Division of Soils, Soil Publications 27.

Rayment, G.E. and Brooks, G.W. (1974), Using the DTPA soil test to define high copper, manganese and zinc levels in Queensland soils, in Australian Soil Science Conference Working Papers, Latrobe University, Melbourne, Victoria, February 1974. pp. 4-1 to 4-4 (Canberra, 1974).

Rosser, J., Swartz, G.L., Dawson, N.M. and Briggs, H.S. (1974), A land capability classification for agricultural purposes, Queensland Department of Primary Industries, Division of Land Utilisation Technical Bulletin Number 14.

Soil Survey Staff (1975), Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, United States Department of Agriculture, Agriculture Handbook 436 (United States Government Printing Office: Washington DC).

Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. (1968), A Handbook of Australian Soils, (Rellim Technical Publications: Glenside, South Australia).

van Wijk, C.L. and Crack, B.J. (1972), Map and unpublished report on the Bundaberg Irrigation Project, Queensland Department of Primary Industries and Irrigation and Water Supply Commission.

APPENDIX I

Detailed morphological descriptions of soil types

Notes:

General: Soil types are presented in the same order as in the map reference.

Soil Profile Morphology:

. The most commonly observed ranged of profile attributes is described, together with less requent variations outside this range.

. The soil profile diagram indicates upper and lower depth limits of each horizon.

. Soil profiles are described according to McDonald and Isbell (1984).

. Colour: Moist colours were recorded using the revised Standard Soil Colour Chart (Oyama and Takehara 1967).

. Field pH: As per Raupach and Tucker (1959) and Soil Survey Staff (1951).

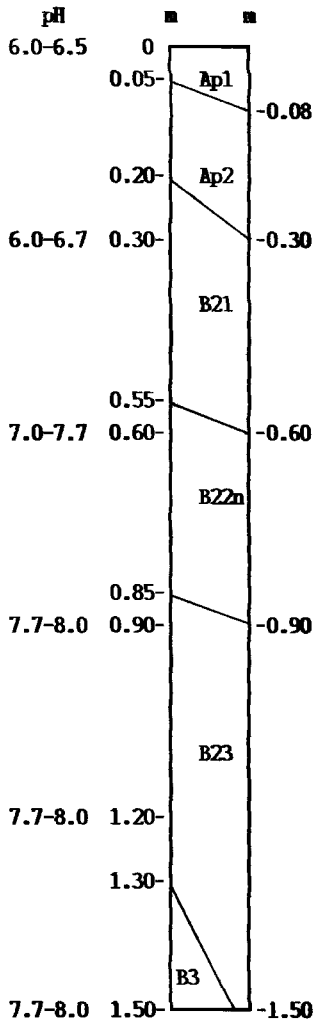
References:

McDonald, R.C. and Isbell, R.F. (1984), Soil Profile, In, Australian Soil and Land Survey Field Handbook, (McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S.) (Inkata Press, Melbourne).

Oyama, M. and Takehara, H. (1967), Revised Standard Soil Colour Charts, (Fujihara Industry Co. Ltd: Tokyo).

Raupach, M. and Tucker, B.M. (1959), The field determination of soil reaction, Journal of the Australian Institute of Agricultural Science 25, 129-133.

Soil Survey Staff (1951), Soil Survey Manual, United States Department of Agriculture, Agriculture Handbook Number 18 (United States Government Printer: Washington DC).

Soil Type	P.P.F.	Profile diagram	Description of the soil type	Landscape unit
Woongarra	Uf6.31		**Euchrozem:**	Upper slope position on gently undulating plain

Surface condition: cultivated, loose

Ap1 horizon: Dark reddish brown (2.5YR 3/3); light to light medium clay; strong <2mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-

Ap2 horizon: Dark reddish brown (2.5YR 3/3); light to light medium clay; weak fragments; dry moderately firm to very firm; very few fine ferromanganiferous nodules. Clear or abrupt to-

