Department of Agriculture, Victoria
Division of Agricultural Chemistry

Northern Wimmera soils
and
their significance to local agriculture

By

Nabil S. Badawy
Soils Officer

NATIONAL LIBRARY OF AUSTRALIA
CATALOGUING-IN-PUBLIATION DATA

Badway, N.S. (Nabil Sayed), 1942

Northern Wimmera soils and their significance to local aagriculture.

ISBN 0 7241 8148 2.

1. Soils – Victoria – Wimmera.
2. Land use, Rural – Victoria – Wimmera
I. Victoria. Dept. of Agriculture.
II. Title. (Series: Technical report series (Victoria. Dept. of Agriculture: No. 54) ISSN 0314-5912

631.4'7'9458

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

SECTION 1 - SCOPE AND PURPOSE OF INVESTIGATION

(i) Introduction

The Northern Wimmera encompasses a wide variety of soils many of which rank amongst the Victorian most productive dryland cereal-cropping soils. In some parts of that region, however, soils are either unsuitable for cropping due to extremely low inherent fertility, or require specific management practices. Generally, the agricultural land use capabilities of the region's soils vary widely depending, to a large extent, on the soil physical and chemical properties and the interaction of these properties with climatic conditions and farming techniques.

In order to optimise the agricultural land use in a region, it is essential to identify its soils, i.e., recognising their profile detail, and appreciate the agricultural significance of the various soil properties. Bearing this in mind, this report has been prepared in its present format with the aim of facilitating the recognition of the Northern Wimmera main soils and their related agronomic potentials. In the report, each soil is most importantly, the interpretation of that knowledge in relation to agricultural usage.

(ii) Area and Location

The area investigated in this report is about 1.5 million hectares located in the northern half of the Wimmera District, Western Victoria. The area lies between the 500 mm average annual rainfall isohyet, the South Australia/Victoria border and the northern and eastern boundaries of the Wimmera District (Figure 1).

Figure 1 – Locality Plan

SECTION 2 - THE MAIN SOILS

The area investigated in this report includes a wide range of soils, many of which vary markedly in their physical and chemical properties. Consequently, the productivities, optimum management and agricultural land use capabilities of these soils usually significantly differ. Listed below are the main six soils commonly found in the study area, grouped according to their texture profiles.

<u>* UNIFORM TEXTURE PROFILES</u>

(i) Coarse-textured (SANDS)

- Bleached Sands with a Colour B Horizon; Uc 2.2 . Soil 1

(ii) Fine-textured (CLAYS)

- Grey Self-Mulching Cracking Clays; Ug 5.2 ……. Soil 2

<u>*GRADATIONAL TEXTURE PROFILES</u>

- Calcareous Earths; Gc 1.1 ……………………….. Soil 3

<u>* DUPLEX TEXTURE PROFILES</u>

(i) Red Duplex Soils

- Hard Alkaline Pedal Red Duplex Soils; Dr 2.13, .23, .33, .43 ………………………………….. Soil 4

(ii) Yellow Duplex Soils

- Hard Pedal Mottled-Yellow Duplex Soils; Dy 3.4 . Soil 5
- Sandy Neutral and Alkaline Pedal Mottled-Yellow. Duplex Soils; Dy 5.42, .43 ………………….. Soil 6

The approximate distribution of these soils has been only estimated (Figure 2) due to the absence of a detailed soil survey of the area investigated. In this section, each main soil is discussed with regard to the following aspects :-

(a) <u>Soil morphology, including</u>

(i) A summary list of the soil's main distinguishing features.

(ii) A general morphological description of the soil.

(b) **<u>Agricultural significance;</u>** a discussion of those soil properties which may significantly affect cropping, with particular reference to:

(i) Soil workability, regarding the ease with which the soil can be worked.

(ii) Crop establishment, regarding the effect of seedbed condition, and its reaction to wetting and drying, on crop emergence and early growth stages.

(iii) Crop development, regarding the effect of the soil profile properties on crop performance up to maturity.

(c) **Occurrence -** The common occurrence for each soil has been briefly discussed with regard to:

(i) A description of the land form with which the soil is commonly associated.
(ii) An indication of this distribution of the soil within the study area. This has been also shown on a separate map for each soil.

For the purpose of this report, each soil map indicates the areas of common and minor occurrences for the soil investigated. No attempt was made to locate boundaries within soil complexes.

(d) **Land use** - a summary of the main current agricultural uses of the land.

Definitions of the soil terms used are given in an appendix.

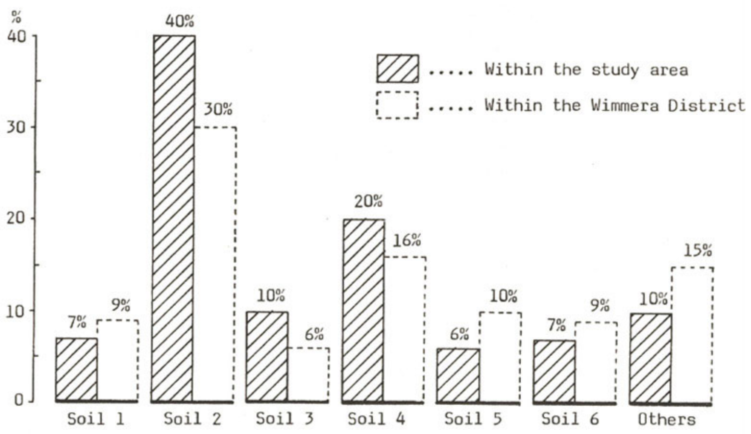

*Figure 2- Distribution** of The Main Soils In The Wimmera*

SOIL 1 - BLEACHED SANDS WITH A COLOUR B HORIZON (Uc 2.2)

1.1 Soil Morphology

Distinguishing Features

- Uniform texture profile which is sand (coarse-texture) throughout.
- Soil pedality is lacking throughout the soil profile.
- The A_1 horizon (surface soil) is dark, loose sand 'single grains'.
- Condition of the surface soil is soft (non-hard setting).
- A_2 horizon (subsurface soil) is present and strongly bleached. It is thick, non-coherent loose sand 'single grains'.
- The B horizons (subsoils) are of similar material to those of the A horizons except for soil colour (ie. Colour B Horizon).
- The 'Colour B Horizon' is either whole-coloured or mottled. Its thickness and main colours vary widely.
- Soil reaction (pH) is acid throughout the soil profile.

1.1.2 Soil Description

These soils have uniform coarse-textured profiles which are moderately deep to very deep (1 m to > 6 m) strongly bleached sands.

