ASSESSMENT OF NITROGEN MINERALISING POTENTIAL OF SOILS IN TWO DIFFERENT LANDSCAPES IN THE AUSTRALIAN SUGAR INDUSTRY—IMPLICATIONS FOR N FERTILISER MANAGEMENT

By

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Abstract

Currently, nitrogen fertiliser recommendations in the Australian sugar industry are general in nature, for use across regions and soils. However, differences in soil chemical, physical and pedological properties, within and between the Herbert River and Bundaberg sugar-growing regions have suggested that soils may differ markedly in their ability to mineralise nitrogen during the growing season. Topsoil samples taken from 24 different soil types in the Herbert and seven different soil types in the Bundaberg area were categorised according to the amount of nitrogen mineralised during a two week aerobic incubation. This index, based on easy mineralisable (aerobic) N values, indicates that a large variation in the ability of soils to release N from organic matter is apparent, both within and across the two regions considered. These findings have important implications for nitrogen fertiliser application rates. Lower rates of N applied in certain circumstances could ultimately lead to sugarcane with improved CCS values. In addition, more targeted use of N would minimise off-site effects associated with fertilisation.

Introduction

Currently, fertiliser recommendations in the Australian sugar industry are general in nature for use across regions, with little modification according to soil type or soil chemical, physical and pedological properties (Wood *et al.*, 1997). In particular, nitrogen fertiliser recommendations are based on the results of yield calibration experiments that have been averaged across districts and soils (Chapman, 1994). The apparent lack of recognition of the effects of basic soil properties has resulted in a set of recommendations (Table 1) that were supposedly applicable to the 'average' soil within the Australian sugar industry. Only three separate categories exist: one for the Burdekin region, one for 'average' soils in all other districts and the other for 'richland' soils (Calcino, 1994). Unfortunately, no quantitative criteria exist to distinguish the 'richland' soils from the 'average' category. However, with reinterpretation of some of the original trial data where some basic soil properties had been recorded, Schroeder *et al.* (1998) identified that it was possible to group different responses to applied N according to general soil type (based on soil colour and texture) in various cane-growing regions.

Table 1—BSES nitrogen fertiliser recommendations for the Australian sugar industry (Calcino, 1994).

Soil	Crop	Nitrogen fertiliser recommendations (kg N/ha)	
		Burdekin	All other regions
All types	Fallow plant	135–150	120–150
	Replant & ratoons	210–250	160–200
		All regions	
Richland	Fallow plant	80	
	Replant & ratoons	120	

KEYWORDS: Soil Properties, Nitrogen, Easy Mineralisable (Aerobic) N, N Mineralisation Potential.

In the South African sugar industry, it is recognised that soil influence (based on the N mineralisation potential) is of major importance in the overall management of nitrogen on-farm (Meyer and Wood, 1994). As such, soil samples submitted by growers to the Fertiliser Advisory Service (FAS) laboratory of the South African Sugar Association Experiment Station (SASEX) are routinely characterised according to their ability to mineralise N (within four N mineralisation potential categories–low, moderate, high and very high), with recommended rates of N reflecting these differences (Meyer and Wood, 1994). Although N mineralisation is currently assessed by near infra-red spectroscopy (NIR), the original calibration curves were based on soil type, and specifically on organic matter and clay content (Meyer *et al.*, 1986). Locally, Wood and Stewart (1985) have suggested that N fertiliser recommendations for the Herbert River district be based on soil categories that take account of differences in organic matter content.

Although the founding scientists at the Bureau of Sugar Experiment Stations (BSES) recognised that fertiliser needs should be linked to basic soil properties such as colour, texture, chemical composition and native vegetation (Maxwell, 1902), there has been little systematic use of soil classification or soil field properties for guiding nutrient management in the Australian sugar industry over the past century (Schroeder *et al*, 1998). However, recently the Cooperative Research Centre for Sustainable Sugar Production (CRC-Sugar), which includes participating parties such as BSES, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Queensland Department of Natural Resources (QDNR) and CSR Ltd, have developed a short course (including a course manual) that has aimed to rectify this apparent anomaly (Bruce, 1999).

This paper reports on an investigation aimed at determining differences in soil N mineralising potential values (based on the amount of N mineralised during a two-week aerobic incubation) and linking these to basic properties and organic matter contents of soils found within the Herbert River and Bundaberg cane growing regions. An assessment is also made of the implications for N fertiliser management in the Australian sugar industry.

