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SOILS OF THE UTCHEE CREEK SUBSTATION

I.J. Heiner, C.D. Smith
Land Resources Branch

Queensland Department of Primary Industries

Queensland Government Technical Report

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SUMMARY

The 267 ha Utchee Creek Substation is located 16 km south west of Innisfail, North Queensland and 9.5 km west of the South Johnstone Research Station. The Substation was established in 1941 to enable experimental work carried out at the Research Station to proceed on a larger scale. Clearing of virgin rainforest at Utchee Creek took place sporadically over a 26 year period.

The Substation is situated on low hills of the Barron River Metamorphics and flows of the Atherton Basalt. A soil survey and agricultural land classification were carried out to assess the soil resources of the Substation. Free survey methods were used and representative profiles were analysed.

Three soil series, two phases and one variant were mapped at 1:25 000 scale from 57 ground observations. The survey identified 86.8 ha of arable land, 12.2 ha of limited arable land, 22.4 ha of pastoral land and 146.4 ha of non-agricultural land. A diversity of land uses are therefore able to be researched.

1. INTRODUCTION

The Queensland Department of Primary Industries 267 ha Utchee Creek Substation is located along an unnamed creek flowing into Utchee Creek, 16 km south west of Innisfail (Figure 1). The Substation was established in 1941. Virgin rainforest was cleared to carry out large scale experimental pasture research which has continued to the present.

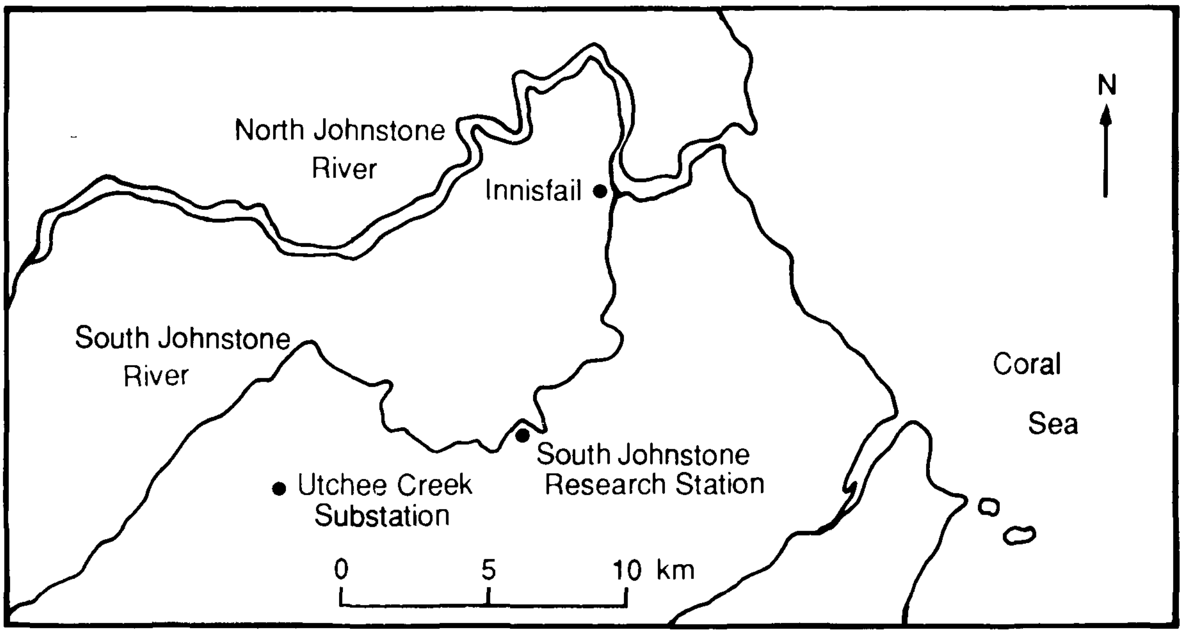

Figure 1. Locality plan

The present study was initiated because the South Johnstone Research Station Committee requested that Land Resources Branch conduct a very high intensity soil survey and an agricultural land assessment of both South Johnstone Research Station and the associated Utchee Creek Substation. Soil Conservation Services Branch was also requested to provide detailed topographic information for both research establishments. The work was requested for the following reasons :

. The absence of any comprehensive land resource documentation and classification and

. The prospect of an anticipated expansion of tropical horticultural research involving a range of species with varying soil requirements.

The Johnstone Research Station report is available separately (Heiner and Smith 1990).

2. PHYSICAL RESOURCES

2.1 Climate

2.1.1 General

The Utchee Creek Substation is situated on the wet tropical coast of North Queensland which is characterised by a tropical maritime climate. The dominant climatic feature is the high, summer dominated rainfall. Winters are warm and summers hot and humid.

2.1.2 Rainfall and evaporation

Table 1 shows the mean and median monthly and annual rainfall and mean number of rain days at Utchee Creek Substation. Over 60% of the mean annual rainfall falls between December and March while only about 10% is received between June and September.

Table 1. Rainfall at Utchee Creek Substation (1966-1986)

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	597	659	703	460	286	115	79	74	92	93	184	222	3617
Median	431	583	646	354	272	89	78	47	70	58	148	131	3379
Mean No. of Rain days	15	20	20	17	15	11	9	8	10	8	10	11	154

Monthly rainfall is extremely variable especially in the summer months (Figure 2). Summer rainfall is influenced by low pressure cells in the Coral Sea region. Tropical cyclones cross the tropical coast from the Coral Sea area once every 2 to 3 years.

Evaporation is highest from October to January and lowest from May to July. Monthly evaporation exceeds the mean monthly rainfall in August, September and October (Figure 3).

2.1.3 Temperature and daily sunshine

The highest average daily maximum air temperatures occur from November to March and the lowest average daily minimum temperatures from June to September (Figure 4). The highest temperature recorded at the Substation was 37.4°C while the lowest was 5.1°C.

Daily sunshine is at its maximum from October to January and at its minimum from March to June (Figure 5).

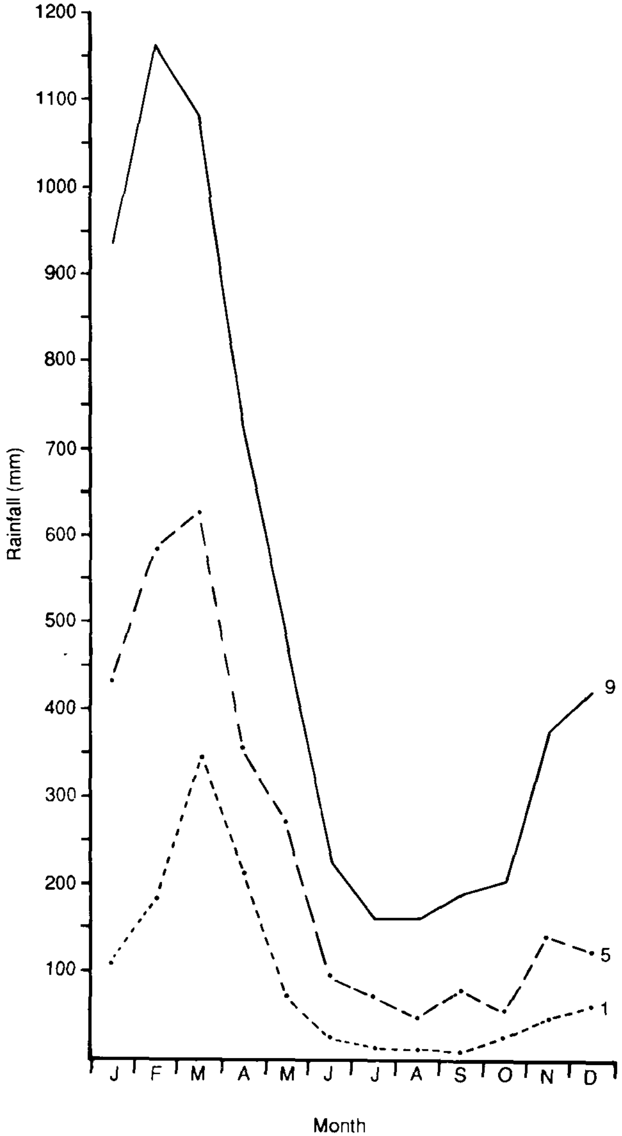

Figure 2 Rainfall deciles (1, 5, 9) - Utchee Creek Substation (1966 to 1986)