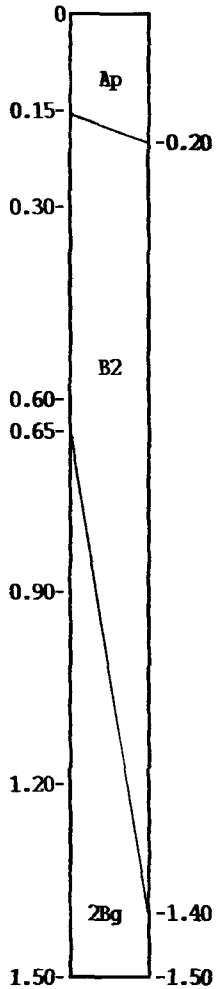
B21 horizon: Dark reddish brown (2.5YR 3/4); light clay; moderate 5-20 mm polyhedral; dry to moderately moist moderately firm to very firm; very few fine ferromanganiferous veins and nodules. Clear to-

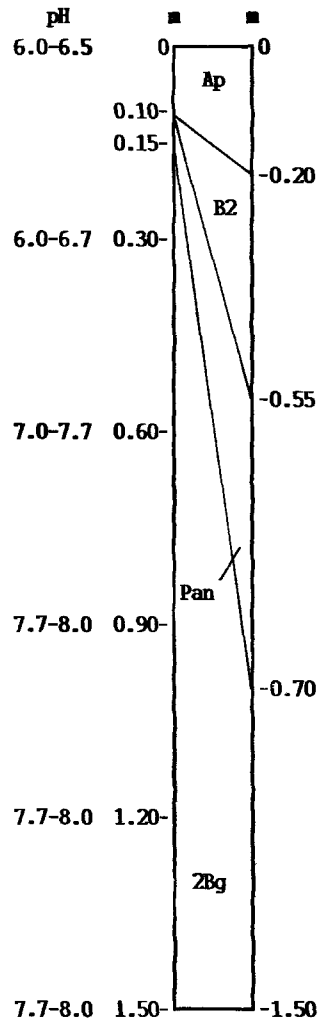
B22n horizon: Dark reddish brown (2.5YR 3/4); light clay; moderate to strong 2-10 mm platy secondary, moderate 2-10 mm polyhedral primary; dry to moderately moist moderately firm; few fine ferromanganiferous veins and nodules. Gradual or diffuse to-

B23 horizon: Dark red (10R 3/4); light clay; weak 5-10 mm platy secondary, weak 2-10 mm polyhedral primary; dry to moderately moist moderately weak to moderately firm; very few fine ferromanganiferous nodules. Clear to-

B3 horizon: as above; very few to few small to medium weathered basalt pebbles and gravel.

Soil Type	P.P.F.	Profile diagram	Description of the soil type	Landscape unit
Telegraph	Uf6.31 Uf6.34 Uf6.4	pH 6.0-6.5 6.0-6.7 7.0-7.7 7.7-8.0 7.7-8.0 7.7-8.0	**Xanthozem:** Surface condition: cultivated, loose **Ap horizon**: Dark brown (10YR 3/3); clay loam to light clay; strong 2mm granular; dry loose; very few fine ferromanganiferous nodules. Weakly developed compaction layer (Ap2); weak fragments; dry very firm. Clear or sharp to- **B2 horizon**: Brown (10YR 4/6) to yellow-brown (10YR 5/6) with none to few red mottles; light clay; weak angular blocky to polyhedral; dry to moderately moist moderately weak to moderately firm; very few to few fine to medium ferromanganiferous and ferruginous nodules and soft segregations. Sub horizons due to mottles, nodules and segregations are present. Clear or abrupt to- **2Bg horizon**: Grey (5Y, 7.5Y 5/1) with red and/or yellow mottles; medium heavy clay; weak lenticular; moderately moist to moist; very few to few small to coarse weathered basalt pebbles. Sub horizons due to colour and mottles are present. Variants: (i) Profile generally redder throughout with 5YR hue and yellow mottles. 2Bg horizon not encountered by, or before, a total depth of 1.5m. These are transitional soils between the Woongarra and Telegraph soil types. (ii) Alkaline to depth	Mid to lower slope position on gently undulating plain



Soil Type	P.P.F.	Profile diagram	Description of the soil type	Landscape unit
Ashgrove	Uf6.4 Gn3.52 Gn3.92		**Prairie soil**:	Lower slope position on gently undulating plain