Materials and methods

A number of soil reference sites were established in the Herbert and Bundaberg sugarcane growing regions. In the Herbert River district, these sites were selected to represent the major soil types (Table 2) previously identified during soil surveying conducted by the Technical Field Department of CSR Ltd (CSR) at a scale of 1:5000 over 45 000 ha or about 70% of the cane area of the Herbert region (Wood *et al.*, 1997). As the soils in the Bundaberg sugarcane growing area are less variable than those encountered in the Herbert, only seven reference sites have initially been established, predominantly south of the Burnett River. In this case, these sites (Table 3) were selected to encompass the range of soils identified as part of the soil-mapping and land suitability assessments conducted by staff of the QDNR (Donnollan *et al.*, 1998). All the sites sampled were within existing blocks of sugarcane that had been cropped over a number of years. Green cane trash blanketing had generally been applicable during the ratoon crops.

Selected mean chemical and physical data (Tables 4 and 5) for both sets of soils (Herbert and Bundaberg) were obtained from analysis reports associated with the CSR and QDNR (Donnollan *et al.*, 1998) soil surveys.

Composite (five cores) topsoil samples (0–200 mm depth) from each site (over an area coving 10 rows of cane 20 m long) were collected during the winter season of 2000. The samples were air-dried, ground to pass through a 2 mm sieve and stored in plastic containers in a dry environment prior to incubation. Easy mineralisable (aerobic) N values for each soil were obtained by determining the mean difference in mineral N values (2 M KCl extractable nitrate and ammonium), before and after incubation (aerobic, 30°C for a two-week period) on duplicate samples according to the procedure of Saunder *et al.* (1957). According to this procedure, soils were kept at approximately field capacity during incubation, with the amount of water (added as dilute Ca-phosphate solution) calculated according to soil texture.

Results and discussion

Classification of soils in both the Herbert and Bundaberg cane growing regions (Tables 2 and 3) indicates that soils differ considerably, in terms of pedology, within and between the two areas, and that soil type is markedly influenced by position in the landscape. Although the different soil types can be named according to the Australian Soil Classification system (Isbell, 1996), this procedure is complex. In addition, the names convey little information about the

Table 2—Herbert soil types according to various classification systems. General positions in the landscape are indicated.

CSR[1] soil type	Position in landscape	Nearest Great Soil Group[2]	Australian Soil Classification[3]
Clay loam	Lowest part of flood plain	Grey clay	Redoxic hydrosol
Grey brown loam	Broad low ridges across Seymour floodplain	Gleyed podzolic	Redoxic hydrosol
Coarse sandy clay	Low area of floodplain below sandy colluvial fans	Soloth	Oxyaquic Hydrosol
Black organic clay	Low lying swampy depressions	Humic gley	Redoxic Hydrosol
Pale brown sandy loam	Acid volcanic colluvial fans in Seymour area	Gleyed podzolic	Redoxic Hydrosol
Fine black sand	Middle sections of the acid volcanic colluvial fans	Rudimentary podzol	Oxyaquic Hydrosol
Fine grey sand	Lower sections of the acid volcanic colluvial fans	No suitable group	Redoxic Hydrosol
Clay	Flat areas of the lowest part of the floodplain	(Bleached)grey clay	Redoxic Hydrosol
Terrace silty loam	Terraces along main rivers in lower floodplains	Yellow/grey podzolic	Redoxic Hydrosol
River bank	River banks and levees	Alluvial soil	Chernic Tenosol
River sand	Recent deposits of sand along main rivers	Alluvial soil	Clastic Rudosol
Silty clay	Low-lying areas adjacent to clays & terrace silty loams	Soloth/solodic	Redoxic Hydrosol
Red loam	High terraces and benches well above the flood level	Red earth/red podzolic	Red Kandosol
River overflow	Highly productive soils on active river terraces/floodplains	Brown earth	Brown Dermosol
Clay ridge	Broad winding ridges along prior stream channels	No suitable group	Oxyaquic Hydrosol
Sandy clay	Shoulders of sand ridges formed along prior streams	Soloth	Redoxic Hydrosol
Heavy clay	Lowest part of the floodplain	Grey clay	Aquic Grey Vertosol
Sand ridge	Narrow winding ridges along prior stream channels	Grey/yellow earth	Brown Kandosol
Grey sand	Lower hillside positions on granitic colluvial fans	Earthy sand/grey earth	Redoxic Hydrosol
Red sand	Upper hillslope positions on granitic colluvial fans	Red earth	Red Kandosol
Coarse sandy loam	Crests and upper slopes of broad sandy areas on higher ground	Grey/yellow earth	Othic Tenosol
Fine sandy loam	Middle/lower slopes of broad sandy areas on higher ground	Solodic soil	Redoxic Hydrosol
Beach sand ridge	Old beach ridges close to the coast	Podzol	Rudosol