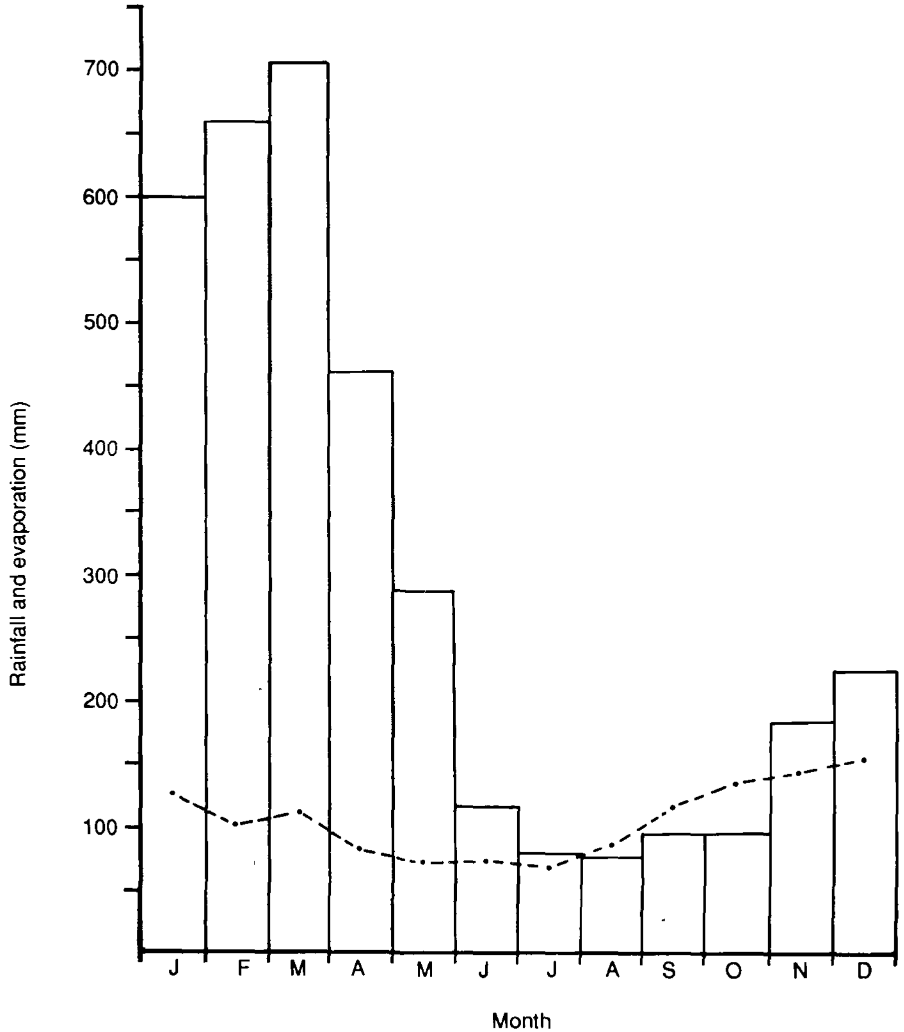

Figure 3 Mean monthly rainfall (bars) and evaporation (dashed line) - Utchee Creek Substation

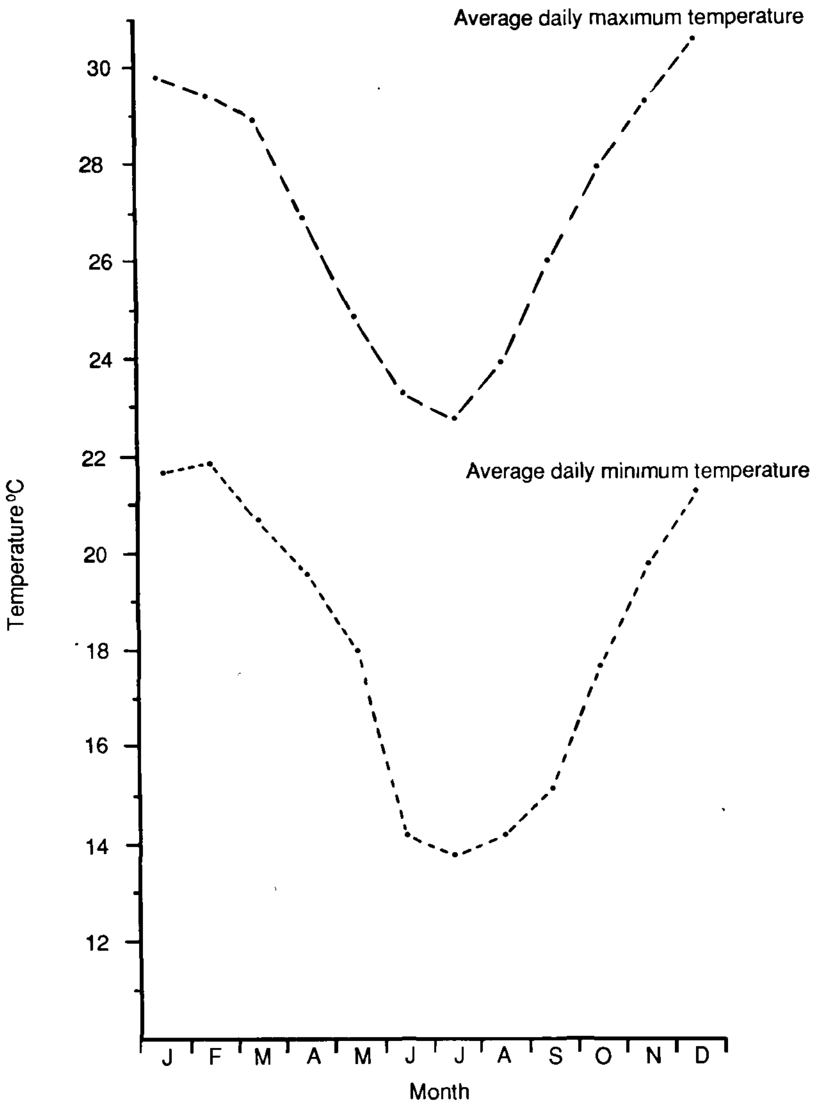

Figure 4. Daily maximum and minimum temperatures Utchee Creek Substation (1975 to 1986)

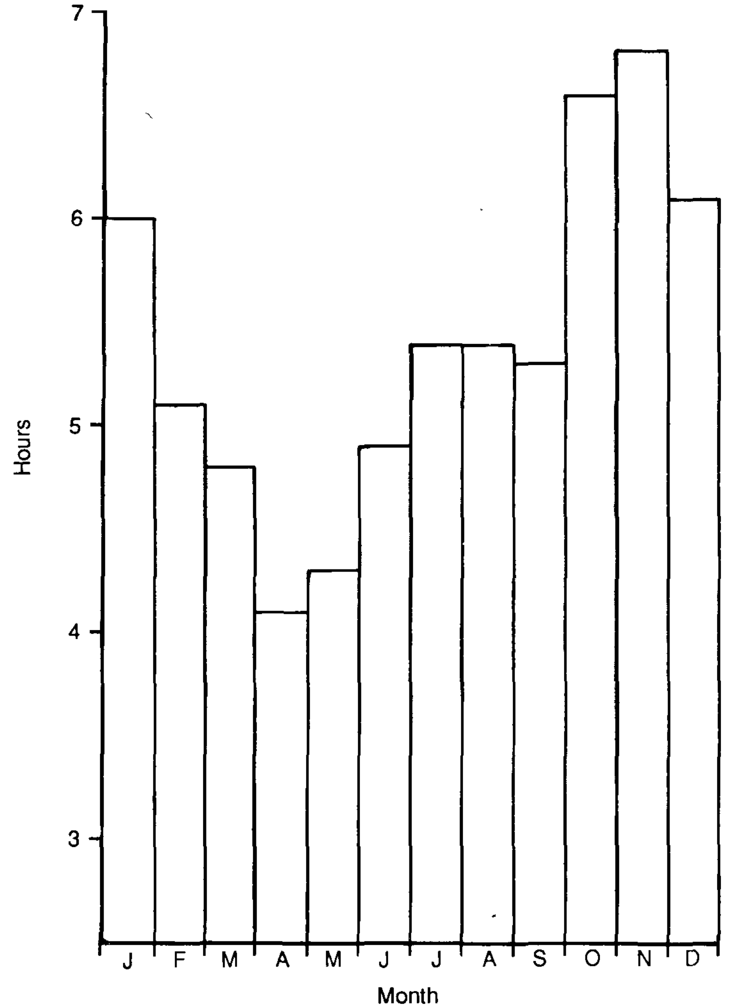

Figure 5. Average daily sunshine - Utchee Creek Substation (1975 to 1986)

