SOILS AND LANDSCAPES OF MULGA LANDS WITH SPECIAL REFERENCE TO SOUTH WESTERN QUEENSLAND

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ABSTRACT

Physical and chemical characteristics of soils of part of the mulga (Acacia aneura) *lands of south western Queensland are discussed in relation to landscape development. Mulga is associated predominantly with red earth soils on slightly undulating to flat plains derived from the dissection of the Tertiary land surface. Soils formed are closely related to landscape development with deep red earths occurring on lower slopes and sandy red earths on sand plains and dunefields.*

INTRODUCTION

Mulga lands are widespread throughout all the mainland States of Australia with the exception of Victoria. Early studies by Prescott (1931, 1944), Teakle (1937), Blake (1938) and Beadle (1948) provided generalised soil maps covering sections of the mulga lands. Jessup (1951, 1960), Northcote *et al* (1960, 1966, 1967, 1968), Litchfield (1962, 1963), Jackson (1962), Holland and Moore (1962), McArthur *et al* (1967), Isbell *et al* (1967) and Bettenay *et al* (1967) have mapped and described soils of mulga lands during the course of regional surveys.

This paper considers the mulga soils and landscapes of a part of south western Queensland comprising 15 million hectares which has been mapped into land systems by Dawson (in press). The study area is situated south of the 26° latitude and west of the 145°30′ longitude. It is bounded by the New South Wales and South Australian borders.

Rainfall is low, ranging from less than 200 mm in the west to 380 mm in the east, erratic with frequent long dry periods and occurs mainly in summer. In the southern part of the area the winter component is significant.

MULGA LANDSCAPES

The study area forms part of the Eromanga Basin which is a sub-basin of the Great Artesian Basin. During the Cretaceous period sediments of the Rolling Downs Group formed a vast peneplain here and during the late Cretaceous or early Tertiary (Senior *et al* 1969) upper parts of these sediments were subject to chemical alteration forming a weathered mantle. This process has commonly been referred to as lateritisation in Queensland.

Following this weathering process the fluviatile Glendower Formation was deposited. Further silicification and weathering occurred in the late Tertiary and resulted in the formation of a silcrete cap which is still evident over much of the upland areas. The depth of this cap varies considerably, generally being thicker in the west (Mabbutt, 1969).

The mulga lands are mainly associated with red earth soils on landscapes formed as a result of the dissection and re-distribution of this Tertiary land surface. Five mulga landscapes made up of groups of mulga land systems are described. The vegetation associations of these landscapes have been described by Boyland (1973). The distribution of the four important landscapes is shown in Figure 1. Burrows and Beale (1969) drew attention to the relationship of vegetation patterns and topography in this area.