* Approximate only

Surface Soils (A horizons)

A_1 horizon:
Brownish grey to very dark grey (almost black) sand to loamy sand, apedal (single grains). Soil consistence is loose to soft (dry and moist) and non-plastic and non-sticky (wet). In thickness, this horizon ranges from 10 cm to 80 cm (commonly 30 cm). Diffuse to clear boundary to:

A_2 horizon:
Soil material is similar to that of the A_1 horizon above except for the soil colour which is strongly bleached, near white. This horizon varies from 10 cm to 200 cm thick. In the deeper profiles, the A_2 horizon usually comprises more than 50% of the total soil depth. Diffuse to clear boundary to:

Subsoil (B horizon)
The subsoil is similar to that of the surface soils. The main morphological differences however, are only in colour and in a slight increase in soil coherence.

In these soils, the B horizon is referred to as a 'Colour B Horizon'. It is 30 cm to 100 cm thick and is either whole-coloured or mottled. The main colours range from yellow-brown to very dark brown or black. The degree of mottling varies widely.

Soil Reaction (pH)
The soil reaction is acid throughout the profile. Soil acidity may increase with depth.

Agricultural Significance

(a) Soil workability
These soils are easy to work due to the condition of their surface layers which remains soft (single grains) after wetting and drying and non-sticky when wet.

(b) Soil permeability
These soils are usually highly permeable to water, air and root penetration. Some surfaces, however, are difficult to wet.

(c) Soil moisture
In these soils, owing to their low clay content and high degree of porosity, the field moisture capacity is low.

(d) Soil salinity
In the study area, most of these sands are freely drained to depth and hence have low salt content.

(e) Inherent fertility
As a general rule, the inherent fertility of these leached sands is very low. They are deficient in most of the macro and micro nutrient elements.

(f) Root development
Root development in these sands is significantly affected by their limited supplies of soil available moisture and plant nutrients.

(g) Soil erosion
The non-coherent nature of these sands together with their topographical position makes them prone to wind and water erosion. The degree of erosion is often increased by the absence of adequate vegetative cover due to fire, commonly, or overgrazing.

1.3 Occurrence
The leached sands are usually associated with the sand dunes and sand hills which are commonly found on the undulating sand plains west of Dimboola (Little Desert) and north of Nhill and Kaniva (Big Desert). They also occur on many of the dissected sand dunes that are scattered on the undulating plains west of Natimuk. Figure 3 shows the distribution of these sands within the area studied in this report.

1.4 Land use

Large areas of these soils have remained undeveloped and provide only sparse grazing on native herbage. Success in cropping or improved pasture establishment depends on heavy fertiliser use.

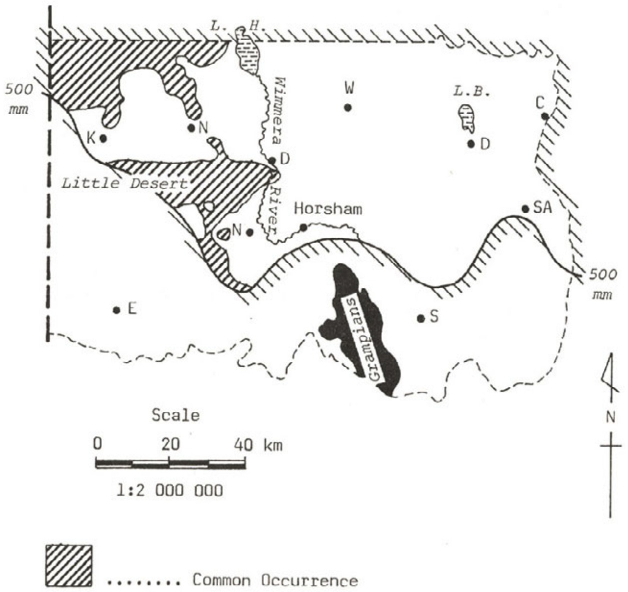

Figure 3-Distribution of Soil 1 (Uc 2.2) in the Study Area

SOIL 2 - GREY SELF-MULCHING CRACKING CLAYS <u>(Ug 5.2)</u>

2.1 Soil Morphology

2.1.1 Distinguishing Features

- Uniform texture profile, which is clayey (fine-texture) throughout.
- The soils crack significantly when dry.
- The surface soils are self-mulching and usually friable.
- A_2 horizon (subsurface soil) is absent.
- The soil material exhibits strong blocky structure characterised by dominantly smooth-ped fabric throughout the soil profile.
- The dominant soil colour is grey to grey brown.
  Browner or paler colours may appear in the deep subsoils.
- Gilgai formation is common.
- The soil profile is usually calcareous throughout and the occurrence of high amounts of carbonates at shallower depths is not common.
- Accumulation of salts and gypsum are common in the deep subsoils.

2.1.2 Soil Description

These soils are commonly known as "The Wimmera Self-Mulching, or Friable, Grey Clays". They have uniform fine-textured (clayey) deep to very deep (> 150 cm) profiles.

<u>Surface Soil</u>

Grey to grey-brown light to medium clay, strong granular soil aggregate which are self-mulching. Soil consistence is soft to slightly hard (dry), friable to semi-friable (moist), plastic and sticky (wet). Gradual to clear boundary to:

Subsoil
Grey to grey-brown medium to heavy clay, strong fine to medium angular and subangular blocky structure, smooth-faced peds. The soil aggregates are moderately hard to very hard (dry), friable to semi-friable (moist), plastic and sticky (wet).

Commonly, the subsoil changes gradually into paler or browner colours and strong coarse blocky structure with depth.

Streaks of surface soil material are often found as 'in-fills', to various depths in the subsoil.

Soil Inclusions
Trace to slight amounts of hard nodules (2-10 mm in size) of carbonates (lime) are usually scattered on the surface. Varying amounts of hard and soft lime occur throughout the soil profile.

Typically, moderate to high concentrations of soluble salts are commonly found in the subsoils below 30-50 cm and varying amounts of gypsum often occur as fine crystals in the deep subsoils.

Soil Reaction (pH)
The soil reaction trend shows an increase in pH value down the soil profile. The soils are neutral to alkaline at the surface, becoming strongly alkaline with depth.

Seasonal Cracking
Seasonal cracking is a prominent characteristic of these clays as they expand and contract significantly with moisture changes. Upon drying, they develop cracks with a minimum occurrence of one crack, at least 6 mm wide and 30 cm deep, per square metre. Such cracks, however, may not be apparent at the soil surface.

Gilgais
Gilgais (melon-holes, crab-holes … etc) are a common feature of these soils. The gilgai depressions (troughs) range from 3 to > 20 m in diameter, separated by a network of mounds (puffs) 1 to 3 m across. On a continuously cropped land, gilgais become obscured at the surface due to grading, cultivation and seedbed preparation. They reappear, however, when the land is left undisturbed for a number of wetting and drying seasons. The puffs are usually raised up to 30 cm above the ground level and the depressions vary in depth between 5 and 50 cm.

2.2 Agricultural Significance

(a) Soil workability
In the dry to moist stage, most of these grey clays are friable and easy to work. They become very sticky when wet. Non-friable clays, however, occur in some depressions and low lying areas.