Surface condition: cultivated, loose

Ap horizon: Brownish black (7.5YR 3/2); clay loam to light clay; granular; dry loose; few medium ferromanganiferous nodules; very few small to medium basalt pebbles. Weakly developed compaction layer (Ap2), weak fragments; dry very firm. Clear to-

B2 horizon: Greyish yellow brown (10YR 4/2, 5/2) to dull yellowish brown (10YR 4/3) with none to distinct yellow mottles; medium to medium heavy clay; moderately moist moderately firm; few medium ferromanganiferous nodules.

Sub horizons due to colour and mottles are present. Abrupt to-

Pan Weakly cemented, discontinuous ferromanganiferous nodular pan. Abrupt to- (Dm horizon)

2Bg horizon: Grey (5Y 5/1) with red and/or yellow mottles; medium heavy clay; weak lenticular; moist to wet very weak to moderately weak; very few to few medium ferromanganiferous nodules; very few weathered basalt pebbles.

Variants: (i) Ap - reddish brown (5YR 3/2)
(ii) B - Brownish black (7.5YR 3/2)

APPENDIX II

Morphology and analytical results for representative profiles

Notes:

Soil Profile Morphology: As per Appendix I.

Chemical Data: Are presented on an oven dry (O.D.) basis, except for pH, E.C. and fertility data.

SOIL TYPE: WOONGARRA (Wg)
SITE NO: B 2
A.M.G. REFERENCE: 439 265 m E 7 251 435 m N ZONE 56

GREAT SOIL GROUP: Euchrozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Tropeptic Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .08 m	Dark reddish brown (2.5YR3/3); light medium clay; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-
Ap2	.08 to .28 m	Dark reddish brown (2.5YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Abrupt to-
B21	.28 to .60 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm polyhedral; dry moderately firm; very few fine ferromanganiferous veins. Clear to-
B22n	.60 to .90 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm platy secondary, moderate 5-10 mm polyhedral primary; dry moderately firm; few fine ferromanganiferous veins, few fine ferromanganiferous nodules. Gradual to-
B23	.90 to 1.70 m	Dark red (10R3/4); light clay; weak 5-10 mm polyhedral; dry moderately firm; very few fine ferromanganiferous soft segregations.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	5.6	.13	.002	4	10	15	74	11	3.4	6.6	.12	.63	.19	.11	.07	3.1		21	.20	
.30	5.7	.09	.004	2	10	17	73	7	2.7	4.4	.10	.17	.17	.08	.05	3.3		23	.16	
.60	6.8	.07	.003	2	10	22	69	9	3.5	5.2	.19	.03	.17	.08	.05	3.0		23	.01	
.90	6.6	.07	.003	1	9	23	70	9	3.7	5.5	.26	.04	.08	.06	.02	3.1		24	.00	
1.20	6.8	.07	.003	1	5	18	78	9	3.6	5.5	.27	.03	.13	.07	.01	3.3				
1.50	7.1	.07	.003																	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Extr. Phosphorus Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
Bulk .10	1.5	.18	43	54	.76	44	315	16	8.9