2.2 Geology and geomorphology

2.2.1 Geology

The geology of the Innisfail area has been mapped by de Keyser (1972). The Substation is mapped into two geological units:

Atherton Basalts (Cza) and
Barron River Metamorphics (Pzb)

During a Carboniferous orogeny, silty and sandy deposits laid down during the Middle Palaeozoic were intensely folded and faulted to become the Barron River Metamorphics. These are low grade metamorphics and include slate, phyllite and schist formed from fine grained sediments.

Lavas and pyroclasts of the Atherton Basalt flowed down many of the post-tertiary valleys towards the coast in the Pliocene period. The lavas are olivine rich augite basalts, and the pyroclasts consist of cinder deposits.

2.2.2 Geomorphology

The north-south flowing unnamed creek on the Substation approximates the boundary between the two geological units. To the east of the creek, undulating to steep low hills are formed on the Barron River Metamorphics. Lateral water movement is evident in the profile morphology of soils formed on the upper slopes. On some lower slopes, krasnozems have formed either on the contact zone between the basalt and more basic schists or on amphibolite. In other lower slope positions, alluvial fans from the metamorphics have been deposited over the basalt.

The basalt landscape to the west of the creek is predominantly undulating although some steep slopes are located along incised drainage lines.

Adjacent to the entrance road on the western boundary, there is a slightly raised area where a fan of metamorphic material is deposited over the basalt flow.

2.3 Vegetation

The vegetation of the wet tropical coast has been mapped by Tracey (1982). He shows the vegetation of the steep metamorphic low hills in the east of the Substation and along the creek as mesophyll vine forest. The species he lists for this vegetation formation are given in Appendix I. Some of this area has been logged.

The remainder of the Substation is cleared and a variety of grasses and legumes are used in species evaluation and pasture management trials. The original vegetation was most likely complex mesophyll vine forest.

3. LAND RESOURCE SURVEY METHOD

The scale of published soil maps should be determined by the purpose of the survey (McDonald 1975). The density of ground observations should be appropriate for the selected scale.

Utchee Creek Substation is used for pasture trials, with the possibility of some horticultural trials in the future. A 1:25 000 scale was therefore considered most appropriate for mapping. However, for convenience of use as a working document, the map is published at 1:5 000 scale.

The Substation was divided into two areas for survey purposes. The first was a 145 ha area along the eastern boundary with slopes greater than 30 percent. This was considered to be non-agricultural land and only two sites were described. The remaining 122 ha was mapped at a scale of 1:25 000. A free survey method was used to describe and classify soils and landform at 55 sites. This gave an observation density of one site per 2.3 ha.

The soil series established by Murtha (1988) were used as the basis of the mapping units in this survey. The term soil series is defined in the Soil Survey Manual (Soil Survey Staff 1951) as a group of soils having horizons with essentially similar properties, arrangement in the profile and developed from similar parent materials. However, Murtha (1986) states that factors such as land use significance, and ease of distinction from similar soils were also important criteria in the establishment of series in the Innisfail area.

Three soil series, two phases and one variant were described and mapped. A soil profile was sampled for laboratory analysis from each of the three soil series. Profile samples from 0 to 0.1 m, 0.2 to 0.3 m, 0.5 to 0.6 m, 0.8 to 0.9 m, 1.1 to 1.2 m and 1.4 to 1.5 m were analysed. A bulked surface sample comprising nine 0 to 0.1 m samples was collected from each sampled site. Laboratory analysis was carried out according to the methods described by Bruce and Rayment (1982). Table 2 lists the analyses undertaken for this survey.

Table 2. Analytical determinations for sampled profiles

All Samples:	pH, electrical conductivity, water soluble chloride.
Bulked 0 to 0.1 m:	Organic carbon, total nitrogen, acid extractable phosphorus, bicarbonate extractable phosphorus, hydrogen chloride extractable potassium, DTPA extractable iron, manganese, copper and zinc.
Profile 0 to 0.1 m 0.2 to 0.3 m 0.5 to 0.6 m 0.8 to 0.9 m:	Air dry moisture, particle size analysis, effective cation exchange capacity, ammonium chloride extractable cations, -1500kPa moisture, dispersion ratio, exchange acidity, exchangeable aluminium.
Profile 1.1 to 1.2 m:	As for profile to 0.9 m except for -1500kPa moisture and dispersion ratio.

4. SOILS - MORPHOLOGY AND CLASSIFICATION

4.1 Soil series, phases and variants

The area has been previously mapped by Murtha (1986) at 1:50 000 scale. The current survey identified soil series not mappable at the smaller scale. The soils identified on the Substation on metamorphic rocks were Galmara steep phase, Bingil, Mission and Mission gravelly variant. The soils identified on the basalt were Pin Gin and Pin Gin rocky phase. These soil series are described in detail in Appendix II and their major distinguishing attributes and landform occurrence are listed in Table 3.

Table 3. Major distinguishing attributes and landform elements/patterns of the soil series.

Soil Series	Major distinguishing attribute	Great Soil Group[1]	PPF[2]	Landform Element/Pattern[3]
Pin Gin	Red light clay A horizon over red to red-brown light medium clay moderately to strongly pedal B horizon.	Krasnozem	Uf6.31	Slopes of undulating to rolling low hills.
Galmara	Red-brown clay loam A1 horizon over red-brown clay loam A2 horizon over red light clay weakly to moderately pedal B horizon with metamorphic gravel throughout.	Red podzolic soil	Gn3.14	Upper slopes of rolling low hills.
Bingil	Red clay loam A horizon over red clay loam B1 horizon over red light clay weakly to moderately pedal B2 horizon with metamorphic gravel throughout.	Krasnozem	Gn3.11	Mid slopes of undulating to rolling low hills.
Mission	Red, red-brown to brown clay loam fine sandy A horizon over acid red clay loam fine sandy to light clay massive B horizon with metamorphic gravel throughout.	Red earth	Gn2.11 Um5.52	Alluvial fans and lower slopes of undulating low hills.

1. After Stace et al. (1968)
2. Principle Profile Form after Northcote (1979)
3. After Speight (1984)

4.2 Soil distribution and morphology

The distribution of soil series on the Substation is shown on the enclosed map. The Pin Gin series is formed on Atherton Basalt. This soil is a uniform red, light to light medium clay, moderate to strongly structured throughout. In some areas significant amounts of basalt rock fragments are found on the surface. This has been called Pin Gin rocky phase. Uncleared areas along the creek have been included in this unit.

Two soil series, one phase and one variant were identified on the Barron River metamorphics. Galmara steep phase is a gradational soil with a red to red-brown A1 horizon over a pale clay loam A2 horizon over a red light clay B horizon found on the very steep upper slopes. Downslope from this unit, a gradational soil (Bingil series) with a red clay loam A horizon over a red light clay pedal B horizon with some metamorphic gravel was mapped. Mission series occurs on the fans emanating from the metamorphic hills. It is a gradational or uniform soil with a red, red-brown or brown clay loam fine sandy A horizon over a red, light clay, occasionally clay loam fine sandy, massive B horizon. In an area where runoff water accumulates, a soil similar to Mission series but with abundant weathered metamorphic gravel (Mission gravelly variant) was mapped. All soils derived from the Barron River metamorphics have a fine sandy particle size noticeable in the field texture.