(b) Crop establishment
On these soils, crop establishment is usually related to the structure and consistence of their surface layers. Cereal crops grown on friable clays, however, are usually more liable to cereal cyst nematode "eelworm" (*Heterodera Avenae)* than those grown on non-friable, or massive, clays.

(c) Soil permeability
When dry, the friable cracking clays are usually better structured soils that are well aerated and highly permeable to water. Upon wetting, however, these clays expand reducing their total porosity which, in turn, affects soil aeration and slows further water infiltration.

(d) Soil moisture
Most of the clay soils have a high field moisture capacity. The availability of this moisture to the plant, however, depends largely on the soil structure and consistence and, in general, the ease with which plant roots can penetrate the subsoil. In the non-friable coarse blocky subsoils, it is not uncommon to find appreciable amounts of unused 'available' moisture at depth.

(e) Seasonal cracking
Upon rapid wetting, wide cracks in dry soils assist in rapid subsoil water recharge which may be of crucial value to the survival of plants near wilting. Also, cracks contribute appreciably to soil aeration being the main natural passageways for air in the soil mass.

Some agricultural disadvantages of these cracks, though, include acceleration of soil moisture evaporation, some loss of surface soil material down into the subsoils and the protection of pests such as crickets and mice.

(f) Gilgais

Amounts of carbonates and salts are usually higher in the gilgais puffs than in the depressions. Levelling of gilgais reduces the depth of the surface soils on the mounds and sometimes exposes their subsoils.

Such soil variability often significantly affects the land's productivity and complicates its management.

(g) Soil reaction (pH)

In spite of the capability of these soils to grow a wide range of plant species, their high alkalinity and the presence of appreciable concentrations of carbonates at shallow depths reduce the soil's potential to successfully support some crops (e.g. lupins).

(h) Soil salinity

Flooding at irregular intervals helps in eliminating the upward movement of higher concentrations of subsoil salts. Under irrigation, or more frequent flooding, these clays may develop salinity problems following waterlogging of subsoils or rising watertables. In low-lying areas, soluble salts often accumulate at shallower depths in amounts harmful to the productivity of crops and pastures.

(i) Plant nutrients

Generally, the inherent fertility of these clays is moderate. They have high cation exchange capacities, high calcium and potassium status, moderate amounts of total nitrogen and low phosphorus contents. The soils mineralise nitrogen readily in cultivated bare fallows and initially produce high yields of crops but the total nitrogen contents diminish upon cropping. On these soils, cereals and legumes including subterranean clover and medic pastures respond to the additions of phosphorus and zinc.

(j) Root development

On these clays, deeper root development is often dependent on the density and friability of the subsoils.

Note:

Intermingled with these grey clays, in many areas, are the "Brown Self-mulching Cracking Clays". Both soils have similar distinguishing features, except for the following differences:

- The brown clays have grey-brown to reddish brown medium clay surface soils underlain by brown, red-brown or red heavy clay, becoming paler and yellower with depth.
- The soil aggregates of the brown clays are less friable in the dry to moist stage and stickier when wet.
- The surface soils of the brown clays are often more readily dispersive, resulting in a surface seal and/or crust upon wetting and drying.
- The subsoils of the brown clays usually contain higher amounts of soluble salts than in the grey clays.
- In general, productivity of the brown clays is usually limited by the shortage of soil available moisture.
- The gilgai formations are absent, or only weakly developed, on the brown clays.

2.3 Occurrence

The grey and brown clays are the main soils on the gently undulating gilgai plains located north and east of the Wimmera river. They also occur in small areas, associated with other soils, in most of the remaining parts of the study area (Figure 4).

2.4 Land use

These clays are extensively cropped for cereals, mainly wheat and barley and support many legumes and oilseed crops. Also, sown pastures are usually successfully established on these soils.

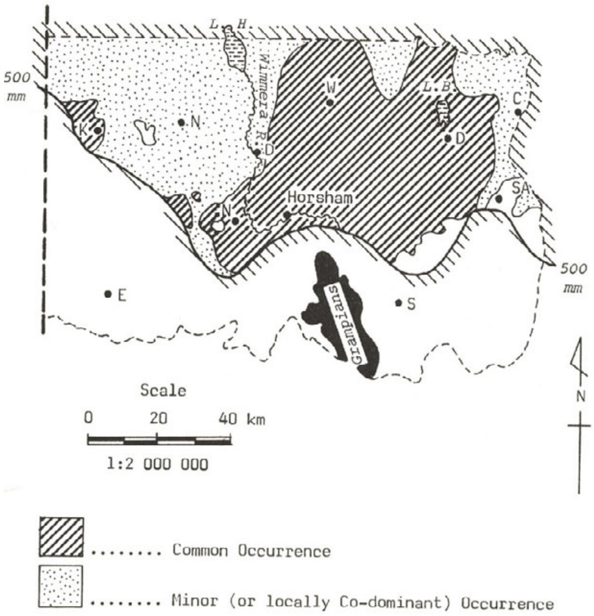

Figure 4 - Distribution of Soil 2 (Ug 5.2) in the Study Area

SOIL 3 - CALCAREOUS EARTHS (Gc 1.1)

3.1 Soil Morphology

3.1.1 Distinguishing Features

- Gradational texture profile (ie., very gradual increase in soil clayiness with depth).
- The soil profile is highly calcareous throughout. Carbonates are clearly visible in the surface soils and their amounts increase at shallow depths.
- Soil pedality is lacking throughout the soil profile.
- The surface soils are dark greyish brown to red-brown sand to clay loam.
- Condition of the surface soil is soft (non-hard setting). It is either loose (single grains) or weakly coherent.
- The subsoils are light brown sandy clay loam to medium clay.
- Soil reaction (pH) is neutral to alkaline in the surface and strongly alkaline in the subsoil.

3.1.2 Soil Description

These soils are commonly referred to as "Mallee Soils". They have gradational texture profiles that are calcareous throughout, structureless and deep to very deep (1-5 m).

Surface Soil

Very dark greyish brown to red-brown sand to clay loam (commonly sandy clay loam or loam), apedal (single grains to slightly compacted). Soil consistence is soft (dry and moist) and non-plastic and non-sticky (wet). Carbonates (varied amounts) are clearly visible.

Subsoil

Light brown sandy clay loam to medium clay (very gradual increase in clay contents with depth), apedal 'single grains or weakly coherent'. Soil consistence is loose to soft (dry and moist) and non-plastic and non-sticky (wet). Soil plasticity and stickiness usually rise with depth, following the increase in clay content. Carbonates are present in varied amounts.

Soil Inclusions

Carbonates (lime) are a prominent feature of these soils. They occur in the fine earth fraction and as soft and hard segregations. With depth, the amounts of visible carbonates increase. Carbonates in the fine earth fractions contribute to the apparent clayiness of the field texture, so that subsoils usually seem to be more clayey than indicated by their true clay content. The depth to the horizon of maximum carbonate content varies between profiles and is a diagnostic feature of these soils in the field.