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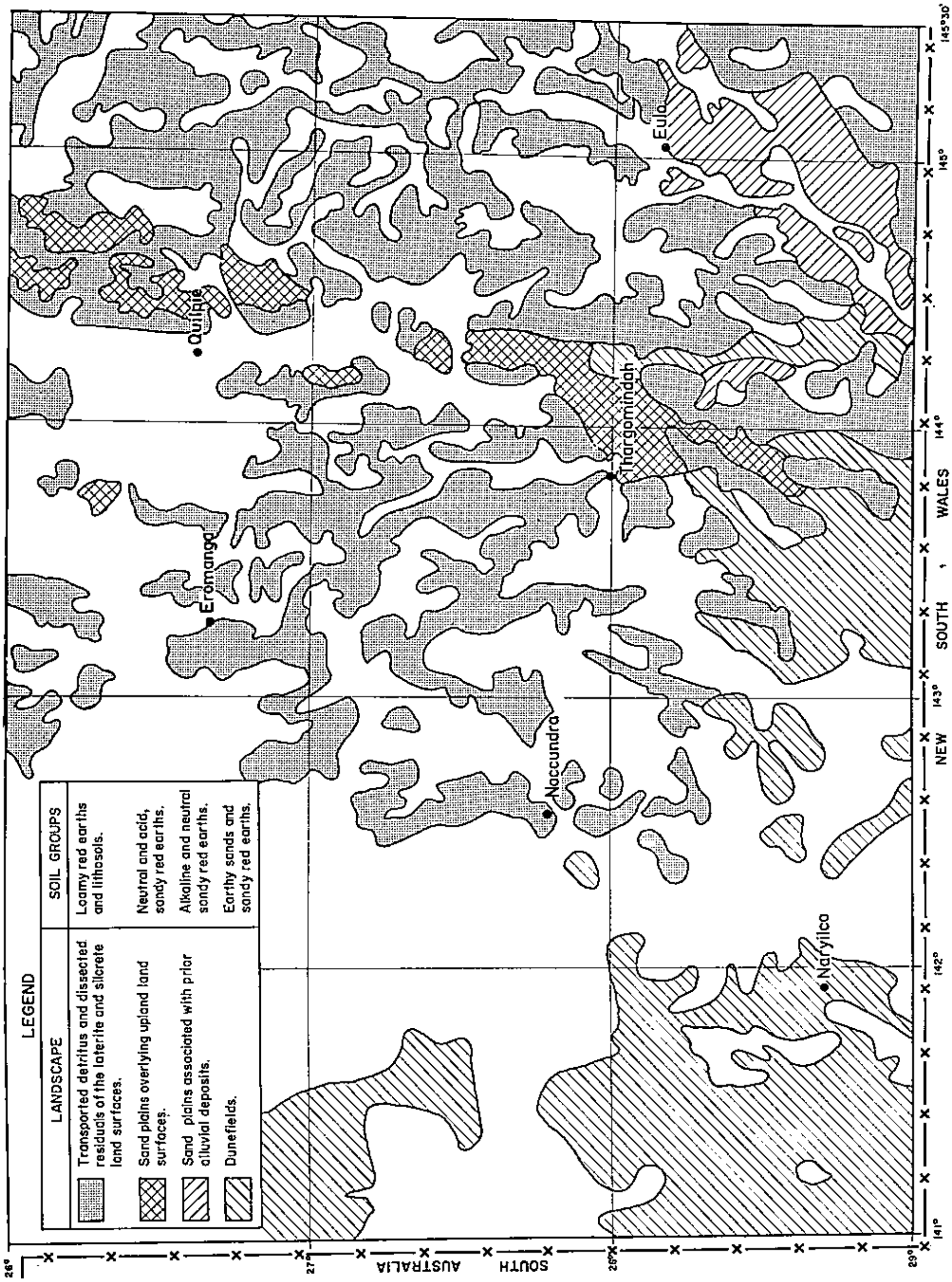
FIGURE 1

Distribution of landscapes and major soil groups of the Mulga lands of South Western Queensland.



Landscape 1—Dissected residuals

This landscape is made up of the mesas, buttes, and plateaux which are remnants of the Tertiary land surface. It forms the backbone of the mulga lands, but because well developed mulga shrublands are not widespread, it is not represented in Figure 1. Soils are predominantly shallow stony lithosols commonly with exposed laterite and silcrete occurring intermixed. Areas of shallow stony red earths also occur. The landscape is closely related to landscape 2, small areas of which occur within it. Its position in relation to landscape 2 is represented in Figure 2.