4.3 Soil classification

The Great Soil Group (Stace *et al.* 1968), Principle Profile Form (Northcote 1979) and Soil Taxonomy (Soil Survey Staff 1975) classifications of all sampled soil profiles are given in Appendix III .

4.4 Key to the soil series

Soil series may be identified using the following key.

A Fine sand is clearly evident in field texture — SERIES

- **B** Slopes 30% or greater — GALMARA STEEP PHASE
- **B** Slopes less than 30%
    - **C** B horizon of profile is at least moderately structured — BINGIL
    - **C** B horizon of profile is massive.
        - **D** Profile has few (<10%) metamorphic gravels — MISSION
        - **D** Profile has greater than 20% metamorphic gravels — MISSION GRAVELLY VARIANT

A Fine sand is not clearly evident in field texture and surface texture is light clay

- **B** Little or no (<2%) basalt rock fragments on surface — PIN GIN
- **B** 2 to 20%, >60 mm basalt rock fragments on surface — PIN GIN ROCKY PHASE

5. SOILS - CHEMICAL AND PHYSICAL ATTRIBUTES

5.1 General

Three representative soil profiles were sampled to characterise the soil series of the Substation. All profiles were sampled in pastures which have received regular fertiliser applications. Profile morphology and analytical results appear in Appendix III .

Unless otherwise stated, methods of analysis and interpretations of results are those of Bruce and Rayment (1982).

5.2 Chemical attributes

5.2.1 Summary of fertility data

Fertility data for the 0 to 0.10 m bulk samples are presented in Table 4.

Table 4. Ratings for soil chemical analysis data for 0 to 0.10 m bulk samples.

	Soil Series		
	Pin Gin	Bingil	Mission
pH	strongly acid	very strongly acid	strongly acid
Acid extr.P	very low	low	medium
Bicarb. extr. P	medium	medium	medium
Extr. K	low	low	low
Total N	high	high	high
Organic C	high	high	medium
Extr. Mn	high	medium	medium
Extr. Cu	medium	medium	medium
Extr. Zn	medium	medium	medium

The fertility of the Substation soils is generally low. The pH of the soils varies from very strongly to strongly acid in the surface and at depth. Electrical conductivity and chloride levels are very low to low reflecting the lack of soluble salts in these soils due to the leaching effect of the high rainfall. Extractable phosphorous levels vary from very low to medium. Organic carbon and total nitrogen levels are medium to high, reflecting the pasture present on all sampled profiles.

5.2.2 General comments on tropical soil fertility

In the following sections, the implications for soil fertility management on the Substation are discussed. Data is taken from other sources on the wet tropical coast and compared to the Substation samples.

The fertility status of virgin wet tropical coast soils is variable but generally low as indicated by the data in Table 5. Arable cropping and pasture production require the addition of macronutrients and in many cases micronutrients to achieve adequate production. Research shows that the quantities and proportion of added nutrients required to maintain fertility need to be tuned to the particular soil-plant system. Local pasture research has demonstrated that well drained soil types of contrasting natural fertility can achieve the same animal production with appropriate fertiliser inputs (Teitzel, unpublished data).

An aspect of fertility which underpins fertiliser strategy is the charge status of soils. In summary there are three mechanisms which provide the soil with charge and hence cation exchange capacity, namely the charge on clay particles, organic matter and accumulated phosphate radicals. When these tropical soils are utilised for agriculture organic matter and negative charge on clay particles usually decrease, especially with intensive arable cropping. A compensating factor in the case of arable cropping on the wet tropical coast, has been the addition of often large quantities of phosphate fertiliser which supplies phosphate radicals to the soil, and hence acts as a "bank" of negative charge. Additionally it would be expected that higher levels of organically compounded elements in soils under well managed pasture mean less dependence on clay particle charge for the retention and supply of nutrients.

5.2.3 Cation exchange capacity (CEC)

Gillman (1979) has shown that methods which equilibrate the soil solution to a predetermined pH overestimate the CEC of highly weathered wet tropical coast soils. This work demonstrated that the charge status of most of these soils is dependant on pH.

A more meaningful estimate of CEC is the compulsive exchange technique (Gillman and Sumpter 1986a). This method gives a good estimation of the soils ability to retain calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na), that is, basic cation exchange capacity (CEC_B). The results for CEC given in Table 5 for the Substation samples are based on the sum of cations to approximate the compulsive exchange method.

Table 5. Comparison of selected analytical data from Substation samples with mean values of virgin and cultivated sites on the wet tropical coast[1] (WTC) (surface samples).

Parent material	Soil	Organic carbon (%)	pH	CEC[2]	Ca	Mg	K	Al	Avail.P	Management (no. of samples)
METAMORPHIC ROCK	WTC mean values	2.6 (R) 1.2 (S)	4.7	3.1 (R) 1.6 (S)	0.39	0.45 (R) 0.13 (S)	0.1	2.8	12.3 (R) 6 (S)	V (10)
		1.2	4.9	1.6	0.8	0.13	0.27	1.5	60	C (9)
	Galmara[3]	2.9	5.2	1.4	0.3	0.6	0.22	1.3	5	unfertilised grass (1)
	Johnstone[3]	3.5	4.3	0.7	0.2	0.1	0.14	1.42	25	fertilised grass (1)
	Mission[4]	2.4	5.3	3.8	2.1	1.3	0.41	0.23	21	fertilised grass/legume (1)
ALLUVIUM (W)	WTC mean values	3.2	5.4	6.1	4.1	2.1	0.45	1.0	23	V (9)
		1.5	4.7	3.9	1.46	1.4	0.26	2.1	142	C (19)
	Innisfail[3]	2.1	5.0	3.0	0.9	0.7	1.0	1.02	27	fertilised grass (1)
	Liverpool[3]	2.5	5.7	10.0	6.2	2.5	1.0	0.01	55	fertilised grass (1)
BASIC ROCK	WTC mean values	6.2	5.6	5.2	2.53	2.1	0.52	0.6	10	V (5)
		1.6	4.8	1.7	0.53	0.11	0.13	1.0	62	C (18)
	Pin Gin[4]	3.5	5.4	6.0	3.6	1.7	0.18	0.01	9	fertilised grass (1)
	Bingil[4]	3.3	4.8	4.2	2.5	1.3	0.28	0.2	15	fertilised grass/legume (1)

1 Data from Gillman and Abel (1987), Murtha (1986) and Cannon, Smith and Murtha(in press).
2 Compulsive charge method Gillman (1979) for WTC sites; sum of basic cations for Research Station samples.
3 South Johnstone Research Station, sample site.
4 Utchee Creek Substation, sample site.

V - virgin
C - cultivated (sugar-cane)
(W) - well drained
(R) - rainforest
(S) - sclerophyll

5.2.4 Cation exchange chemistry and soil management

Gillman and Sumpter (1986b) demonstrated the potential for an acidification problem in cultivated soils of the wet tropical coast. Declining pH, which is associated with fertiliser use (Helyar 1976), results in a lower CEC than occurs in the virgin state. This reduction in cation retention capacity is also a result of organic matter loss.

These findings are demonstrated in Table 5 which compares data from virgin wet tropical coast soils to equivalent soils growing sugar-cane and pasture. The data indicates:

. a generally low fertility status in virgin soils.

. the contribution of organic matter (OM) to CEC.

. the decline of CEC with OM loss and/or pH decline in cultivated soils.

. the effect of exchange aluminium (Al) on acidity.

In the case of alluvial and basaltic soils, CEC and pH in intensively cultivated soils decline significantly from levels in virgin soils. This is associated with the loss of organic matter and an increase in Al. It appears that because little liming of these soils occurs in the sugar industry, the acidifying effect of nitrogenous fertilisers in particular have not been counteracted. Hence reserve acidity has increased as a result of the doubling of exchange aluminium.

The metamorphic soils do not indicate the same decline in pH with intense cultivation, yet CEC is generally half that in the rainforest. In contrast to the other groups, exchange Al levels are half that of virgin soils. This explains the maintenance of pH levels, and reflects the liming which is more common in this soil group when used for sugar-cane. It therefore appears that the fall in CEC is the result of OM decline only. This point is reinforced by the comparison of organic carbon and CEC in soils with sclerophyll and rainforest communities.