Dark manganiferous segregations may be present in the subsoils.

Soil Reaction (pH)
The soil reaction trend shows an increase in pH value down the soil profile. The soils are neutral to moderately alkaline at the surface, becoming strongly alkaline with depth.

3.2 Agricultural Significance

(a) Soil workability
The surface soils remain soft (single grains to weakly coherent) after wetting and drying. These soils, therefore, are usually easy to work over a wide range of moisture contents.

(b) Crop establishment
The physical properties of the Calcareous Earths' seedbed are usually favourable for crop establishment. It is common, however, that in cool wet winters most of the cereals grown on these soils become infested by cereal cyst nematode "eelworm" (*Heterodera Avenae)*.

(c) Soil permeability
Except for the horizons of maximum carbonate concentration, these soils are usually highly permeable to water and air and offer low resistance to root penetration.

(d) Soil moisture
Depending on their clay and carbonate contents, these soils range from low to high with regard to their capacity to store and supply moisture to the plants. Loams and clay loams store high amounts of available moisture. Heavy concentrations of carbonates affect the soil's field moisture capacity.

(e) Soil salinity
Salt contents are usually low in the surface soils and moderate to high in the subsoils. Under irrigation, however, and in areas where subsoil permeabilities are restricted by the horizons of maximum carbonate concentrations, some watertable and attendant salinity problems develop. These subsoils may also contain appreciable levels of exchangeable sodium percentages (i.e., sodicity).

(f) Inherent fertility
The Calcareous Earths have low to moderate levels of natural fertility which is significantly increased by the addition of superphosphate and the use of medic leys. Responses to applications of zinc are also common.

(g) Root development
Except for the soil horizons containing high amounts of carbonate concretions, other physical properties of these soils are, in general, favourable for root development.

(h) Soil erosion
An adequate vegetative cover is always warranted to protect these soils against wind and/or water erosion.

3.3 Occurrence
The Calcareous Earths are usually associated with the unconsolidated, highly calcareous coarse-to-medium-textured parent materials. They are commonly found on the undulating plains and sand dunes. With regard to the area studied in this report, these soils are dominant in two locations (Figure 5); i.e., north of Dimboola and north-east of Warracknabeal.

3.4 Land use
These soils are widely used for grazing, mixed farming and some irrigated crops.

In the study area, cereals (notably wheat and barley) are commonly grown on these soils using rotations including long fallows (to conserve moisture) and legumes (to enhance nitrogen status). Lucerne and medic leys also are grown successfully.

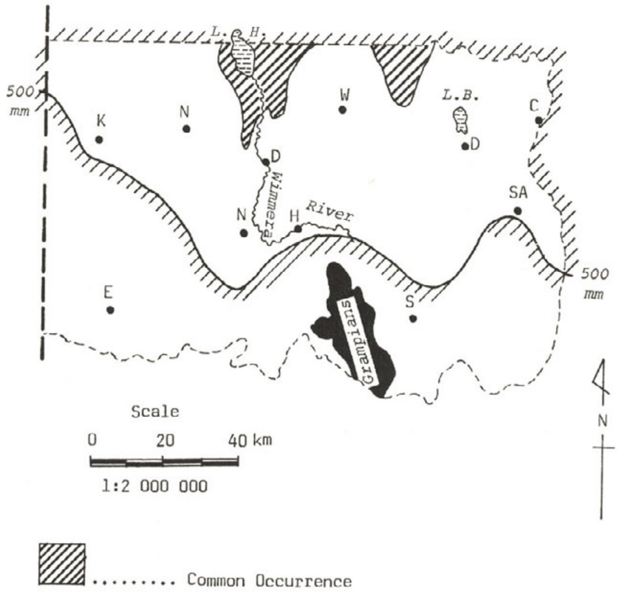

Figure 5- Distribution of Soil 3 (Gc 1.1) in the Study Area

SOIL 4 - HARD ALKALINE PEDAL RED DUPLEX SOILS (Dr 2.13, .23, .33 and .43)

4.1 Soil Morphology

4.1.1 Distinguishing Features

- Duplex texture profile (i.e., district texture contrast between the surface and subsoil).
- The A_1 horizon (surface soil) is grey-brown to reddish brown loamy sand to clay loam.
- The surface soil is hard-setting.
- A_2 horizon (subsurface soil) is either:
  (i) absent ………………………………………..(Dr 2.1),
  (ii) present but not bleached …………………….(Dr 2.2),
  (iii) present and sporadically bleached …………..(Dr 2.3),
  or (iv) present and conspicuously bleached ……..…(Dr 2.4)
- The depth to the clayey subsoil is commonly 10-30 cm (range: 3-50 cm).
- The uppermost segment of the clayey B horizon (subsoil), that is at least 15 cm thick, is whole-coloured and red to red-brown. With depth, the red subsoils often become yellower and, sometimes, distinctly mottled.
- Soil pedality is lacking in the surface horizons but moderate to strong in the subsoils.
- The subsoils are variably sodic and contain various amounts of soluble salts.
- Segregations of carbonate occur in the subsoils and often are associated with the colour change. Gypsum may occur in the deep subsoils.
- The soil reaction trend is alkaline.

4.1.2 Soil Description

These soils have distinct texture contrast between the surface horizons and the clayey subsoils. Condition of the surface soil is hard-setting and the total depth to the parent material ranges from 30 to 200 cm (commonly 50 to 100 cm).

Surface Soils (A horizons)
The total thickness of the A horizon, usually, varies between 10 to 30 cm.

A_1horizon:
Ranges from dark grey-brown to brown, dark brown, reddish brown or dark reddish brown loamy sand to clay loam. It is massive, hard to very hard (dry), friable to non-friable (moist) and non-plastic and non- to slightly sticky (wet). Gradual to clear boundary to:

A_2 horizon:
This horizon is lacking in the Dr 2.1 soil profile form. When present, though, it is of similar soil material to that of the surface soil layer above, except for the colour which is lighter in the A_2 horizon. Whitish areas of sporadic bleaching occur throughout the A_2 horizons of Dr 2.3 soils or at the interface between the A and B horizons. The A_2 horizons of Dr 2.4 are prominent and conspicuously bleached. Clear to abrupt boundary to:

Subsoil (B horizon):
Red to red-brown (sometimes dark reddish brown) medium to heavy clay coarse blocky to prismatic or columnar structure breaking into smaller blocky peds with smooth and shiny fabric. Soil colour often becomes browner or yellower with depth and may contain distinct mottles. Soil consistence is usually hard to very hard (dry) friable to slightly friable (moist) and plastic and sticky (wet).