[1] CSR Technical Field Department soil-naming system
[2] Stace *et al.* (1968)
[3] Isbell (1996) as applied by Simon Eldridge (CRC Sugar)

Table 3—Selected Bundaberg soil types according to various classification systems. General positions in the landscape are indicated.

DNR[1] soil mapping unit	Position in landscape[1]	Nearest Great Soil Group[2]	Australian Soil Classification[3]
Ashgrove	Lower slopes and drainage line of rises (volcanic)	Prairie soil	Redoxic Hydrosol
Woongarra	Crest/upper to midslope positions of rises (volcanic)	Euchrozem	Red Ferrosol
Seaview	Bottom land positions and slightly elavated (volcanic)	Prairie soil	Black/brown Ferrosol
Oakwood	Localised elevated position on plains	Red earth	Red Kandosol
Quart	Lower slopes of plains	Yellow earth	Yellow Kandosol
Kepnock	Lower slopes/drainage depressions on plains	Yellow podzolic	Yellow Dermosol
Maroondan	Mid to toe-slopes on basaltic hills	Black earth	Black/brown Vertosol

[1]Donnollan *et al.* (1998)
[2]Stace *et al.* (1968); [3]Isbell (1996)

Table 4—Selected mean topsoil (0–200 mm) chemical and physical values for the Herbert soil types.

CSR[1] soil type	Topsoil texture				pH (water)	Org C[2] (%)	Total N (%)
	Particle size distribution			Textural Classes			
	Sand (%)	Silt (%)	Clay (%)				
Clay loam	35.8	31.7	32.6	Clay loam	4.8	1.20	0.12
Grey brown loam	58.6	23.3	18.2	Sandy loam	5.1	0.59	0.05
Coarse sandy clay	73.2	11.4	15.3	Sandy loam	5.0	0.67	0.05
Black organic clay	26.0	32.8	41.2	Clay	4.8	1.98	0.20
Pale brown sandy loam	67.4	15.2	17.4	Sandy loam	4.7	0.87	0.07
Fine black sand	70.4	15.8	13.9	Sandy loam	5.0	1.88	0.13
Fine grey sand	70.3	15.5	14.3	Sandy loam	5.1	0.66	0.05
Clay	33.9	32.2	33.9	Clay	5.0	1.25	0.12
Terrace silty loam	52.4	24.3	23.2	Sandy clay loam	4.8	0.75	0.07
River bank	68.1	14.7	17.1	Sandy loam	4.8	0.79	0.06
River sand	81.3	7.1	11.6	Loamy sand	5.2	0.50	0.05
Silty clay	47.4	27.3	25.3	Sandy clay loam	4.9	0.81	0.07
Red loam	61.4	17.3	21.3	Sandy clay loam	4.9	0.78	0.06
River overflow	45.3	28.4	26.2	Loam	5.1	1.17	0.10
Sandy clay	66.2	15.7	18.1	Sandy loam	5.1	0.71	0.06
Heavy clay	30.9	24.3	44.8	Clay	4.8	1.29	0.12
Sand ridge	81.3	7.2	11.5	Loamy sand	5.0	1.10	0.07
Grey sand	73.1	12.0	14.8	Sandy loam	4.9	0.64	0.05
Red sand	81.3	7.1	11.6	Loamy sand	5.2	0.50	0.05
Coarse sandy loam	73.2	11.4	15.3	Sandy loam	5.0	0.67	0.05
Fine sandy loam	69.3	13.3	17.1	Sandy loam	4.9	0.76	0.06
Beach sand ridge	70.0	16.0	14.0	Sandy loam	5.0	1.95	0.14

[1]CSR Sugar Technical Field Department soil-naming system
[2]Walkley and Black (1934)

Table 5—Selected mean topsoil chemical and physical values for the Bundaberg soil types based on DNR[1] data.