Included in Table 5 are equivalent data from the sampled sites on South Johnstone Research Station and Utchee Creek Substation. Descriptions of the former are contained in Heiner and Smith (1990). The samples taken in fertilised grass pasture on the alluvial and basic rock soils indicate less chemical degradation than occurs in intensively cultivated soils. Organic carbon levels are up to twice that of intensively cultivated soils and Al levels do not increase. This in turn is reflected in only small reductions in pH and slight reductions or improvements in exchange chemistry.

The data for the sampled metamorphic soils on the Research Station generally indicate less chemical degradation in pasture systems compared to equivalent more intensively cultivated soils. However, differences between the Station soils reflect different pasture management strategies and parent material effects. The Galmara sample is from a grass pasture which has not been fertilised since establishment. This is reflected in low basic cation and available P levels.

The Johnstone sample is from a high stocking rate grass pasture which has received annual applications of ammonium nitrate. This appears to explain the low pH and basic cation levels compared to samples from grass/legume pastures, but similar to intensively cultivated soils. It also is likely that given the higher organic carbon levels, organic matter is contributing as much to cation exchange as clay. A point to note in considering the effects of high nitrogen application to this soil is that it has not been limed since 1983.

The Mission sample (Utchee Creek Substation) has an exceptional fertility status compared to other fertilised metamorphic soils in this region. Given the proximity of this soil to basaltic soils (as discussed in Section 2.2.2), it would appear to have been enriched by basaltic material.

The Liverpool sample has exceptional fertility status in the context of wet tropical coast soils. This is typical of this soil series, being a young soil which receives annual flood water deposition containing weatherable minerals and nutrients.

5.2.5 Nutrient use efficiency

Table 6 indicates a contrast in exchange chemistry which can occur between a pasture system and an intensive horticultural cropping system on the same soil. The examples pertain to South Johnstone Research Stations, but have implications to wet tropical coast soils in general.

Table 6. Exchange cations (meq/100 gms) for Innisfail series (one bulked surface sample.)

	Pasture	Banana trial
pH	5.0	4.4
Ca	0.9	0.53
Mg	0.7	0.31
K	1.0	0.44
Al	1.02	2.85

Source: unpublished data

The nutrient levels in the banana trial samples from South Johnstone Research Station are remarkably low despite regular applications of dolomite (2.5 tonnes/ha, twice annually) and a mixed fertiliser, CK7 (300 kg/ha/month). The latter supplies 612 kg of K, 61 kg of phosphorus (P) and 396 kg of nitrogen (N) in the form of ammonium sulphate per hectare per year. This acidifying fertiliser can create conditions where basic cations are leached from the root zone (Gillman 1987). In contrast, the pasture soil receives 30 kg of P every five years and 180 kg of urea. The resultant exchange chemistry of this soil suggests the possibility of greater use efficiency of added nutrients than is occurring in the banana trial.

5.2.6 Production effects

Despite extremely acid conditions and the low base status of the banana trial soil, yields are twice district average.

Also, Teitzel (personal communication) reports that pastures on granite sands and beach ridges have maintained high growth rates despite low pH and basic cation levels. Secondly, in beef production trials on metamorphic soils, control treatments which received establishment fertiliser and then annual nitrogen dressings have performed as well as those receiving maintenance dressings of P and other elements over a period of eight years. The pH in these has fallen to 4.2.

The situation is therefore unclear. Good production in pastures is attainable for extended periods once the initial P, K and other deficiencies are corrected, and in certain situations despite low pH and detectable nutrient levels. In intensive cultivation, good production occurs on soils with high exchangeable Al, low pH and detectable basic cation levels, the latter occurring despite large fertiliser inputs intended to maintain adequate pH and cation status.

A number of possible conclusions are suggested from the above:

. Empirical extractants used in laboratory analysis do not sufficiently reflect plant nutrient supply in the soils under study.

. Potassium chloride extractable Al is probably not a good indicator of plant growth suppression. It extracts various forms of Al (Bell and Edwards, 1987) including soluble organically complexed (polymeric) forms which are not phytotoxic (Bartlett and Riego 1972; Hue et al., 1986). Monomeric phytotoxic Al must therefore be distinguished from polymeric Al in the first instance (Kervin and Edwards, 1987), then Bruce (1987), has shown that Al activity rather than saturation is a better indicator of relative root length.

. In intensively cultivated situations at least, the use of less acidifying fertilisers may enable production to be maintained with lower overall fertiliser application rates.

5.2.7 Raising pH

Gillman and Sumpter (1986b) have argued that an optimum level for pH in wet coast soils would be near 5.5, as aluminium toxicity problems would be avoided as well as other undesirable nutritional problems caused by low pH. However they have also shown that the ease with which soil pH can be raised depends on soil type.

Soils of basic rock origin are distinct from others in that their iron oxide content confers a capacity to develop positive charge as pH declines. This has the effect of consuming hydroxyl ions produced by the addition of lime.

Other soils however simply acquire more Al on exchange sites and pH elevation is a matter of Ca replacement of Al. The formula for lime requirement to raise pH to 5.5 in these soils is:

$$\text{tonnes lime/ha for 0.1 m} = \frac{\text{meq\% of KCl extractable Al}}{2}$$

For basic rock derived soils, raising pH may require large quantities of lime and hence is economically doubtful. For other soils, liming is potentially cost effective, but questions as to the longevity of the effect have to be resolved.

5.3 Physical attributes

5.3.1 Particle size analysis

There is good agreement between field texture and the particle size analysis results shown in Table 7. The Pin Gin series is dominated by the clay fraction. The sand fraction is slightly higher in this sample than Murtha (1986) reported for the Pin Gin series, but cannot be detected in the field texture. The metamorphic soils (Bingil and Mission) are dominated by the fine sand fraction. In the field this fine sand fraction is clearly evident to the naked eye and imparts a "gritty" feel to the textures.

Table 7. Particle size analysis for sampled profiles

Depth (m)	Pin Gin				Bingil				Mission			
	CS	FS	Si	C	CS	FS	Si	C	CS	FS	Si	C
0-0.10	14	24	10	52	9	46	8	37	13	54	4	31
0.20-0.30	9	24	6	61	5	44	7	45	12	56	4	28
0.50-0.60	9	25	6	60	8	41	10	42	15	52	3	29
0.80-0.90	9	24	8	60	7	34	9	50	13	54	3	29
1.10-1.20	9	23	10	59	8	23	12	58	16	49	4	31

5.3.2 Soil available water capacity estimates

Results of -1500kPa water contents for the sampled profiles are shown in Table 8.

Table 8. -1500kPa moisture per cent for sampled profiles

Depth (m)	Pin Gin	Bingil	Mission
0-0.10	19	15	11
0.20-0.30	19	15	11
0.50-0.60	21	16	10
0.80-0.90	20	18	10

Data on the field capacity of these soils is scant. Gillman (personal communication) suggests the field capacity gravimetric moisture content of the Pin Gin series is approximately 30% . This gives an approximate available soil moisture content of 11% in the surface soil. Standley (unpublished) found available soil moisture ranges of 9.5% in the surface to 4.3% at depth for -33 and -1500 kPa water retentions on the Pin Gin series. Daniells (personal communication) found available water capacities for the Pin Gin, Bingil and Mission series were 184, 166 and 168 mm respectively for an effective rooting depth of 1.0 m.

Published data is not available on the field capacity of the Bingil and Mission series but it would be expected that the available moisture storage capacity of these soils would be less due to the increased sand fraction resulting in less pores.

6. LAND USE

Utchee Creek Substation was established in the 1940s to enable economic assessment of large scale grazing trials to be undertaken.

The first clearing at Utchee Creek was of four hectares and took place in 1941. In 1948 a further sixteen hectares was cleared and regrowth on earlier cleared areas controlled. Further clearing took place in 1952 and in the early 1960s.

Apart from some early work on maize, soybeans and fibre crops, the majority of research carried out on the Substation has involved pasture production. This work included species evaluation, soil fertility, weed control, stocking rates, pasture and animal production and whole systems assessment. This work has been comprehensively reviewed by Teitzel and Middleton (1980).