Soil Inclusions
Segregations of soft and/or hard nodules of carbonates (lime) occur in the subsoils, often associated with the colour change. Gypsum may occur in the deep subsoils.

Some profiles contain trace to moderate amounts of ironstone gravel and/or rock fragments, particularly, in the A horizons.

Soil Reaction (pH)
The soil reaction trend is alkaline, showing an increase in pH value down the profile. Surface soils are typically slightly acid but may be neutral to slightly alkaline and the subsoils are alkaline to strongly alkaline.

4.2 Agricultural Significance

(a) Soil workability
These soils are normally not easy to manage owing, largely, to the adverse structural properties of their surfaces. Upon wetting and drying the surface soils usually set hard and become difficult to work. The range of optimum moisture content at which these soils can be easily worked is very narrow and, consequently, over most of the year the soils are either too wet or too dry for cultivation. Gypsum has been successfully used to ameliorate many of these hard-setting soils.

(b) Crop establishment
The hard-setting condition of the surface soils is a major limiting factor to crop establishment. On these soils, crop establishment is largely dependant on the time and intensity of the first follow-up rain (i.e., first rain after sowing). With adequate seedbed moisture content, seasons with no rain (or only with very light showers) received between sowing and crop emergence are favourable for crop establishment. Due to the structural instability of surface soil aggregates, heavy rains (or more frequent rainstorms) falling on these soils when cultivated, often induce surface sealing and compaction and, in turn, affect crop establishment.

(c) Soil permeability
In general, these soils are moderately permeable to water and air. Soils with bleached A_2 horizons are often less permeable than those which are either without A_2 horizons or with non-bleached A_2 horizons.

Permeability through these hard setting soils is, primarily, restricted by the compaction of the surface layers. Also in the dense clay subsoils, permeability is generally low and tends to decrease as the amount of exchangeable sodium increases. Improved permeabilities, however, have been obtained on sodic soils by the application of gypsum.

(d) Soil moisture
As a rule, the texture of a soil significantly affects its capacity to store water and to supply this water to the plant. On these duplex soils, therefore, the field moisture capacity of the surface horizons varies greatly depending on their textures. The clayey subsoils usually have moderate capacities to store available moisture.

(e) *Soil salinity*
Generally, subsoil salinity is moderate to high in these soils. Soluble salt contents usually rise with depth. Unlike the freely drained soils, subsoils with low permeabilities often contain appreciable amounts of salts. Improvement of profile drainage, therefore, is essential for decreasing soil salinity.

(f) *Inherent fertility*
Most of these soils have low to very low phosphorus and nitrogen contents, moderate levels of potassium and low zinc availability. Generally, they respond well to fertilisers.

(g) *Root development*
On these soils, structural properties and depth of the soil profile are major factors affecting root development.

(h) *Soil erosion*
The structural instability of these soils greatly contributes to their erosion. Most of the surface material, when cultivated dry, breaks to very fine aggregates 'powder' and becomes wind erodable. Upon heavy rain, unprotected surfaces are also usually prone to water erosion and the sodic subsoils often develop tunnelling and eroded gullies.

4.3 *Occurrence*
The hard-setting red duplex soils usually occur on the gently undulating depositional plains. In the area investigated in this report, the Dr 2.33 soil is more common that the other red duplex soil profile forms. In general, these soils are widespread throughout the study area with the main occurrence in two locations (Figure 6); ie.

(i) The gently undulating plains north of the Little Desert.

(ii) The gently undulating plains in the eastern section (Charlton-St. Arnaud area).

4.4 *Land use*
In the area studied, most of the soils are extensively used for cereal-cropping, notably wheat and barley. They are also commonly used for sheep-grazing on native, volunteer or sown pastures.

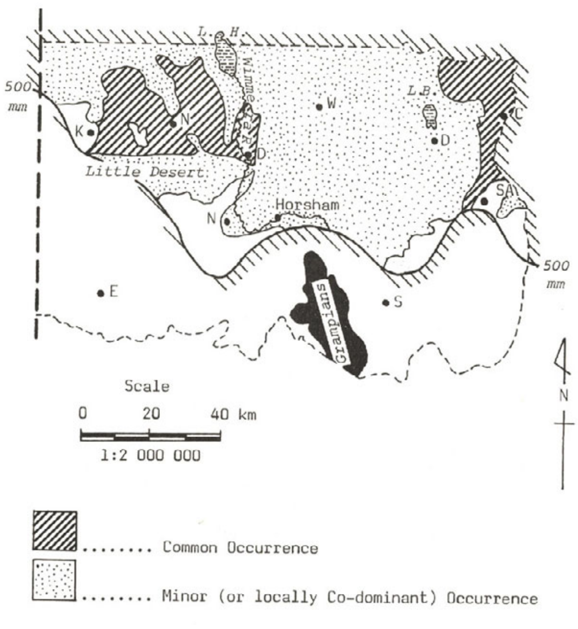

Figure 6- Distribution of Soil 4 (Dr 2.13, (.23), (.33), (.43) in the study area

SOIL 5 - HARD PEDAL MOTTLED-YELLOW DUPLEX SOILS (Dy 3.4)

5.1 Soil Morphology

5.1.1 Distinguishing Features

- Duplex texture profile (i.e., distinct texture contrast between the surface and subsoil).
- The A_1 horizon (surface soil) is grey-brown to light brownish grey loamy sand to clay loam.
- A_2 horizon (subsurface soil) is present and conspicuously bleached. It is massive and usually very hard when dry.
- The depth to the clayey subsoil is about 30 cm (range: 5-60 cm).
- The uppermost segment of the clayey B horizon (subsoil), which is at least 15 cm thick, is mottled and the dominant colours are grey-brown, yellow-brown and brownish grey. With depth, mottling may decrease and the main colours tend to become yellower and paler.
- Soil pedality is lacking in the surface horizons but the subsoils are moderately to strongly pedal. Their structural type is commonly prismatic or columnar, breaking to smaller soluble salts.
- Segregations of small black manganiferous segregations are commonly present in the A_2 horizon and the uppermost portion of the clayey subsoils.
- Soil reactions (pH) are mildly acid to neutral in the surface horizons and, often, increase with depth to moderately or strongly alkaline (Dy 3.42 and Dy 3.43). Profiles with slightly acid deep subsoils (Dy 4.31) also occur.

5.1.2 Soil Description

In these soils, the surface horizons have a distinct texture contrast to the clayey subsoils. Upon wetting and drying the surface soil material is characterised by the hard setting condition. The total depth to the parent material ranges from 100 to 300 cm (commonly about 100 cm).

Surface Soils (A horizons)

The total thickness of the A horizon, usually, varies between 5 and 60 cm, commonly about 30 cm.