SOIL TYPE: WOONGARRA (Wg)
SITE NO: B 7
A.M.G. REFERENCE: 439 420 m E 7 251 090 m N ZONE 56

GREAT SOIL GROUP: Euchrozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Tropeptic Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:
LANDFORM ELEMENT TYPE: Crest
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .07 m	Dark reddish brown (2.5YR3/3); light clay; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-
Ap2	.07 to .25 m	Dark reddish brown (2.5YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Abrupt to-
B21	.25 to .55 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm polyhedral; dry very firm; very few fine *ferromanganiferous nodules, very few fine ferromanganiferous veins. Clear* to-
B22n	.55 to .95 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm platy secondary, moderate 2-5 mm polyhedral primary; dry moderately firm; few fine ferromanganiferous nodules, few fine ferromanganiferous veins. Gradual to-
B23	.95 to 1.70 m	Dark red (10R3/4); light clay; weak 5-10 mm platy secondary, weak 2-5 mm polyhedral primary; dry moderately weak; very few fine ferromanganiferous nodules.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures		Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM 1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g						%		% @ 105C			
.10	6.5	.14	.003	4	11	13	73	10	3.5	5.5	.27	1.45	.19	.15	.06	3.4	22	.20	
.30	6.4	.14	.006	3	9	17	74	10	3.6	5.8	.34	.20	.17	.06	.06	3.4	23	.16	
.60	6.8	.09	.007	2	9	21	72	11	3.6	6.8	.42	.03	.15	.05	.03	3.3	23	.06	
.90	6.8	.09	.008	2	10	22	69	4	1.4	2.1	.54	.03	.13	.06	.02	2.9	24	.03	
1.20	7.0	.10	.009	1	11	22	70	8	3.2	3.9	.40	.02	.12	.05	.02	3.0			
1.50	7.0	.10	.010																

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Extr. Phosphorus Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm	ppm	m.eq%	ppm			
Bulk .10	1.6	.18	56	64	1.2	41	290	14	7.3

SOIL TYPE: WOONGARRA (Wg)
SITE NO: F 2
A.M.G. REFERENCE: 439 435 m E 7 251 510 m N ZONE 56

GREAT SOIL GROUP: Euchrozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Tropeptic Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1.7 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .05 m	Dark reddish brown (2.5YR3/3); light clay; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-
Ap2	.05 to .30 m	Dark reddish brown (2.5YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Abrupt to-
B21	.30 to .55 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm polyhedral; dry moderately firm; very few fine ferromanganiferous nodules. Clear to-
B22n	.55 to .90 m	Dark reddish brown (2.5YR3/4); light clay; strong 2-5 mm platy secondary, strong 2-5 mm polyhedral primary; dry moderately firm; few fine ferromanganiferous nodules. Gradual to-
B23	.90 to 1.55 m	Dark red (10R3/4); light clay; weak 5-10 mm polyhedral; dry moderately firm; very few fine ferromanganiferous nodules. Clear to-
B3	1.55 to 1.80 m	Dark red (10R3/4); light clay; very few small rounded platy weathered basalt pebbles; weak 5-10 mm polyhedral; dry moderately firm; very few fine ferromanganiferous nodules.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures		Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b 15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g						%		% @ 105C			
.10	6.0	.14	.003	4	13	14	71	7	2.5	3.7	.18	.76	.18	.11	.06	3.1	21	.19	
.30	6.1	.13	.004	2	11	18	75	7	2.5	4.0	.22	.12	.13	.06	.04	3.4	24	.13	
.60	6.8	.07	.003	2	11	19	74	8	2.8	4.7	.23	.04	.13	.06	.02	3.2	23	.03	
.90	6.9	.06	.004	1	10	22	72	8	2.9	4.9	.23	.03	.08	.05	.02	3.0	24	.02	
1.20	7.6	.07	.005	5	14	18	68	9	3.1	5.3	.33	.02	.06	.11	.01	3.7		.02	
1.50	7.6	.07	.005																

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
Bulk .10	1.6	.17	51	64	.94	48	330	15	9.7

SOIL TYPE: WOONGARRA (Wg)
SITE NO: G 6
A.M.G. REFERENCE: 439 585 m E 7 251 285 m N ZONE 56

GREAT SOIL GROUP: Euchrozem
PRINCIPAL PROFILE FORM: Uf 6.31
SOIL TAXONOMY UNIT: Tropeptic Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 1.4 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .05 m	Dark reddish brown (2.5YR3/3); light medium clay; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-
Ap2	.05 to .25 m	Dark reddish brown (2.5YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Clear to-
B21	.25 to .55 m	Dark reddish brown (2.5YR3/4); light clay; moderate 2-5 mm polyhedral; dry moderately firm; very few fine ferromanganiferous nodules, few fine ferromanganiferous veins. Clear to-
B22n	.55 to .95 m	Dark reddish brown (2.5YR3/4); light clay; moderate 5-10 mm platy secondary, moderate 2-5 mm polyhedral primary; dry moderately firm; very few fine ferromanganiferous veins, few fine ferromanganiferous nodules. Gradual to-
B23	.95 to 1.80 m	Dark red (10R3/4); light clay; weak 5-10 mm platy, weak 2-5 mm polyhedral primary; dry moderately firm; very few fine ferromanganiferous nodules.