7. AGRICULTURAL LAND SUITABILITY

7.1 Introduction

Utchee Creek Substation comprises a range of soil and landform types. A diversity of land uses are therefore able to be researched. In view of this, the Research Station Committee requested that an agricultural suitability classification be provided in addition to soil and land survey information to assist in future research planning.

Land Resources Branch provides interpreted land resource information in the form of either a five class land suitability classification for individual land uses, or as broad agricultural land suitability groups, namely arable, limited arable, pastoral and non-agricultural land. The latter has been chosen because when displayed on a map, it provides an immediate indication of the most intensive use appropriate for each mapped land type.

7.2 Agricultural land use suitability groups

This is a hierarchical ranking which assumes that the arable land, (the most valuable and versatile land) is also suitable for lower ranked uses. Pastoral land on the other hand is not suitable for higher ranked uses. One proviso however, is that land mapped as arable land is not necessarily suitable for every adapted arable land use, but rather indicates the area of land suitable for the combination of all adapted arable uses.

Agricultural land classification is based on the assessment of land properties which determine the viable long term productivity of particular land uses while limiting land degradation. These properties have been termed **land limitation factors** (Anon in press), shortened to **limitations** . These limitations affect crop growth, machinery and irrigation usage and land degradation.

The primary limitations used to allocate land to one of the four agricultural land suitability groups in the present survey are erosion potential, and rockiness and land slope as they affect machinery operation.

7.2.1 Arable land

The limit to arable land on the Substation was determined by erosion potential. Viable long term productivity cannot be maintained on land which is eroding at rates greater than the rate of soil formation. In the wet tropics, this soil loss tolerance rate is estimated to be in the order of 20 tonnes/ha/yr (Kirkby 1980). Soil loss will depend on:

. soil erodibility
. land slope
. crop type
. erosion control measures.

For each soil /crop management system there is a slope limit above which soil loss cannot be kept below the soil loss tolerance level. This slope limit has been determined on the basis of local soil conservation research and in consultation with extension personnel. For the soils on the Substation, the slope limit to arable land is 15%.

7.2.2 Limited arable land

This type of land use tolerates greater slopes than arable land because it is assumed that a permanent grass sward is maintained, thereby providing protection to more than 80% of the soil surface. The upper slope limit of this land use group is dictated by a topographic limit to machinery operation.

To carry out normal management practices, horticultural tree crop land has to be trafficable throughout the year. From the point of view of safe and effective machinery operation, there is therefore a slope limit to machinery use in this high rainfall environment. Inability to carry out various management practices requiring machinery will lead to declining productivity and profitability. This in turn may lead to land degradation.

In consultation with horticultural crop specialists and soil conservationists, it has been determined that 20% is the upper slope limit to horticultural tree crop land.

7.2.3 Pastoral land

This type of land use assumes the maintenance of a complete grass cover. The upper slope limit of this land use is dictated by a topographic limit to machinery operation. Areas with prohibitive soil limitations to arable and limited arable land are also included in this category.

Land between 20 and 30% is suitable only for improved pastures in this environment.The 30% slope limit reflects the upper limit to safe and efficient machinery operation. Improved pasture production on the wet tropical coast requires far fewer machinery operations than horticultural tree crop production, and there is no necessity to operate in wet conditions. While it is feasible to negotiate steeper slopes, consultation with industry specialists and operators indicates that 30% is an acceptable limit for safe usage. The observation associated with this criterion is that pastures on slopes steeper than 30% are invariably degraded, suggesting an inability or difficulty in effecting normal management practices.

Rock fragments in the plough zone interfere with the efficient use of, and may damage, agricultural machinery. Assessment is based on the size, abundance and distribution of rock fragments in the plough layer, together with machinery and farmer tolerance of increasing size and content of rock fragments. The level of rock fragments associated with this suitability group allows for cultivation associated with pasture establishment but not the more intensive cultivation necessary in the previous two groups.

7.2.4 Non-Agricultural land

This land is too steep for any permanent, profitable agricultural use. The implication for agriculture on the wet tropical coast is that land over 30% slope should not be cleared. Its most appropriate use is for catchment protection, fauna habitat and where appropriate, timber extraction.

7.2.5 Other non-agricultural land types

Stream Channels: These include areas of permanent water flow. The areas of occasional water flow will inevitably be colonised by species such as para grass, as it is often inappropriate to encourage tree species. These areas will therefore be a component of the grazing resources of the property, but are excluded from those areas recommended for pasture development.

7.3 Agricultural limitations of the soil series

Table 9 indicates that the six different soil series, phases or variants occur in the various agricultural land suitability groups. The distribution of the suitability groups is shown on the enclosed map. The suitability of soils for specific land uses is assessed by considering the **land limitation factors** referred to previously. Explanations of the application of these limitations to a range of agricultural uses on the wet tropical coast is given by Smith *et al.* (in preparation).

Table 9 . Areas of arable land and other land suitability categories (ha).

	Arable	Limited arable	Pastoral	Non-agricultural
Pin Gin	66.8	1.7	2.8	12.5
Pin Gin, rocky phase	-	-	3.2	21.8
Galmara, steep phase	-	-	1.3	94.5
Bingil	0.9	3.2	11.4	16.7
Mission	19.1	7.3	1.2	0.8
Mission, gravelly variant	-	-	2.5	0.1
Total	86.8	12.2	22.4	146.4

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APPENDIX I.

Vegetation - Scientific names

Canopy

Alstonia muellerana
Cardwellia sublimis
Cryptocarya mackinnoniane
Doryphora arematica
Endiandra montana
Eugenia sp.
Flindersia pimenteliana
Grevillea pinnatifida

Sub Canopy

Archontophoenix alexandrae
Arenga appendiculata
Austremyrtus minutiflorus
Brombya platynema
Delarbrea micheana
Guioa acutifolia
Helicia nortoniana

Understory Species

Bowenia spectabilis
Cyathea rebeccae
Eugenia wilsonii
Pandanus monticola

APPENDIX II.

Morphology of the Soil series

Notes

1. The most commonly observed range of profile attributes are described, together with less frequent variations outside this range.

2. Principal profile forms (PPF) are listed with the most frequently occurring first.

3. Colour codes are those of the revised standard soil colour charts (Oyama and Takehara 1967). Colour names are those of McDonald (personal communication) based on the value/chroma rating system of Northcote (1979) and utilising the following table.

Value/chroma 2a = 4/1 - 4/2 to 6/1 - 6/2
Value/chroma 2b = 5/3 - 5/4 to 6/3 - 6/4

Value/ chroma rating	1	2a	2b	4	5
Hue					
10R	dark	red-grey	red-brown	red	red
2.5YR	dark	grey-brown	red-brown	red	red
5YR	dark	grey-brown	brown	red-brown	red-brown
7.5YR	dark	grey-brown	brown	yellow-brown	brown
10YR	dark	grey	yellow-brown	yellow	brown
2.5Y	dark	grey	yellow-grey	yellow	olive-brown
5Y	dark	grey	yellow-grey	yellow	olive

4. Texture, structure and consistence as per McDonald and Isbell (1984).

5. Field pH: as per Raupach and Tucker (1959) except that values were used from indicator applied to crushed soil fragments rather than from a paste of soil and indication fluid at depths of 0.10, 0.30, 0.60, 0.90 and 1.2m.

6. Clear or abrupt boundaries are indicated by —— while - - - indicates gradual or diffuse boundaries.

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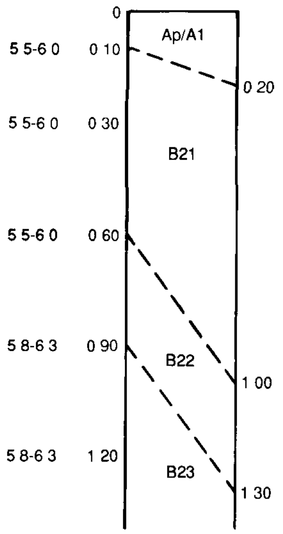
Soil Series | P.P.F. | pH | m | Description

PIN GIN Uf6.31



Krasnozem

Ap/A1 horizon: Red, (2.5YR 3/3-4); light clay; moderate to strong 2 to 5mm cast; with or without very few rounded basalt gravels.