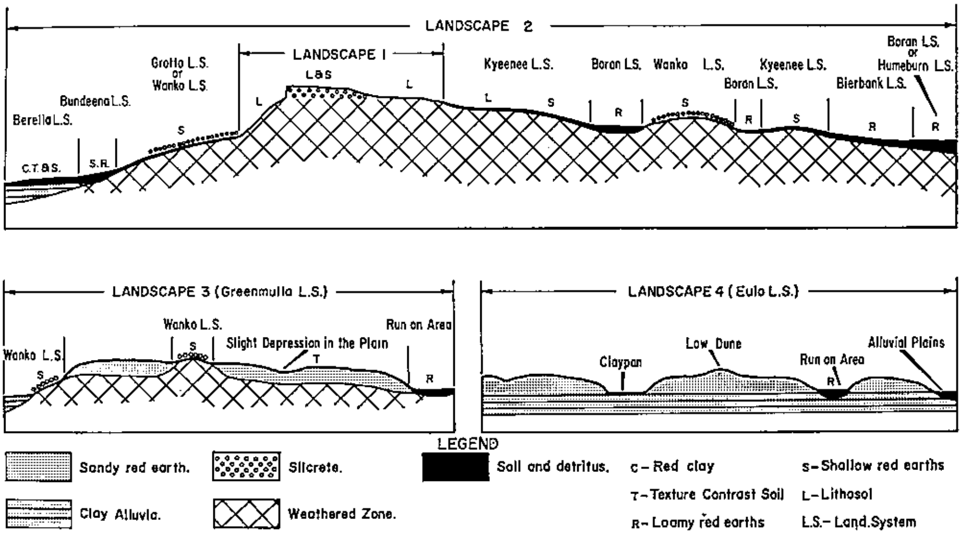


FIGURE 2

Idealized section showing relationship between landscape units

Landscape 2—Transported detritus and dissected residual of the laterite and silcrete land surface

The dissection and erosion of the Tertiary land surface has resulted in a complex landscape. In places the Tertiary land surface was warped resulting in the formation of a landscape with scarp retreats and gently sloping backslopes with a number of different land systems, the distribution of which, within the landscape, is shown in Figure 2. Elements of landscape 1 form a small part of the mapped area of this landscape.

On the lower slopes of the scarp retreats, shallow red earths (Kyeenee land system) and shallow red earths with silcrete intermixed (Wanko land system) occur where erosion has not penetrated the weathered zone. Slopes are generally less than 3 per cent.

Where the scarp retreat has exposed less weathered rock a complex of soils and vegetation results (Grotto land system). In these situations admixtures of gidgee (*Acacia cambagei*) and mulga occur on shallow red earths, lithosols, and shallow texture-contrast soils.

Soil and detritus derived from the erosion of the dissected residuals have been transported down the slopes and re-distributed as alluvia, pediment mantles and fans. The depth of detritus which has been deposited in the alluvial run-on areas varies from 30 cm to greater than 120 cm. Soils are loamy red earths (Boran and Humeburn land systems). On the pediment plains with very low slopes poorly developed mulga groves may occur (Bierbank land system) on moderately deep to deep, loamy red earths. This land system grades into the run-on areas.

In the vicinity of Eromanga, and in other areas mainly west of the Grey Range, well developed mulga groves occur on very low sloping fans which overlie older clayplains (Berella land system). A soil complex comprising shallow red earths and shallow to moderately deep texture-contrast soils with earthy surfaces occurs on the intergrove areas whilst red cracking clays and red loamy-surfaced texture-contrast soils occur in association with gilgai depressions in the well developed grove area.

Landscape 3—Sand plains overlying upland land surfaces

Sand plains formed by the movement of aeolian sand over silcreted upland surfaces occur mainly east of the Bulloo River (Greenmulla land system). The plains are of low relief and have few defined drainage lines. Soils are predominantly deep, acid to neutral, sandy red earths. In these plains deep, loamy-surfaced, texture-contrast soils and deep, loamy red earths occur in small depressions. Shallow stony red earths occur as outcrops in the sand plains and poorly developed mulga groves may occur on the edges of the plains. Figure 2 shows the relationship of these units to one another.

Landscape 4—Sand plains associated with prior alluvial deposits

These sand plains, which are best developed in the vicinity of Eulo, are of low relative relief and commonly interspersed with clay alluvia (Eulo land system). Small claypans occur as depressions in the plains.

Soils are predominantly moderately deep sandy red earths with alkaline soil reaction and commonly with hardpans. Small areas of neutral sandy red earths occur as low dunes whilst loamy red earths occur in run-on depressions. Sandy red earths with massive surfaces fringe the edges of the alluvial plains. Figure 2 shows the relationship of these units to one another.