DNR[1] Soil-mapping unit	Range of clay (%)	Topsoil texture classes	PH (water)	Organic C (%)		Total N (%)	
				0–100 mm depth	[2]0–200 mm depth	0–100 mm depth	[2]0–200 mm depth
Ashgrove	32–54	Light clay	6.3	2.8	2.1	0.27	0.20
Woongarra	42–76	Medium clay	6.2	1.4	1.1	0.16	0.12
Seaview	25–50	Light clay	5.9	3.5	2.6	0.26	0.19
Oakwood	20–48	Clay loam	5.7	2.4	1.8	0.15	0.11
Quart	1–12	Loamy sand	5.8	0.9	0.7	0.04	0.03
Kepnock	6–21	Sandy loam	5.6	1.6	1.2	0.07	0.05
Maroodan	49–63	Heavy clay	6.5	2.6	1.9	0.23	0.17

[1] Queensland Department of Natural Resources—Donnollan *et al.* (1998)
[2] Estimated from 0–100 mm depth (using a factor of 0.75)

appearance and properties of the different soils. The system also fails to separate soils according to different nutrient management needs. For example, almost half the soil types recognised in the Herbert are redoxic hydrosols using this classification. Alternatively, classification according to the Handbook of Australian Soils (Stace *et al.*, 1968) appears to be somewhat easier. Unfortunately, certain soils in Queensland cannot be classified according to this system, as criteria for differentiating soil types were essentially developed in the southern States and do not fully cover the range of properties found in tropical and sub-tropical soils (M.G. Cannon, pers. comm.). Evidence of this may be seen in Table 2, where the soils described by the CSR system as 'Fine grey sand' and 'Clay ridge' could not be assigned to applicable Great Soil Groups. An alternative practice of naming soil-mapping units according to local names (as in Bundaberg—Table 3) has some advantage, but extrapolation to other regions proves difficult. The simple system used by CSR (Table 2) using names based on colour, texture and topographic position is practical and simple to use (Wood *et al.*, 1996). Growers in particular appear to be more able to relate to such names and recognise the concepts more easily (including basic soil properties and position in the landscape).

Soils within and between the two regions also differ markedly in terms of selected physical (either particle size distribution or clay %) and chemical (pH and organic carbon content) properties (Tables 4 and 5). In the Herbert, topsoils range from clays (about 45% clay and 31% sand in the 'heavy clay' soil) to loamy sands (11% clay and 81% sand in the 'river sand' and 'sand ridge' soils). Soil pH values generally fall within a relatively small pH range (4.8–5.2), and organic carbon values range from as little as 0.5% C ('river sand' and 'red sand') to >2.0% C in the 'black organic clay'. Although soils in Bundaberg appear to be less variable over distance within the landscape than in the Herbert, they also differ markedly in their basic physical and chemical properties. Topsoils range from loamy sand (Quart soil) to heavy clays (Maroondan soil). Soil pH values range from 5.6 to 6.5, and organic carbon values range from 0.7% C (Quart soil) to 2.6% C (Seaview soil) in the 0–200 mm depth interval.

As with the organic matter content values, a relatively large variation in the amounts of easy mineralisable (aerobic) N was noted in the topsoils from the two areas (Table 6). Although a fairly broad range of values [5.2 mg N/kg (about 10 kg N/ha) to 28.5 mg N/kg (about 55 kg N/ha)] was obtained for the Herbert soils, the Bundaberg soils gave rise to an even broader range of values [6.2 mg N/kg (about 12 kg N/ha) to 42.1 mg N/kg (about 82 kg N/ha)]. These differences generally reflected the ranges of organic C and total soil N values both within and across the two regions. Correlation coefficients (r^2) of 0.57 (Figure 1) and 0.53 (Figure 2) were obtained respectively when the amounts of easy mineralisable (aerobic) N were plotted against soil organic C and total soil N for the combined group of Herbert and Bundaberg soils.

Irrespective of the region or soil, it was evident that all the soils considered were able to mineralise some organic N, but the ability to do so varied markedly with soil type. Based on the premise that the amounts of N mineralised during a two-week aerobic incubation provided an index of N mineralisation potential under field conditions over a growing-season, it seems reasonable that some modifications to existing N fertiliser recommendations are possible. A preliminary set of N fertiliser recommendations is

Table 6—N mineralised by various soils during a two-week aerobic incubation.