Depth (metres)	1:5 Soil/Water pH	EC mS/cm	Cl %	Particle Size CS FS S C % @ 105C	CEC	Exch. Cations Ca	Mg	Na	K m.eq/100g	Total Elements P	K %	S %	Moistures ADM	1/3b % @ 105C	15b	Disp.Ratio R1	R2
.10	6.0	.13	.001	4 12 17 75	7	3.2	3.1	.20	.64	.11	.08	.05	3.5		22	.20	
.30	6.0	.16	.003	2 11 19 76	10	5.1	4.5	.26	.21	.09	.05	.05	3.5		23	.02	
.60	6.6	.10	.009	2 11 18 74	11	6.0	5.2	.30	.04	.10	.05	.02	3.3		23	.00	
.90	6.6	.10	.012	1 9 19 76	12	6.7	4.6	.27	.02	.08	.05	.02	3.2		23	.00	
1.20	6.6	.09	.009	1 7 17 79	8	3.7	3.6	.30	.02	.08	.05	.02	3.2				
1.50	6.6	.08	.008														

Depth (metres)	Org.C (W&B) %	Tot.N %	Extr. Phosphorus Acid	Bicarb. ppm	Rep. K m.eq%	DTPA-extr. Fe	Mn	Cu	Zn ppm
Bulk .10	1.5	.18	60	73	1.0	42	315	19	8.4

SOIL TYPE: WOONGARRA (Wg)
SITE NO: I 6
A.M.G. REFERENCE: 439 715 m E 7 251 310 m N ZONE 56

GREAT SOIL GROUP: Euchrozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Tropeptic Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 2.5 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .05 m	Dark reddish brown (2.5YR3/3); light clay; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Sharp to-
Ap2	.05 to .30 m	Dark reddish brown (2.5YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Abrupt to-
B21n	.30 to .75 m	Dark reddish brown (2.5YR3/4); light clay; weak 10-20 mm platy secondary, moderate 5-10 mm polyhedral primary; dry very firm; common ferromanganiferous veins, very few fine ferromanganiferous nodules. Clear to-
B22	.75 to 1.50 m	Dark red (10R3/4); light clay; weak 5-10 mm platy secondary, weak 5-10 mm polyhedral primary; dry moderately firm; very few fine ferromanganiferous nodules. Clear to-
B3	1.50 to 1.60 m	Dark red (10R3/4); light clay; very few small weathered basalt pebbles; dry moderately firm.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	6.0	.05	.001	5	12	15	76	4	1.9	1.6	.18	.25	.18	.06	.05	3.5		22	.17	
.30	6.6	.05	.001	5	10	19	73	7	4.2	2.8	.32	.05	.16	.05	.04	3.6		24	.15	
.60	7.1	.06	.004	3	10	19	73	7	4.8	1.5	.34	.02	.10	.04	.02	3.5		24	.12	
.90	6.9	.08	.012	3	7	13	82	6	4.2	1.5	.41	.02	.07	.04	.02	3.6		26	.49	
1.20	6.8	.16	.020	1	6	17	79	6	3.8	2.0	.66	.02	.07	.03	.03	4.1				
1.50	6.5	.20	.023																	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
Bulk .10	1.5	.16	26	42	.63	66	320	6.0	7.3