Landscape 5—Dunefields

While mulga shrublands are not always well developed in the dunefields, mulga is the major shrub over large areas. Dunefields are formed on plains of low relief. The dunes vary from less than 4 m high (Dynevor and Clyde land systems) in the vicinity of the Dynevor lakes to greater than 10 m on the South Australian border. Reticulate linked crescentic (Santos and Naryilco land systems) and longitudinal dunes (Arrabury and Poongamulla land systems) occur. Claypans occur in the interdune areas commonly fringed by cemented aprons. Soils are predominantly deep red earthy sands. Red siliceous sands occur on the dunes but generally not in association with mulga. Sandy red earths occur on the lower slopes and interdune areas.

PHYSICAL CHARACTERISTICS OF THE SOIL GROUPS

The classification of soils has been based on "A Handbook of Australian Soils" (Stace *et al* 1968), with the exception of those soils with textural contrasts in the profile. Further subdivision within the red earths has been based on depth, texture and pH. Physical characteristics of 94 profiles were studied, detailed records being made at 10, 20, 30, 60 and 120 cm or where other significant changes occurred. Principal profile forms (PPF) (Northcote, 1965) for each profile were recorded. Soils have been grouped into more than 20 soil families but for this study only seven major groups are distinguished.

Lithosols

This group is characterised by very shallow (<30 cm) soils with limited profile development. Soils are red and yellowish red and generally have sandy loam to clay loam textures. They overlie weathered rock which is commonly exposed. Silcrete is common on some soils. Available moisture is very low due to the shallow profile and low water holding capacities. Runoff is high. PPF's are Um 1.43, Um 1.42, Um 1.23 and Um 1.22.

Shallow Red Earths

These soils range in depth from 20 to 60 cm. They are red acid loams, lack soil structure, but are friable and porous. Most exhibit uniform textural profiles but in the deeper soils there may be a slight increase in texture down the profile. Mean clay percentages range from 28 in the surface soil to 30 in the subsoil. Silcrete cover is associated with some profiles but where absent, ironstone nodules commonly occur. Runoff is high on the shallow sloping soils and wind and water erosion has occurred where the shrub layer has been destroyed. Available soil moisture is low. PPF's are Um 5.51, Gn 2.11, Gn 2.12, Um 5.31, Um 5.41.

Loamy Red Earths

These soils, which occur mainly on lower slopes, are moderately deep to deep (range 50 to $>$ 120 cm) red friable earths which are slightly acid to acid. Surface soils range from sandy loams to clay loams with clay content increasing with depth to light and medium clays. Some soil types have relatively uniform textures throughout. Percent clay is much higher than in shallower red earths farther up the slope. Ironstone nodules are common in the lower parts of the profile. Available soil moisture capacities are moderate. Many of these soils receive run-on water which can double productivity (Ebersohn, 1970). PPF's are Gn 2.12, Um 5.52, Gn 2.11.

Sandy Red Earths

There are two major soil types in this group, those with acid to neutral soil reaction trends and those with alkaline trends. Both are red friable earths with sandy loam to sandy clay loam surfaces and are porous and less coherent than the loamy red earths. Texture may be uniform or gradually increase with depth. Mean clay percentages range from 17 in the top 10 cm to 23 at the base of the profile. Silt contents are significantly lower in the surface, being 5-6 percent compared with 12 percent for the loamy red earths and 9 percent for the shallow red earths, but coarse sand levels are much higher. Available water holding capacities are low to moderate but infiltration rates are high.

The acid to neutral sandy red earths are deep to very deep and susceptible to wind and some water erosion when bare. PPF's are Um 5.52, Gn 2.12 and Um 5.21.

The sandy red earths with alkaline trends are shallow to moderately deep (30-100 cm) and generally are underlain by a hardpan. They are slightly acid to neutral at the surface and alkaline at depth. PPF's are Gn 2.13.

Earthy Sands

These soils, derived from aeolian sands, are deep red loose loamy sands to sandy loams with little profile development. They exhibit an earthy appearance due to the bridging of sand grains by clayey material including iron oxide (Stace *et al* 1967). Soil reaction ranges from slightly acid at the surface to neutral and slightly alkaline at depth. Available water holding capacities are low, but the deep soils have high infiltration rates. PPF's are Uc 5.21 and Gn 2.12.