Soil type/soil-mapping unit	Initial mineral N (pre-incubation)			Final mineral N (post incubation)			Net amount of N mineralised (mg/kg)	[1]Net N mineralised (kg/ha)
	NH_4^+	NO_3^-	Total	NH_4^+	NO_3^-	Total		
	(mg/kg)			(mg/kg)				
Herbert soils								
Clay loam	8.0	7.3	15.3	24.8	9.0	33.8	18.5	36.0
Grey brown loam	3.1	6.7	9.8	19.4	7.3	26.7	17.0	33.1
Coarse sandy clay	8.0	5.1	13.1	22.6	9.4	32.0	19.0	36.9
Black organic clay	22.6	9.6	32.2	20.8	30.4	51.2	19.0	37.0
Pale brown sandy loam	8.7	8.2	16.9	20.7	12.8	33.5	16.5	31.8
Fine black sand	2.0	4.0	6.0	19.5	11.1	30.6	24.5	47.8
Fine grey sand	0.6	5.9	6.5	0.0	20.4	20.4	13.9	27.0
Clay	7.6	10.4	18.0	19.1	20.2	39.3	21.2	41.3
Terrace silty loam	6.0	6.0	12.0	11.3	7.3	18.6	6.6	12.8
River bank	5.9	10.0	15.9	10.9	12.9	23.8	7.9	15.3
River sand	6.5	15.0	21.5	12.2	17.7	29.9	8.3	16.2
Silty clay	9.3	21.7	31.0	21.7	23.9	45.6	14.6	28.5
Red loam	3.5	4.6	8.1	6.6	10.9	17.5	9.4	18.3
River overflow	7.6	23.0	30.6	18.6	30.4	49.0	18.5	36.1
Sandy clay	2.9	5.3	8.2	5.3	11.7	17.0	8.8	17.1
Heavy clay	6.6	7.6	14.6	12.3	30.4	42.7	28.5	55.5
Sand ridge	3.6	7.0	10.6	14.2	12.2	26.4	15.8	30.9
Grey sand	13.4	11.2	24.6	22.0	7.9	29.9	5.2	10.1
Red sand	17.1	6.1	23.2	26.4	5.5	31.9	8.7	16.9
Coarse sandy loam	2.3	3.4	5.7	8.2	5.5	13.7	7.9	15.4
Fine sandy loam	1.3	2.9	4.2	4.1	12.3	16.4	12.2	23.8
Beach sand ridge	4.0	7.9	11.9	16.0	18.1	34.1	22.3	43.4
Bundaberg soils								
Ashgrove	18.4	16.5	34.9	4.6	64.7	69.3	34.5	67.3
Woongarra	8.2	11.6	19.8	1.6	24.6	26.2	6.4	12.5
Seaview	9.3	17.9	27.1	1.8	67.4	69.2	42.1	82.0
Oakwood	10.9	8.5	19.4	3.5	22.2	25.7	6.2	12.1
Quart	0.2	2.7	2.8	1.6	9.1	10.7	7.8	15.2
Kepnock	8.4	13.2	21.6	2.2	33.9	36.1	14.5	28.3
Maroondan	13.3	16.7	30.0	2.3	52.4	54.7	24.7	48.2
			LSD(0.10)				5.4	10.5
			LSD(0.05)				6.5	12.7
			LSD(0.01)				8.7	17.0

[1] Assuming a soil bulk density of 1300 kg/m^3 and N mineralisation within the plough-layer (0–150 mm)

given in Table 7. These proposed N fertiliser recommendations for replant/ratoon cane were determined by assuming that the N mineralised during the season would be available for plant uptake in a manner similar to any other applied mineral N fertiliser. In calculating the appropriate N application rate for each category of soils, the general BSES nitrogen fertiliser recommendation (160 kg N/ha) was used as the standard for the 'very low' N mineralisation potential category. Although an average of 15 kg N/ha was mineralised during the two-week incubation by this group of soils (ranging from about 10 to 17 kg N/ha), this was not considered an additional amount of N available for plant uptake. Rather, it was assumed that this amount was already factored into the existing general BSES nitrogen recommendations and would be applicable for all soil types. The other calculated N application rates were based on the evidence that an additional 10 kg N/ha per category became available with the progression from low to very high N mineralisation potential (Tables 6 and 7).