SOIL TYPE: TELEGRAPH (Tg)
SITE NO: I 8
A.M.G. REFERENCE: 439 780 m E 7 251 165 m N ZONE 56

GREAT SOIL GROUP: Xanthozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 2 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .08 m	Dark brown (10YR3/3); clay loam; strong <2 mm granular; dry loose; very few fine ferromanganiferous nodules. Abrupt to-
Ap2	.08 to .28 m	Dark brown (10YR3/3); light clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Sharp to-
B21	.28 to .60 m	Brown (10YR4/6); light clay; weak polyhedral; dry moderately weak; very few fine ferromanganiferous nodules. Clear to-
B22	.60 to .70 m	Brown (10YR4/6); very few fine faint red mottles; light clay; weak angular blocky secondary, polyhedral primary; dry moderately firm; very few fine ferromanganiferous nodules. Clear to-
B23	.70 to 1.10 m	Brown (7.5YR4/4); few fine distinct red mottles; light clay; weak angular blocky secondary, weak polyhedral primary; dry moderately firm; very few fine ferromanganiferous nodules, very few fine ferruginous soft segregations. Clear to-
2B21g	1.10 to 1.25 m	Grey (5Y5/1); common fine prominent red mottles; medium heavy clay; few coarse pebbles, weathered basalt; moderately moist. Abrupt to-
2B22g	1.25 to 1.60 m	Grey (5Y5/1); few fine distinct yellow mottles, very few fine faint red mottles; medium heavy clay; lenticular; moist.

Depth	1:5 Soil/Water pH	EC	Cl	Particle Size CS	FS	S	C	Exch. Cations CEC	Ca	Mg	Na	K	Total Elements P	K	S	Moistures ADM	1/3b	15b	Disp.Ratio R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	6.5	.04	.001	12	11	14	64	10	5.9	3.7	.30	.17	.20	.05	.05	3.9		22	.22	
.30	7.2	.04	.001	12	9	15	66	10	7.3	2.4	.57	.05	.17	.04	.04	4.0		22	.20	
.60	7.0	.10	.004	11	10	14	68	7	5.3	1.1	.64	.03	.09	.03	.03	3.6		21	.20	
.90	5.1	.22	.024	7	10	16	68	5	3.0	.79	.65	.02	.10	.03	.10	3.6		21	.00	
1.20	5.1	.27	.026	20	14	11	54	8	2.7	3.2	1.4	.02	.10	.01	.13	4.1				
1.50	4.9	.47	.001																	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
Bulk .10	1.6	.17	30	61	.66	71	255	4.3	5.8

SOIL TYPE: TELEGRAPH (Tg)
SITE NO: I 4
A.M.G. REFERENCE: 439 655 m E 7 251 440 m N ZONE 56

GREAT SOIL GROUP: Xanthozem
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Eutrustox
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE: 2.5 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .05 m	Dark reddish brown (5YR3/3); light clay; strong < 2mm granular; dry loose; very few fine ferromanganiferous nodules. Abrupt to-
Ap2	.05 to .25 m	Dark reddish brown (5YR3/3); light medium clay; weak fragment; dry very firm; very few fine ferromanganiferous nodules. Clear to-
B21	.25 to .70 m	Dark reddish brown (5YR3/4); few fine distinct yellow mottles; light clay; moderate 2-5 mm polyhedral; dry moderately weak; common medium ferromanganiferous concretions. Clear to-
B22	.70 to 1.10 m	Reddish brown (5YR4/6); few fine distinct yellow mottles; light clay; moderate 2-5 mm polyhedral; moderately moist moderately weak; very few medium ferromanganiferous concretions. Clear to-
B3	1.10 to 1.50m	Reddish brown (5YR4/6); very few fine faint yellow mottles; light clay; very few small rounded platy weathered basalt pebbles; moderate 2-5 mm polyhedral; moderately moist moderately weak; very few fine ferromanganiferous concretions.

Depth	1:5 Soil/Water		Particle Size					Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	6.2	.07	.002	8	12	15	67	8	4.3	3.4	.15	.29	.19	.07	.06	3.8		21	.18	
.30	6.9	.05	.001	8	11	15	71	7	4.8	2.4	.28	.04	.18	.05	.04	3.9		23	.16	
.60	6.9	.06	.003	6	10	16	73	6	3.6	1.8	.37	.03	.15	.04	.03	3.7		23	.06	
.90	6.6	.08	.008	5	9	15	72	5	2.5	2.0	.35	.02	.08	.03	.02	3.6		24	.00	
1.20	5.8	.13	.017	6	10	14	71	5	1.7	2.4	.43	.02	.08	.03	.03	3.7				
1.50	5.4	.18	.023																	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Extr. Phosphorus Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
Bulk .10	1.6	.17	20	46	.53	70	285	5.3	6.2