Texture-Contrast Soils

These soils are of limited extent in the mulga lands, being associated with the local alluvia, fans and lower sand dunes. Surface textures range from sandy loams on the dunes to clay loams on the alluvia, and hardpans are common. The soils may be alkaline at depth. Surface characteristics range from loose on the low dunes to earthy and massive on the fans and local alluvia. Carbonate may occur in the lower parts of the profile on the fans and local alluvia. Soil depth varies considerably. PPF's are Dr 2.12, Dr 2.13, Dy 2.43.

Red Clays

Small areas of moderately deep to deep cracking red clays occur in gilgai depressions in Berella land system. These soils have surface crusts and occur in association with texture-contrast soils. Water holding capacities are high. PPF's are Ug 5.38 and Ug 5.37.

Discussion

Hardpans in soils of the mulga lands have been recorded by Litchfield and Mabbutt (1962) in Western Australia, South Australia and the Northern Territory. Everist (1949) also noted their occurrence in Queensland and observed that the hardpan assists in the retention of soil water. In Western Australia, Litchfield and Mabbutt (1962) established a relationship between hardpan in soils and position in the landscape. A similar situation occurs in Queensland with hardpans being developed on the pediments, fans and sandplains, but weathered rock forms the base of most profiles in the mulga lands of this area.

Groving of mulga has been recorded by Litchfield and Mabbutt (1962) and Litchfield (1963) in Western Australia and Jackson (1962) and Perry (1960) in the Northern Territory. Groved mulga also occurs in Queensland in two situations. On one type, where the boundaries between grove and intergrove are diffuse, differences between the soils are not well developed, but field evidence indicates better water relations in the grove areas. In some groves the soils are deeper and lighter-textured than in the intergroves.

In the western parts, boundaries between the groves and intergroves are sharp. In the groves, depressions 10 to 40 cm. deep occur and the soils are deep, red cracking clays and red texture-contrast soils. Intergrove soils are shallow red earths and shallow texture-contrast soils. Available moisture capacity is much greater in the groves.

The propensity of arid soils, including the earthy sands, to form crusts following rain has been observed by Litchfield (1963) and Ebersohn (1970). This feature is common in mulga soils and may reduce infiltration. Many shallow red earths are massive and hard in the dry state and runoff is high, but they become more friable when moist. Harder, more impermeable surfaces may result from wind and water erosion.

Laboratory determinations show low available moisture contents ranging from 3-9 percent for the red earths to 2 percent and less for the earthy sands.

CHEMICAL PROPERTIES OF THE SOIL GROUPS

Fifty-nine profiles have been analysed in detail and one hundred and two additional samples have been analysed for pH, salinity and available P (phosphorus) using acid extraction. Analytical data for six representative profiles of the three most important soil groups are presented in Table 1. A general indication of the properties of the 0-10 cm horizon for the three major groups (shallow red earths, loamy red earths and neutral and acid sandy red earths) is provided by mean values in Table 2.

pH

Profiles are acid throughout except for some texture-contrast soils and those sandy red earths mentioned previously which are slightly alkaline to alkaline at depth. Within the three major groups, surface soils of the shallow red earths and sandy red earths are strongly acid while the loamy red earths are moderately acid. O'Hagan (1966) showed that biological activity including nodulation is reduced significantly in the more acid soils.