Although a full range of calculated N application rates is provided, these have been rationalised

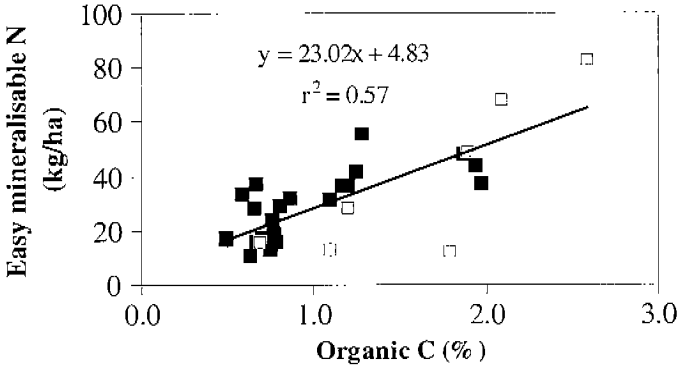

Fig. 1—Easy mineralisable N (determined in a two-week aerobic incubation study) as a function of soil organic carbon (0–200 mm depth). Herbert soils indicated by the closed squares. Bundaberg soils indicated by the open squares.

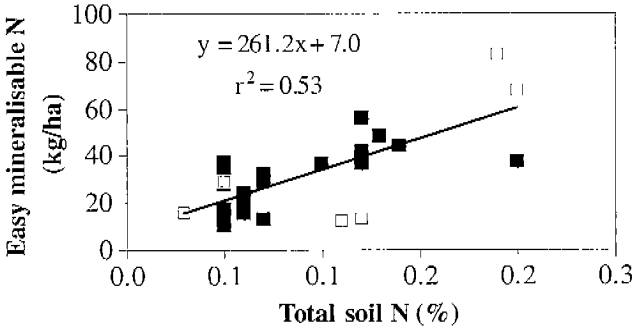

Fig. 2—Easy mineralisable N (determined in a two-week aerobic incubation study) as a function of total soil N (0–200 mm depth). Herbert soils indicated by the closed squares. Bundaberg soils indicated by the open squares.

into a smaller number of suggested N application rate categories to ensure that practical implementation is possible on farm. However, this preliminary system may require modification as more data become available, particularly from a current series of glasshouse and field experiments in both the Herbert and Bundaberg areas. In the absence of a soil type descriptor (either CSR or DNR soil mapping unit name), organic C (%) may be used to estimate easy mineralisable N and hence the appropriate N fertiliser rate in Table 7.

Conclusions

The findings of this study and the recognition of soil properties as a basis for fertiliser N recommendations have important implications for the Australian sugar industry. Not only will the proposed recommendations of reduced N inputs in some soils benefit on-farm profitability, especially in terms of improved CCS values due to avoidance of over application of nitrogen, but they will also be more acceptable environmentally than the current general advice that covers all soil types. A major advantage of this system is that the proposed N rates use the current BSES recommended N rates as the standard, with modifications based on soil properties (colour, texture and position in the landscape) that are easily recognised by, and are accessible to, the grower community. These proposals may also possibly result in the adoption, or at least consideration, of soil and/or site specific recommendations for other nutrient inputs.

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Table 7—Proposed N fertiliser recommendation for the Herbert and Bundaberg soil types.

Easy minneralisable (aerobic) N (kg/ha)	N mineralisation potential category	Herbert: TFD[1] soil type	Bundaberg: DNR[2] soil mapping unit	Proposed N fertiliser recommendations for replant/ratoon cane	
				Calculated N application rate	Suggested N application rate
				(kg/ha)	
<20	Very low	Coarse sandy loam Grey sand Red sand River bank River sand Sandy clay Terrace silty loam	Oakwood Quart Woongarra	160 (Current BSES rate)	160
20–29	Low	Fine grey sand Fine sandy loam Red loam Silty clay	Kepnock	150	
30–39	Moderately low	Black organic clay Clay loam Coarse sandy clay Grey brown loam Pale brown sandy loam River overflow Sand ridge		140	140
40–49	Moderate	Clay Fine black sand Beach sand ridge	Maroondan	130	
50–59	Moderately high	Heavy clay		120	120
60–69	High			110	
>70	Very high		Seaview	100	100

[1]CSR Technical Field Department soil-naming system
[2]Queensland Department of Natural Resources—Donnollan *et al.* (1998)

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