B21 horizon: Red (2.5YR 3/5-6, 10R 3/4-6); light clay; moderate to strong 2 to 4 mm angular blocky; with or without few rounded basalt gravels.

B22 horizon: Red (2.5YR 3/5-6, 10R 3/4-6) to red-brown (5YR 3-4/6); light to medium clay; moderate to strong 5 to 10 mm angular blocky; with or without few subrounded or rounded basalt gravels.

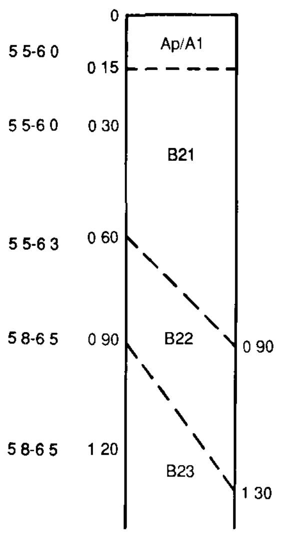
B23 horizon: (Where present) red (2.5YR 4/4) to red-brown (5YR 3,4/6); light medium clay; moderate 2 to 5 mm polyhedral or angular blocky; with or without few subrounded or rounded basalt gravels.

Landform: Hillslopes of undulating to rolling rises, slopes 1 to 30%.

Vegetation: Cleared, fertilised pasture.

Soil Series | P.P.F. | pH | m | Description

PIN GIN ROCKY PHASE Uf6.31



Krasnozem

Ap/A1 horizon: Red (2.5YR 3/4); light clay; moderate 2 to 5 mm cast; very few to few large pebbles or cobbles, subrounded basalt rocks fragments.

B21 horizon: Red (2.5YR 3/6, 10R 3/5); light clay; moderate 2 to 5 mm angular blocky; with or without few rounded basalt gravels.

B22 horizon: Red-brown (5YR 3/5) to red (2.5YR 3/6); light to light medium clay; moderate 2 to 5 mm angular blocky; with or without few rounded basalt gravels.

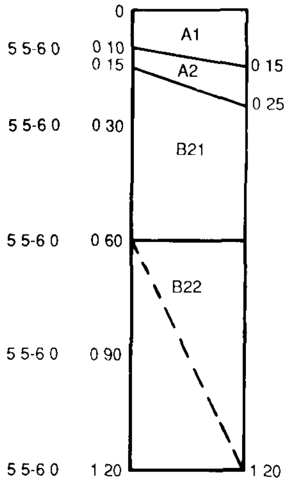
B23 horizon: (Where present) red-brown (5YR 4/6), light medium clay; moderate 2 to 5 mm angular blocky; with or without few rounded basalt gravels.

Landform: Hillslopes of undulating to rolling rises, slopes 1 to 20%

Vegetation: Cleared, fertilised pasture.

Soil Series | P.P.F. | pH | m | Description

GALMARA, STEEP PHASE | Gn3.14



Red podzolic soil

A1 horizon: Red (2.5YR 3/4) to red-brown (5YR 3/4); clay loam to clay loam fine sandy; moderate 2 to 5 mm cast; few subangular metamorphic gravels.

A2 horizon: Red (2.5YR 4/4) to red-brown (5.0YR 3/4); clay loam fine sandy; moderate 2 to 5 mm cast; few subangular metamorphic gravels.

B21 horizon: Red (2.5YR 3-4/6); clay loam fine sandy to light clay; moderate 2 to 5 mm angular blocky, common subangular metamorphic gravels.

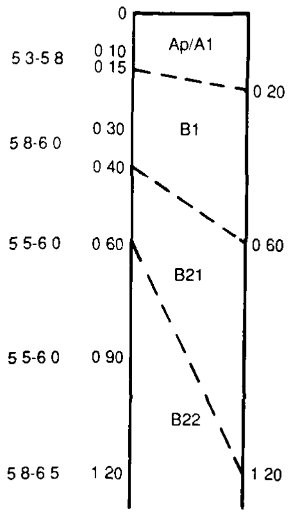
B22 horizon: (Where present) red (2.5YR 3/6); light clay; moderate 2 to 5 mm angular blocky; common subangular metamorphic gravels.

Landform: Upper slopes of low hills, slopes >20%

Vegetation: Mesophyll Vine Forest

Soil Series | P.P.F. | pH | m | Description

BINGIL | Gn3.11



Krasnozem

A1 horizon: Red (2.5YR 3-4/4) to red-brown (5YR 3-4/4); clay loam to clay loam fine sandy; moderate 2 to 5 mm cast; with or without few subangular metamorphic gravels.

B1 horizon: (Where present) red (2.5YR 4/6-7); clay loam to clay loam fine sandy; weak to moderate 2 to 5 mm angular blocky; with or without few to common subangular metamorphic gravels.

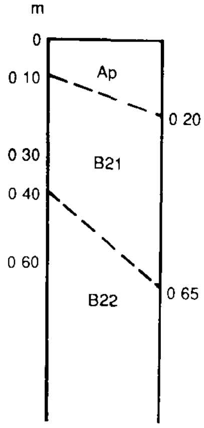
B21 horizon: Red (2.5YR 4/6-7); light clay; moderate 2-5 mm angular blocky; with or without few to common subangular metamorphic gravels.

B22 horizon: (Where present) red (2.5YR 3/4-6, 4/6-7); light to light medium clay; moderate 2 to 5 mm blocky; with without few to common subangular metamorphic gravels.

Landform: Slopes of low hills, slopes 3 to 20%

Vegetation: Cleared, fertilised pasture.

Soil Series	P.P.F.	pH	m	Description
MISSION	Gn2.11 Um5.52	5 5-6 0 5 5-6 0 5 5-6 0		Red earth



Red earth

Ap horizon: Red (2.5YR 3/4-6) to red-brown (5YR 4/4-6); clay loam fine sandy (minor clay loam); moderate 2 to 5 mm cast.

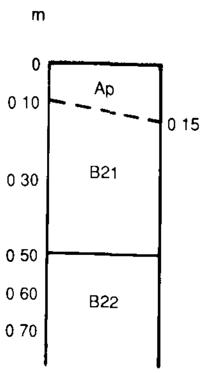
B21 horizon: Red (2.5YR 3/6, 4/5-6); clay loam fine sandy; massive; with or without few subrounded metamorphic gravels.

B22 horizon: Red (2.5YR 3/6, 4/5); clay loam fine sandy to fine sandy light clay; massive, common subrounded metamorphic gravel.

Landform: Fan of sheet-flood fan, slopes 1 to 10%

Vegetation: Cleared, fertilised pasture

Soil Series	P.P.F.	pH	m	Description
MISSION, GRAVELLY VARIANT	Um5.52	5 5-6 0 5 5-6 0 5 5-6 0		Red earth



Red earth

Ap horizon: Red-brown (5YR 4/4) to brown (7.5YR 4/3); clay loam fine sandy; weak to moderate 2 to 5 mm cast; many to abundant subangular metamorphic gravels.

B21 horizon: Red-brown (5YR 4/6) to brown (7.5YR 4/6); clay loam fine sandy; massive; many to abundant subangular metamorphic gravels.

B22 horizon: (Where present) red (2.5YR 3/6); clay loam fine sandy; massive; many to abundant subangular metamorphic gravels.

Landform: Footslope of sheet-flood fan, slope 2%

Vegetation: Cleared, fertilised pasture.

APPENDIX III.

Morphological and analytical data of representative profiles.

Notes

Soil Profile Morphology: as per McDonald and Isbell (1984).

Chemical data: apart from pH, EC and Cl, which are air dry figures, all chemical data are presented on an oven dry basis.

CEC determinations are the sum of the individual basic cations leached by ammonium chloride, added to the exchange acidity.

Refer to Bruce and Rayment (1982) for other laboratory methods.