TABLE 1

Chemical properties of six representative profiles

Depth cm.	pH H_2O 1 : 5	Air Dry Mois. %	% Air Dry Weight T.S.S.	Cl	Org. C	N	P	Particle Size % Oven Dry Weight CS	FS	Si	C	Ex. Cap.	Ex. Cations Ca.	Mg.	K.	Na.	Avail. P. p.p.m. Acid	Bi-carb.	Water Retained percent $\frac{1}{3}$ bar.	15 bar.
												m—equiv./100 g. A.D.								
Shallow Red Earths (A 69)																				
10	5.1	1.8	0.01	0.001	0.6	0.055	0.027	10	50	10	33	7	1.7	0.2	0.85	<0.2	8	5	17	8
20	4.8	2.1	0.01	0.001				9	47	10	36	7	1.7	0.1	0.8	<0.2	5			
Shallow Red Earth (A 39) Silcrete Cover																				
10	4.5	1.6	0.01	0.002	0.4	0.045	0.015	12	58	11	23	3–5	0.6	0.2	0.4	<0.2	5	5	13	6
20	4.7	1.8	0.01	0.002				8	59	12	26	3–5	0.8	0.2	0.5	<0.2	6			
30	4.8	2.2	0.01	0.004				7	58	11	28	3–5	1.6	1.0	0.5	<0.2	5		15	6
45	4.9	2.4	<0.01	0.004			0.026	7	58	11	29	5	2.2	1.6	0.5	<0.2	5			
Loamy Red Earth (A1) Mulga Grove																				
10	4.8	1.6	0.01	0.002	1.3	0.075	0.032	21	44	10	29	8	3.2	0.5	0.65	<0.2	6	7	15	9
20	4.7	1.8	0.01	0.003				17	42	7	33	7	2.9	0.7	0.4	<0.2	5			
30	4.6	2.0	0.01	0.003				16	38	8	40	7	3.2	0.9	0.35	0.2	4		16	11
60	4.9	2.7	0.01	0.004				22	25	5	48	5	2.5	1.1	0.25	0.3	3		17	11
120	5.8	2.8	0.02	0.006			0.014	14	26	12	50	9	3.0	3.4	0.25	0.5	1			
Loamy Red Earth (A 82) Run on Area																				
10	5.0	1.8	0.01	<+	0.7	0.05	0.031	16	44	9	34	7	1.8	0.6	0.7	<0.2	7	10	17	8
20	5.0	2.1	0.01	<				14	43	8	38	6	2.1	0.5	0.7	<0.2	4			
30	5.2	2.3	0.01	<				13	43	9	40	7	2.8	1.2	0.7	<0.2	2		17	9
60	5.6	2.4	0.01	<				11	40	8	43	8	3.1	1.6	0.7	<0.2	3		18	9
120	6.0	2.5	0.01	<			0.023	11	40	7	45	9	3.6	2.6	0.65	<0.2	2			
Sandy Red Earth (A 29) Neutral and Acid Form																				
10	5.3	1.0	0.01	0.002	0.4	0.03	0.01	42	37	5	17	<3	0.4	<.1	0.4	<0.2	3	5	8	5
20	4.8	0.9	0.01	0.001				37	42	5	19	<3	0.8	0.3	0.25	<0.2	5			
30	5.0	1.0	0.01	0.001				37	41	4	20	<3	1.0	0.5	0.2	<0.2	3		9	4
60	5.3	1.4	0.01	0.002				35	40	4	20	3–5	1.2	0.9	0.2	<0.2	2		10	5
120	6.0	1.3	0.01	0.002			0.016	36	39	7	20	3–5	1.8	1.5	0.2	<0.2	3			
Sandy Red Earth (A 72) Alkaline Trend																				
10	6.5	1.1	0.01	<	0.6	0.055	0.028	32	50	6	16	7	3.3	1.5	0.95	<0.2	42	36	11	4
20	8.5	1.4	0.02	0.001				27	49	7	21	8	7.7	1.3	1.45	<0.2	10			
30	8.1	1.4	0.02	0.002				26	51	9	17	7	5.9	1.2	1.3	<0.2	5		12	6
60	8.2	1.6	0.08	0.01			0.017	23	56	9	15	8	7.9	2.0	1.0	0.2	5		10	6