A_1horizon:

Grey-brown to light brownish grey loamy sand to clay loam, structureless massive. Soil consistence is usually very hard (dry), moderately friable to non-friable (moist) and non-plastic and slightly sticky (wet). Gradual to clear boundary to:

A_2 horizon:

Conspicuously bleached near white subsurface soil of similar, or slightly coarser, texture than the A_1horizon. Clear to abrupt boundary to:

Subsoil (B horizon):

The upper part of the B horizon is usually distinctly mottled brownish grey to yellow-brown with some red, yellow or light grey sandy clay to heavy clay. The degree of pedality in the subsoil is moderate to strong and the structural units are prismatic or columnar which often break to smaller blocky peds. Soil consistence is very hard to extremely hard (dry), non-friable (moist) and plastic and very sticky (wet).

In the deep subsoils, the degree of mottling decreases and the main colours become more yellower and paler. Soil structure changes into moderate, fine to medium angular blocky.

Soil Inclusion

Some soft and hard carbonate (lime) segregations may occur in the deep subsoils of some profile forms (Dy 3.43).

Ironstone gravels and rock fragments are often present, in various amounts, in the soil profile and are usually concentrated in the lower A_2 horizon.

Accumulations of black ferro-manganiferous (soft and hard) inclusions are also commonly present, in varied amounts, in the lower A_2 horizon and often extend into the upper segment of the clayey subsoil.

Soil Reaction (pH)

Soil reaction is mildly acid to neutral at the surface and alkalinity often increase with depth (Dy 3.42 and Dy 3.43). Soil profiles with acid subsoils (Dy 3.41) also occur.

5.2 Agricultural Significance

(a) Soil workability

In general, these soils are considered to be difficult to manage due to their narrow range of moisture contents at which optimum workability can be achieved. When wet, the surface soils become waterlogged and their aggregates readily disperse resulting in a compacted hard setting cultivation layer upon drying.

(b) Crop establishment

Crops are usually poorly established on these soils due to the hard setting condition of the surface horizons. Also on these soils, periodic waterlogging and the presence of perched water-tables at shallow depths are major limiting factors to crop establishment.

(c) Soil permeability

Water infiltration rate is commonly low to moderate in the surface soils (depending on soil texture and degree of compaction) and is essentially low to very low in the subsoils.

Permeability problems often result in:

(i) Waterlogging , intermittent perched water-tables in the subsurface horizons (A_2) and partial saturation of the upper B horizons.

(ii) Loss in surface moisture through run off and/or evaporation.

(d) Soil aeration

Aeration is usually deficient in these soils due to surface soil compaction and the high density of the subsoils.

(e) Soil moisture

In these soils, the water holding capacity of the surface horizons varies according to their soil texture. Capacity to store moisture increases with the increase in soil clayiness. During long wet periods the subsoils, slowly, store appreciable amounts of moisture most of which remains unavailable to the plants due to the unfavourable structural properties of the soil profile.

(f) Soil salinity

Salt contents are usually low to moderate in the surface soils and high in the subsoils. If these soils frequently become waterlogged, however, salinity levels may increase at shallow depths.

(g) Inherent fertility

The inherent fertility of these soils is generally low. They are often deficient in phosphorus, nitrogen, and various trace elements. Most of the subsoils are also sodic with moderate to high contents of exchangeable sodium.

(h) Root development

In addition to the cemented bleached subsurface horizons, the tight clay subsoils offer high resistance to root penetration. It is common therefore in these soils to find that root development is confined to the surface horizons and that the majority of roots extend along the tops of subsoil columns rather than penetrate into the deep subsoils.

(i) Soil erosion

On sloping sites erosion is a hazard becoming more severe where the soils are disturbed or have lost their vegetative cover. Deep eroded gullies are also commonly caused by the structural instability of the sodic subsoils.

5.3 Occurrence

The hard-setting mottled-yellow duplex soils are usually associated with the undulating valley plains and hilly areas. With regard to the present report, these soils commonly occur in a narrow north-south strip south of the Little Desert and in some locations in the south-east section of the study area. Subdominant, or locally co-dominant, occurrences of Dy 3.4 soils are also found on most of the western section.

In the study area, soil profiles with neutral and alkaline reaction trends (Dy 3.42 and Dy 3.43, respectively) occur, in general, more commonly than those with acid trends (Dy 3.41). The Dy 3.41 soils however, are commonly found in the south-eastern section of the study area.

The common distribution of the Dy 3.4 soils within the area investigated in this report is shown in Figure 7.

5.4 Land use

In the study area, the main agricultural use of these soils is sheep-grazing on native, volunteer and sown, pastures. In some dryer areas, however, these soils are utilised for cereal cropping and for limited horticultural use.

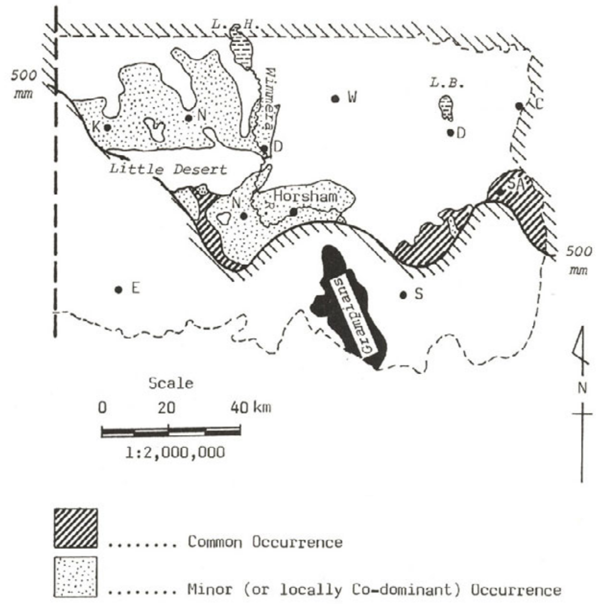

Figure 7- Distribution Of Soil 5 (Dy 3.4) In The Study Area

SOIL 6 - SANDY NEUTRAL AND ALKALINE PEDAL MOTTLED-YELLOW DUPLEX SOILS (Dy 5.42 and Dy 5.43)

6.1 Soil Morphology

6.1.1 Distinguishing Features

- Duplex texture profile (i.e., distinct texture contrast between the surface and subsoil).
- The A_1 horizon (surface soil) is brownish grey to grey-brown sand to sandy loam.
- Condition of the surface soil is soft (non-hard setting).
- A_2 horizon (subsurface soil) is present and strongly bleached.
- The depth to the clayey subsoil is usually greater than 30 cm.
- The uppermost segment of the clayey B horizon (subsoil), which is at least 15 cm thick, is mottled and the dominant colours are yellow, yellow-brown, yellow-grey and grey. Mottling may increase with depth.
- The subsoils are moderately to strongly pedal. Their structural type is commonly prismatic or columnar. They are sodic and often contain high accumulations of total soluble salts.
- Soil reactions (pH) are weakly acid to neutral in the surface soils, gradually increasing with depth to moderately or strongly alkaline in the deep subsoils.