SOIL TYPE: ASHGROVE (Ag)
SITE NO: J 8
A.M.G. REFERENCE: 439 825 m E 7 251 195 m N ZONE 56

GREAT SOIL GROUP: Prairie soil
PRINCIPAL PROFILE FORM: Gn3.92
SOIL TAXONOMY UNIT: Aquic Dystropept
FAO UNESCO UNIT:

SUBSTRATE MATERIAL:
CONFIDENCE SUBSTRATE IS PARENT MATERIAL:

SLOPE:
LANDFORM ELEMENT TYPE: Flat
LANDFORM PATTERN TYPE: Gently undulating plains

VEGETATION
STRUCTURAL FORM:
DOMINANT SPECIES

ANNUAL RAINFALL: 1153 mm

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Recently cultivated, loose

HORIZON	DEPTH	DESCRIPTION
Ap1	0 to .10 m	Brownish black (7.5YR3/2); clay loam; very few small basalt pebbles; granular; dry loose; few medium ferromanganiferous nodules. Clear to-
Ap2	.10 to .28 m	Brownish black (7.5YR3/2); few fine faint red mottles; light clay; weak fragment; dry very firm; few medium ferromanganiferous nodules. Clear to-
B21	.28 to .40 m	Greyish yellow-brown (10YR4/2); medium heavy clay; moderately moist moderately firm; few medium ferromanganiferous nodules. Clear to-
B22	.40 to .55 m	Dull yellowish brown (10YR4/3); few fine distinct yellow mottles; medium heavy clay; moderately moist moderately firm; few medium ferromanganiferous nodules. Abrupt to-
Dm	.55 to .70 m	Grey (5Y5/1); moderately moist moderately firm; nodular discontinuous weakly cemented manganiferous pan; very many medium ferromanganiferous nodules, few coarse ferromanganiferous nodules. Abrupt to-
2Bg	.70 to 1.00 m	Dark greyish yellow (2.5Y5/2); medium heavy clay; wet very weak; few medium ferromanganiferous nodules.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	% @ 105C				m.eq/100g					%			% @ 105C				
.10	6.3	.16	.016	15	11	21	54	21	11	7.4	1.0	.65	.23	0.12	.08	5.1		20	.31	
.30	6.6	.15	.014	17	9	21	55	20	12	6.3	1.3	.17	.02	0.06	.07	5.4		22	.31	
.60	6.7	.13	.011	26	9	13	53	18	8.7	6.7	1.0	.16	.02	0.04	.03	5.9		21	.52	
.90	6.6	.13	.013	28	17	13	45	21	10	8.4	1.5	.16	.24	0.27	.03	6.2		21	.52	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus Acid	Extr. Phosphorus Bicarb.	Rep. K	DTPA-extr. Fe	Mn	Cu	Zn
metres	%	%	ppm	ppm	m.eq%	ppm			
Bulk .10	2.8	.25	46	76	.76	112	245	4.4	8.8

APPENDIX III

Criteria for land capability classification for dryland agriculture (Rosser et al. 1974) applicable to the Bundaberg Research Station

Limiting factor	Degree of limitation	Capability class (if sole limiting factor)	Subclass symbol
Climate other than rainfall "c"	Slight restriction to choice of crops or slightly restricted production potential	II	c2
	Moderate restriction to choice of crops or moderately restricted production potential	III	c3
	Severely restricted choice of crops and severely reduced potential	IV	c4
Moisture availability "m"	Occasional limitation to crop production; 7-8 crops possible in 10 years.	II	m2
	Regular limitation to crop production; 5-7 crops possible in 10 years.	III	m3
	Occasional cropping possible. Less than 5 crops possible in 10 years.	IV	m4
Soil physical factors "p"	Degree of limitation imposed on crop production from soil physical factors affecting the growth of crop plants e.g. surface crusting, hardpans, cementation etc.		
	Slight restriction	II	p2
	Moderate restriction	III	p3
	Severe restriction	IV	p4
Soil salinity sodicity "s"	Soil water availability moderately restricted or moderate structural decay with some toxic effect on crops.	III	s3
	Soil water availability severely restricted or severe structural decay with moderate to severe toxicity.	IV	s4
	Salinity or alkalinity too severe for crops. Tolerant improved species available.	VI	s6