Soil Series: **Pin Gin** | Substrate Material: **Basalt** | Site No: S1

Great Soil Group: **Krasnozem** | Landform Element Type: Slope | AMG Reference: 384 720 mE 8051 130mN Zone 55

Principal Profile Form: Uf6.31 | Landform Pattern Type: Rises

Soil Taxonomy Category: Tropeptic Haplorthox | Vegetation: Cleared, fertilised grass | Annual Rainfall: 3617 mm

Profile Morphology:

Horizon	Depth	Description
Ap	0 to .15 m	Dark reddish brown (2.5YR 3/3) moist; light clay; strong 2 to 5 mm cast; moist moderately weak. Gradual change to -
B21	.15 to .65 m	Dark reddish brown (2.5YR 3/6) moist; light clay; moderate 2 to 5 mm subangular blocky; moist very weak. Diffuse change to -
B22	.65 to 1.45 m	Dark reddish brown (2.5 YR 3/6) moist; light medium clay; very few medium pebbles, rounded basalt rocks; moderate 5 to 10 mm polyhedral; moist moderately weak. Diffuse change to -
B23	1.45 to 1.90 m	Dark reddish brown (2.5YR 3/5) moist; medium clay; few medium pebbles, rounded basalt rocks; moderate 2 to 5 mm polyhedral; moist moderately weak; very few fine manganiferous nodules.

Laboratory Data:

Depth Metres	1:5 Soil/Water pH	EC mS/cm	Cl %	Particle Size CS	FS	S	C	Exchangeable Cations CEC	Ca	Mg	Na	K	Moistures ADM % @ 105 C	15mPa	Disp. Ratio R1	Exchange Acidity	Al
				% @ 105 C				m.eq/100g								m.eq/100g	
Bulk .10	5.4	.06	.001														
.10	5.7	.15	.001	14	24	10	52	6	3.6	1.7	.18	.18	3.6	19	.09	.06	0.01
.30	5.4	.02	.017	9	24	6	61	16	0.1	0.2	.09	.06	2.3	19	.00	.04	0.01
.60	5.4	.02	.001	9	25	6	60	1	0.2	0.1	.09	.18	2.4	21	.00	.03	0.01
.90	5.4	.01	.001	9	24	8	60	1	0.1	0.1	.06	.08	1.8	20	.00	.02	0.01
1.20	5.3	.01	.001	9	23	10	59	1	0.3	0.1	.05	.04	1.6			.022	0.01
1.50	5.3	.01	.001														

Depth Metres	Org. C (W & B) %	Total N %	Extr. Phosphorus Acid	Bicarb	Rep. K	DTPA extr. Fe	Mn	Cu	Zn
			ppm		meq%	ppm			
Bulk 0.1	3.5	.44	9	25	.20	101	99	3.6	2.8

Soil Series: **Bingil**

Great Soil Group: **Krasnozem**

Principal Profile Form: Gn3.11

Soil Taxonomy Category: Tropeptic Haplorthox

Substrate Material: Metamorphic Rocks

Landform Element Type: Mid-slope

Landform Pattern Type: Low Hills

Vegetation: Cleared, fertilised grass/legume

Site No.: S2

AMG Reference: 384 645 mE 8052 720mN Zone 55

Annual Rainfall: 3617 mm

Profile Morphology:

Horizon	Depth	Description
Ap	0 to .10 m	Dark reddish brown (2.5YR 3/3) moist; clay loam fine sandy; strong 2 to 5 mm cast; moist very weak. Gradual change to -
B21	.10 to .70 m	Dark reddish brown (2.5YR 3/6) moist; light clay; very few medium pebbles, subrounded metamorphic rocks; moderate 2 to 5 mm subangular blocky; moist very weak. Diffuse change to -
B22	.70 to 1.30 m	Dark reddish brown (2.5 YR 3/6) moist; light clay; moderate 5 to 10 mm subangular blocky; moist very weak. Diffuse change to -
D1	1.30 to 1.90 m	Dark reddish brown (2.5YR 3/6) moist; medium clay; strong 5 to 10 mm polyhedral; moist moderately weak.

Laboratory Data:

Depth Metres	1:5 Soil/Water pH	EC mS/cm	Cl %	Particle Size CS	FS	S	C	Exchangeable Cations CEC	Ca	Mg	Na	K	Moistures ADM	15mPa	Disp. Ratio R1	Exchange Acidity	Al
				% @ 105 C				m.eq/100g					% @ 105 C			m.eq/100g	
Bulk .10	5.0	.09	.001														
.10	5.2	.14	.001	9	46	8	37	5	2.5	1.3	.14	.28	2.0	15	.09	.28	.20
.30	5.1	.02	.001	5	44	7	45	2	0.1	0.1	.10	.08	1.8	15	.18	.98	.85
.60	5.1	.02	.001	8	41	10	42	1	0.1	0.1	.09	.14	1.6	16	.24	.75	.64
.90	5.2	.01	.001	7	34	9	50	1	0.2	0.1	.14	.07	2.0	18	.11	.25	.20
1.20	5.1	.01	.001	8	23	12	58	1	0.1	0.1	.16	.04	2.0			.04	.01
1.50	4.9	.01	.001														

Depth Metres	Org. C (W & B) %	Total N %	Extr. Phosphorus Acid ppm	Bicarb ppm	Rep. K meq%	DTPA extr. Fe ppm	Mn	Cu	Zn
Bulk .10	3.3	.28	15	30	.20	245	5	0.7	0.8

Soil Series: Mission

Great Soil Group: **Red earth**

Principal Profile Form: Gn2.11

Soil Taxonomy Category: Typic Haplorthox

Substrate Material: Metamorphic Rocks **Site No.: S3**

Landform Element Type: Fan

Landform Pattern Type: **Sheet-flood fan**

Vegetation: Cleared, fertilised grass/legume

AMG Reference: **384 510 mE**
8052 630mN
Zone 55

Annual Rainfall: 3617 mm

Profile Morphology:

Horizon	Depth	Description
Ap	0 to .12 m	Dark reddish brown (5YR 3/3) moist; clay loam fine sandy; moderate 2 to 5 mm cast; moist very weak. Clear to -
A3	.12 to .30 m	Dark reddish brown (5YR 3/4) moist; clay loam fine sandy; moderate 2 to 5 mm cast; moist very weak. Gradual to -
B21	.30 to .60 m	Reddish brown (2.5YR 4/6) moist; fine sandy light clay; very few medium pebbles, sub-rounded metamorphic rock; massive; moist very weak. Diffuse to -
B22	.60 to 1.03 m	Reddish brown (2.5YR 4/6) moist; fine sandy light medium clay; few medium pebbles; sub-rounded metamorphic rock; massive; moist very weak. Gradual to -
D1	1.03 to 1.50 m	Reddish brown (2.5YR 4/7) moist; light medium clay; common large pebbles, subrounded metamorphic rock; moderate 2 to 5 mm angular blocky; moist moderately weak. Diffuse to-
D2	1.50 to 1.80 m	Reddish brown (2.5YR 4/7) moist; medium clay; few large pebbles, subrounded metamorphic rock; moderate 2 to 5 mm angular blocky; moist moderately weak.

Laboratory Data:

Depth Metres		1:5 Soil/Water pH	EC mS/cm	Cl %	Particle Size CS	FS	S % @ 105 C	C	Exchangeable Cations CEC	Ca	Mg	Na	K m.eq/100g	Moistures ADM	15mPa % @ 105 C	Disp. Ratio R1	Exchange Acidity	Al m.eq/100g
Bulk	.10	5.3	.08	.001														
	.10	5.1	.19	.001	13	54	4	31	4	2.1	1.3	.13	.41	2.7	11	.04	.35	.23
	.30	4.8	.07	.001	12	56	4	28	2	0.4	0.2	.12	.19	1.9	11	.04	1.04	.92
	.60	5.5	.01	.001	15	52	3	29	2	0.7	0.2	.14	.14	1.2	10	.30	.51	.41
	.90	5.2	.02	.001	13	54	3	29	1	0.1	0.2	.08	.10	1.6	10	.19	.57	.48
	1.20	5.0	.01	.001	16	49	42	31	1	0.2	0.1	.14	.04	2.0			.46	.37
	1.50	4.9	.01	.001														

Depth Metres		Org. C (W & B) %	Total N %	Extr. Phosphorus Acid	Bicarb ppm	Rep. K meq%	DTPA extr. Fe	Mn	Cu	Zn ppm
Bulk	.10	2.4	.25	21	33	.19	148	15	1.4	1.0