6.1.2 Soil Description

These soils have distinct texture contrast between the surface horizons and the clayey subsoils. Conditions of the surface soil is soft (non-hard setting).

Surface Soils (A horizons)

A_1horizon:
This horizon ranges, in colour, from light brownish grey to dark grey-brown (commonly brownish grey) and gradually becomes paler with depth. It is sand to light sandy loam, apedal (single grains to weakly coherent), loose to soft (dry and moist) and non-plastic and non-sticky (wet). Gradual boundary to:

A_2 horizon:
As above **but**; thick (up to 50 cm) strongly bleached very pale brown to white. Clear to abrupt boundary to:

Subsoil (B horizon):
The upper part of the B horizon is usually strongly mottled light brownish grey to yellow-brown with some red, yellow or brown, sandy clay. Subsoil texture gradually changes to heavy clay and the degree of mottling may increase with depth. Soil consistence is usually hard (dry), non friable (moist), plastic and sticky (wet). Degree of pedality is either moderate or strong and the structural units vary from blocky peds < 5 cm in size to large prisms and columns. The deep subsoils, however, are almost structureless massive and have a diffuse boundary to weathered sandy parent material (C horizon) at depths of 1-2 m.

Soil Inclusions
Accumulations of black ferro-manganiferous (soft and hard) inclusions often occur, in varied amounts, in the A_2 and B horizons.

Soft and hard nodules of carbonates (lime) may be found in the deep subsoils.

Ironstone gravels occur in varied amounts in some soil profiles, with more concentrations at the junction between A and B horizons. Heavy amounts of gravels, however, are commonly found in soils associated with lateritic residuals.

Soil Reaction (pH)
The soil reaction trend shows a gradual increase in pH value down the soil profile. The soils are slightly acid to neutral at the surface, becoming moderately alkaline at depth. In some profile forms, however, the deep subsoils are strongly alkaline.

6.2 Agricultural Significance

(a) Soil workability
Unless waterlogged or where the clayey subsoils occur at very shallow depths, these soils are easy to work due to the weakly (or non-) coherent condition of their surface horizons. In general, wetting and drying do not result in a severe compaction of their cultivation layers.

(b) Crop establishment
The sandy non-compacted condition of the seedbed assists in crop establishment. In cool wet winters however, it is common for the roots of many young cereal plants grown on these soils to become infested by cereal cyst nematode "eelworm" (*Heterodera Avenae).*

(c) Soil permeability
The water infiltration rate for the sandy surface soils is far greater than for the clayey subsoils. Consequently, short-term saturation and perched water-tables in the A_2 horizons are commonly found following heavy rains. In some soils, however, the dry sand surfaces are water-repellent and difficult to soak up moisture. Also, unlike the dense clayey subsoils, the surface horizons are highly aerated due to their high porosity.

(d) Soil moisture

(i) ***Surface soils:*** The surface soils have a very low field moisture capacity due to their low clay content.

(ii) ***Subsoil:*** After prolonged wetting, water eventually penetrates through the tight clay subsoils which, usually, have a moderate to high field moisture capacity. Due to the high density and other adverse structural properties of these subsoils, however, most of the moisture remains unexploited by plant roots.

(e) Soil salinity

Salt contents are usually low in the surface soils and high to very high in the subsoils. When these soils are subjected to more frequent subsoil waterlogging however, appreciable levels of salinity are commonly found at shallow depths.

(f) Inherent fertility

The inherent fertility of these soils is low. The surface horizons have low contents of clay, organic matter and phosphorus. They are also often deficient in trace elements e.g., zinc, copper and molybdenum. The dense clay subsoils are commonly sodic to highly sodic with exchangeable sodium occupying up to 50% of their total exchange capacity.

(g) Root development

The tight clay subsoils offer high resistance to root penetration, reducing the plant's ability to use subsoil moisture and nutrients.

(h) Soil erosion

On ridges and lunettes, these loose sandy soils are susceptible to wind and water erosion, particularly where adequate vegetative cover is lacking. The structural instability of the sodic clay subsoil aggregates often results in gully erosion.

6.3 Occurrence

The sandy mottled-yellow duplex soils are commonly found on sand sheets, dunes and hill slopes. These soils are usually associated with Soil 1 (Bleached Sands with a Colour B Horizon; Uc 2.2) and hence have similar areal distribution to it (Figure 8).

6.4 Land use

These soils are commonly used for cattle and sheep-grazing on native and improved pastures. In some areas they are also used for cereal and forage cropping with various degrees of success.

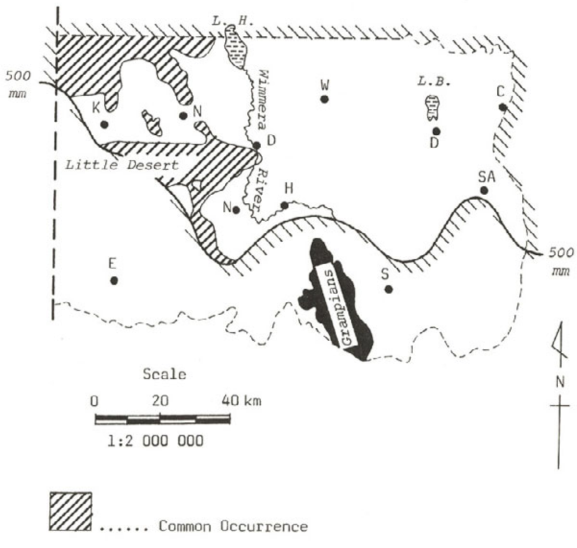

Figure 8- Distribution Of Soil 6 (Dy 5.42, (.43) in the Study Area

REFERENCES

1. Northcote, K.H. (1960a). "Atlas of Australian Soils". Map and Legend No. 1 – Dominant Soils for Sheet 1, Port Augusta – Adelaide – Hamilton Area (C.S.I.R.O. Aust. and Melb. Univ. Press, Melbourne).

2. Northcote, K.H. (1960b). "Atlas of Australian Soils". Explanatory Data for Sheet 1, Port Augusta – Adelaide – Hamilton Area (C.S.I.R.O Aust. and Melb. Univ. Press, Melbourne).

3. Northcote, K.H. (1979) "A Factual Key for the Recognition of Australian Soils". 4th edition (Rellim Technical Publications: Glenside, S.A.).

4. Northcote, K.H., Hubble, G.D., Isbell, R.F., Thomson, C.H. and Bettenay, E. (1975). "A Description of Australian Soils". (C.S.I.R.O Aust.)

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

ACKNOWLEDGEMENT

Thanks are extended to Mr J.J. Martin, Senior Soils Officer, and Miss Cris Lawson, typist, for their assistance in the preparation of this report.

Appendix - Definition Of Soil Terms

Aggregate Stability - The stability of the soil aggregate to water falling as rain or applied as irrigation.