+ <0·001% air dry weight

TABLE 2

Chemical properties of 0–10 cm. horizon

	pH H_2O 1 : 5	Org. C	N	C/N	P	Avail. P Acid ppm	Avail. P Bicarb. ppm	Ca	Ca/ CEC	Mg	Ex. Cations Hg/ CEC	K	K/ CEC	Na	Na/ CEC	(CEC) Ex. Cap.	Clay % oven dry weight	CEC/ 100 g clay
			% Air Dry Weight					m. equiv./100 g A.D.										
Loamy Red Earths (0–10)																		
No. of samples		15	15	15	19	25	25	17	17	17	17	17	17	17	17	17	17	17
Median	5.9																	
Mean		0.75	0.065	12	0.024	13	12	3.4	43%	2.0	25%	1.0	12%	<0.2	2%	8	30	26
C.V. %		30	27	20	29	48	35	38	31	43	37	32	93	54	—	16	22	—
Shallow Red Earths (0–10)																		
No. of samples		9	9	9	8	15	15	11	9	11	9	11	9	11	9	9	9	9
Median	5.1																	
Mean		0.55	0.055	10	0.025	9	9	1.5	27%	0.6	12%	0.65	12%	<0.15	2.5%	5	26	20
C.V. %		25	27	10	48	43	46	35	38	53	51	29	24	34	37	22	17	
Sandy Red Earths (0–10)																		
No. of samples		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Median	5.1																	
Mean		10.5	0.035	13.5	0.017	12	11	0.9	29%	0.3	8%	0.4	12%	<0.15	4%	3	17	19
C.V. %		40	38	17	26	45	36	69	71	66	57	26	25	31	—	19	19	—

Salinity

Salinity levels are very low, being below 0.03 percent total soluble salts (T.S.S.) and 0.02 percent chlorides for most profiles, but higher values occur in the lower profiles of the alkaline sandy red earths. Some eroding sites on one soil type within the shallow red earths have up to 0.17 percent T.S.S. and 0.07 percent chloride in the profile.

Exchangeable Cations

Cation exchange capacities are low with variation between samples being largely related to clay content. The lower base saturation of the shallow red earths and sandy red earths in relation to the loamy red earths is in keeping with the pH values.

Calcium is the dominant exchangeable cation, although some profiles show a relatively greater increase in magnesium with depth. The exchangeable calcium and magnesium levels of the surface 10 cm of the loamy red earth group indicate a satisfactory plant nutrient level for these elements. In the shallow red earths and sandy red earths the lower Ca and Mg status could indicate deficiency levels. Cowie (1968) showed Ca deficiency in the presence of applied phosphorus in lateritic red earths.

Exchangeable potassium as a percent of C.E.C. is similar for surface samples in all three major groups and indicates satisfactory plant nutrient levels. Although exchangeable K usually decreases with depth a significant number of sites have uniform K profiles.

Exchangeable sodium values are low throughout all red earth profiles examined.

Phosphorus (P)

The mean value of 0.023 percent total P for the surface of all red earth sites agrees with the value of 0.020 percent given by Wild (1958) for red earth soils. Mean subsoil value is 0.020 percent. Available P values are variable but generally low, similar values being obtained by both bicarbonate and acid extractions. Cowie (1968) and Christie (1970) show phosphorus as the main limiting plant nutrient in these soils. For buffel grass (*Cenchrus ciliaris*) Christie (1970) showed that 25 p.p.m. available P was the critical level.

Nitrogen and Organic Carbon

Surface nitrogen and organic carbon levels are low, in common with arid soils, with the sandy red earth levels being considerably lower than the shallow red earths or the loamy red earths.

While considerable amounts of litter were found on the surface of some sites this condition is not always reflected in higher organic carbon levels in the 0-10 cm sample.

Prescott (1931) drew attention to the relationship of soil nitrogen to rainfall and to soil phosphorus, and Jackson (1962) obtained a good correlation between total N and total P for acid soils. Our study shows a weak correlation between total N and total P ($r_{31} = 0.39$ ($P < 0.05$)) but a better relationship between total N and clay ($r_{31} = 0.62$ ($P < 0.01$)). In this environment of low and irregular rainfall, clay content could be a good indicator of available moisture and therefore of plant growth.

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