Limiting factor	Degree of limitation	Capability class (if sole limiting factor)	Subclass symbol
Effective soil depth "d"	Effective soil depth 60-100 cm	II	d2
	Effective soil depth 45-60 cm	III	d3
	Effective soil depth 25-45 cm	IV	d4
	Effective soil depth <25 cm	VI	d6
Soil nutrient fertility "n"	Moderate deficiencies which may be economically corrected with careful management.	II	n2
	Severe deficiencies, difficult to correct and which require special management practices.	III	n3
Soil workability "k"	Soil properties affecting machinery and thus reducing average production potential eg. stiff clay, columnar structure, compaction, narrow moisture range for working.		
	Slight restriction	II	k2
	Moderate restriction	III	k3
	Severe restriction	IV	k4
Wetness "w"	Use of implements delayed occasionally and slightly reduced production potential.	II	w2
	Use of implements delayed regularly and moderately reduced production potential.	III	w3
	Use of implements very difficult and occasional crops only possible.	IV	w4
Rockiness or stoniness "r"	Tillage restricted with some types of machinery.	II	r2
	Tillage restricted with most types of machinery.	III	r3
	Tillage difficult with all machinery, occasional use possible.	IV	r4

Limiting factor	Degree of limitation	Capability class (if sole limiting factor)	Subclass symbol
Susceptibility to water erosion "e"	Simple practices required to reduce water erosion under cultivation to the acceptable level.	II	e2
	Intensive practices required to reduce water erosion under cultivation to the acceptable level.	III	e3
	Requires inclusion of a pasture phase to reduce average water erosion losses to the acceptable level.	IV	e4
Susceptibility to flooding "f"	Subject to occasional overflow flooding	II	f2
	Subject to regular overflow flooding	III	f3
	Subject to severe overflow flooding; permanent cultivation not possible.	IV	f4

FACTOR INTERACTIONS

In most cases the most severe limiting factor will determine the class, but a combination of factors might indicate a class more restrictive than indicated by any one limitation. For example where there are more than two Class III limitations, then the land could be classified as Class IV.

APPENDIX IV

Land capability classes for dryland agriculture (Rosser et al. 1974) applicable to the Bundaberg Research Station

Class II Land suitable for all agricultural uses but with slight restrictions to use for cultivation in one or more of the following categories.

(a) Land with some limitation to the choice of crops and/or slight restrictions to productivity.

(b) Land with some impediment to the use of cultivation machinery which limits the choice of implements or restricts the conditions for successful operation.

(c) Land which under cultivation requires simple conservation practices to reduce soil loss to an acceptable level. (Simple practices include contour working, strip cropping, stubble mulching).

Class III Land suitable for all agricultural uses but with moderate restrictions to use for cultivation in one or more of the following categories:

(a) Land with moderate limitation to the choice of crops and/or moderate restrictions to productivity.

(b) Land with moderate impediment to use of cultivation machinery which limits the choice of implements or restricts the condition for successful operation.

(c) Land which under cultivation requires intensive conservation practices to reduce soil loss to an acceptable level. (Intensive conservation practices include contour banking systems and intensive residue management involving specialised implements).

Class IV Land primarily suited to pastoral use but which may be safely used for occasional cultivation with careful management. Limitations arise from one of the following categories:

(a) Land on which the choice of crops is severely restricted and/or conditions are such that productivity under cropping is severely limited.

(b) Land with severe impediment to the use of cultivation machinery which limits the choice of implements or severely restricts the conditions for successful operation.

(c) Land which cannot be used safely for permanent cultivation. (If cropped, a pasture phase must be the major component in the cropping programme to limit soil loss to an acceptable level).

Class V Land which in all other characteristics would be arable but has limitations which, unless removed, make cultivation impractical/and or uneconomic.

Class VI Land which is not suitable for cultivation but is well suited to pastoral use and on which pasture improvement involving the use of machinery is impractical.