Apedal - See Soil Pedality.

Available Water Capacity - Refers to the amount of soil water that can be extracted by the plant. It has been defined by the difference in soil moisture content between the field capacity and the wilting point.

- **Field Capacity (Field Moisture Capacity):**
  The percentage of water remaining in a soil two or three days after having been saturated and after free drainage has practically ceased.
- **Wilting Point**
  The water content of a soil when indicator plants growing in that soil wilt and fail to recover when placed in a humid chamber.

Bleached - Describes a soil horizon which has become pale in colour owing to leaching. Two degrees of bleaching are recognised as follows:

- **Conspicuous bleach:**
  80% or more of the soil horizon is bleached.
- **Sporadic bleach:**
  Less than 80% of the soil horizon is bleached.

Calcareous Throughout - Means that calcium and/or magnesium carbonates occur throughout the soil profile. Carbonates may be visible or detectable by the application of 2 or 3 drops of N HCl to a representative sample of the soil.

Condition Of Surface Soil - Refer to the natural condition of the surface soil and its reaction to the usual wetting and drying cycle. Cultivation will often alter the condition of surface soil, but most conditions will reform when the soil if left undisturbed.

Cracking Clays - See Seasonal Cracking Soils

Duplex Soil Profile - Refers to a soil profile showing a marked difference in texture between the surface and subsoil horizons. Texture contrast must be at least one and a half texture groups between A and B horizons (Northcote, 1979).

Field Moisture Capacity - See Available Water Capacity

Friable - Refers to Soil Consistence

Gilgai - An uneven surface manifestation of puffs and depressions often referred to as crabholes or melonholes.

Gradational Texture Profile - Refers to the soil profile in which the texture gradually becomes finer (more clayey) with depth.

Gypsum - Hydrated calcium sulphate.

Hardpan - A hardened and/or cemented horizon in or below the soil profile.

Hardsetting - A surface soil is considered to be hard-setting when it becomes hard and apparently apedal on periodic drying out.

Lime - Calcium carbonate either finely divided soft segregations or in concretions (hard nodules).

Massive - Structureless (ie. “apedal”). The soil material is coherent.

Pan (= Soil Pan) - See Hardpan.

Ped - An individual natural soil aggregate.

Pedal - See Soil Pedality.

Plastic - Refers to Soil Consistence.

Seasonal Cracking Soils (Cracking Clays) - The term refers to the seasonal or periodic characteristic of these clay soils which develop and exhibit, during a dry season or period, cracks as wide as, or wider than, 6 mm and at least 30 cm deep. The frequency of cracking normally is more than one crack per square metre.

Self-Mulching -
Self-mulching is that condition of the surface soil, notably of clays, in which a high degree of pedality is exhibited with the peds falling apart, naturally, as the soil dries to form a loose surface mulch. In cultivated soils, ploughing when wet may appear to destroy the surface mulch which, however, will reform upon drying.

Smooth Fabric (= Smooth-Ped Fabric) - Peds are evident, and characteristically more than 50 per cent of them are smooth-faced, that is, have a general lac condition on their surfaces.

Smooth-Faced Peds - See Smooth Fabric

Sodic Soils - The term refers to those soils which have sufficient exchangeable sodium to interfere with the growth of most crop plants. Soils containing exchangeable sodium percentages of 6 or more are considered sodic.

Soil Boundaries - The boundary between soil horizons defines the nature of the change from one horizon to that below. In this report it is specified by the measure of the thickness (or width) of the transition zone between horizons thus :-

- Sharp (or Abrupt) = boundary < 2 cm wide.
- Clear = boundary is 2-5 cm wide.
- Gradual = boundary is 5-10 cm wide.
- Diffuse = boundary > 10 cm wide.

Soil Consistence - Comprises the attributes of soil material that are expressed by the degree and kind of cohesion and adhesion or by the resistance to deformation or rupture. It is markedly affected by the moisture state of the soil. Terms used for consistence include: loose, soft, hard, friable, non-friable, plastic and sticky.

Soil Horizon - A layer of soil, more or less parallel to the land surface, similar throughout and recognisably different from the material above and below. The horizon may be distinguished by differences in one or more of the following characteristics: colour, texture, structure, consistence, mottling, organic matter content and the presence of visible products of weathering and leaching such as calcium carbonate, gypsum, iron oxide and ferruginous concretions. The following horizons in the soil profile may be recognised:

Surface or A Horizon: The surface layer of the soil in which organic matter has accumulated and which may be partly leached of clay and soluble material. It may be divided into two or more sub-horizons as follows:

A_1 horizon: The surface soil more or less darkened by organic matter – a zone of maximum biological activity.

A_2 horizon: A sub-surface layer lower in organic matter that the A_1 and, in consequence, usually lighter in colour. It is the zone of maximum leaching.

Subsoil or B Horizon: Situated below the surface or A horizon and is usually heavier in texture than that horizon. The B horizon represents the zone of accumulation of clay and other materials, including calcium carbonate and iron oxides.

Soil Morphology - The physical constitution of the various horizons and their arrangement in the soil profile.

Soil Pedality - Refers to the relative proportion of peds in the soil, as follows:

Highly pedal (= pedal): in the moderately moist to the moist state, one-third or more of the soil material consists of peds.

Weakly pedal: in the moderately moist to the moist state, less than one-third of the soil material consists of peds.

Non-pedal (= apedal): essentially no recognisable peds.

Soil Profile - This is the vertical section of a soil exposing the sequence of horizons from the surface to an arbitrary depth. For the purpose of this report, soil profiles were only discussed with regard to their A and B horizons.

Soil Reaction Trend - Indicates the general direction of pH changes down the profile,
eg.

Acid trend: The pH values are, for the surface soil, lower than 7.0, and for the deep subsoil, less than 6.5.

Neutral trend: The pH values are, for the surface soil, between 5.0 and 8.0, and for the deep subsoil, between 6.5 and 8.0.

Alkaline trend: The pH values are, for the surface soil, higher than 5.0, and for the deep subsoil, higher than 8.0.

Soil Structure - Describes the way in which the primary soil particles are arranged into soil aggregates (peds).

Soil Texture - Soil texture is a measure of the behaviour of a small handful of soil when moistened to a sticky point (approximately to field moisture capacity), kneaded into a ball and then pressed out between thumb and forefinger. It is strongly influenced by clay content and is affected by other properties, including clay mineral type, organic matter, oxides, carbonates and exchangeable cations. Texture is described in terms of texture grades, examples of which are:

sand, sandy loam, sandy clay loam, clay loam, light clay,
medium clay and heavy clay.

Sticky - Refers to Soil Consistence

Structural Instability - See Aggregate Stability

Uniform Texture Profile - Refers to the soil profile dominated by the mineral fraction with small, if any, texture differences throughout.