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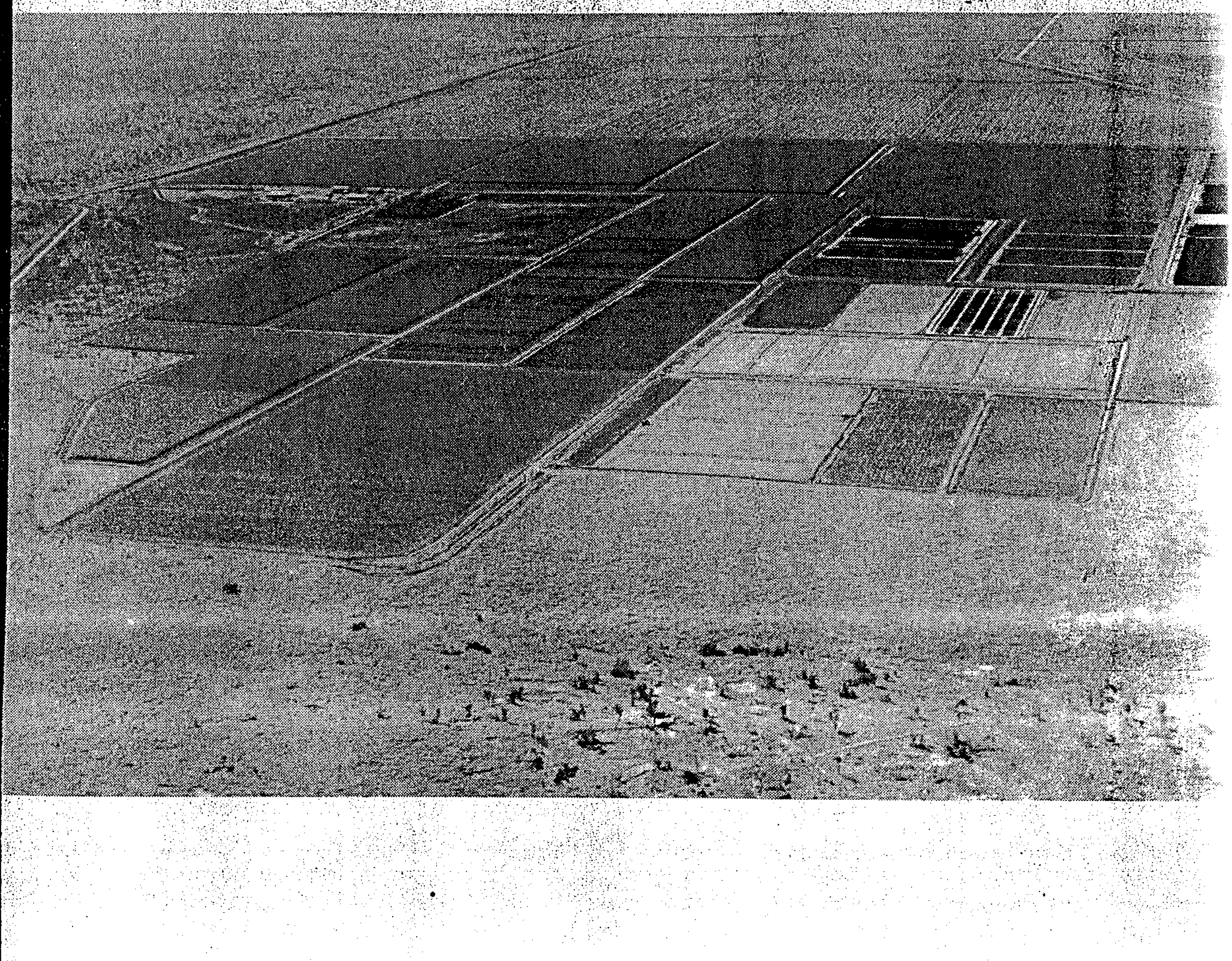

DEPARTMENT OF AGRICULTURE
WESTERN AUSTRALIA

Cover picture

Patchwork of cropping on the clay soils of the Ivanhoe Plain

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Contents

Summary

The Ord River Irrigation Area in the Kimberley Province of Western Australia has a variety of soils used for cropping. We describe here the distribution, chemical and physical properties and natural vegetation of the main soils used for agriculture within the irrigation area. For each soil described the implications for soil management and cropping practice are given.

Introduction

The Ord River Irrigation Area (ORIA) is now characterised by a diversity of agriculture, practised on a wide variety of soils. Farming interest in the area increased with the success of a range of high-value crops in the late 1980s and as farmers in the ORIA recognised the importance of soil and crop management. Department of Agriculture research improved the technological base on which farmers could make decisions, including optimal use of soil and water resources.

There has been information available on the soils of the ORIA in unpublished reports and bulletins since the 1940s. However, this information is not readily available to existing or intending farmers. In 1988, a seminar on the nutrition of crops on the various soils of the ORIA, held by the Department of Agriculture, Western Australia, was conducted as a means of pooling the available information on soil use and crop nutrition. The proceedings of this seminar remain the most comprehensive collection of information on that subject available.

It was apparent that the seminar proceedings and the release of the detailed soils surveys would not satisfy the increasing general enquiries on the soils of the ORIA. This publication has been prepared to provide farmers in the ORIA, and those who are interested in a better understanding of the nature of farming in the area, with background information on the main soil types and the management implications resulting from their diversity. The material presented has been taken from soil surveys (Aldrick 1990, Aldrick and Moody 1977, Burvill 1944, Dixon and Petheram 1979, Dixon and Holman 1980, Gunn 1969, Marshall 1944, Parbery, Rose and Stern 1968, Stoneman 1980) and research papers (Bridge and Muchow 1982, Muchow and Wood 1981) or collected by the authors.

A general description of the information on the soils is followed by detailed treatment of nine of the important soil types. Soil maps of the ORIA have been prepared to show the distribution of the various soils and some indication of their current land use (three map sheets included inside back cover). For further information on the soil types not covered here, reference should be made to the reports of the original soil surveys.

Formation of the soils of the Ord River Irrigation Area

Soils of the Ivanhoe and Packsaddle Plains are considered to be of riverine origin. Old river channels, meanders, and levees can be recognised on these plains. Cracking clay surface soils extend to about 150 cm deep, and have developed under the prevailing climate. Over many years, the course of the Ord River has altered from a more northerly path to its present course. It is likely that the Ord River once flowed through Cave Spring Gap. The Ord River is now well entrenched in its course and flooding over the plains is most unlikely with two dams controlling the flow.

It appears that the last major change in the course of the Ord River occurred in the vicinity of the Frank Wise Institute of Tropical Agricultural Research (previously Kimberley Research Station) when the river diverted to the west. Consequently, the soils to the north are older than those to the south of the research station. The older soils to the north of the Ivanhoe Plain are more leached, less well drained and heavier textured than the younger soils. Slopes in the northern section are very low, with gradients of 1:2500 to 1:3500 being common. Limited areas with greater slope relate to the location of old river levees. Slow erosion since the Ord River changed its course has removed most of the old levees.

The alluvium of the southern areas of the Ivanhoe Plain is younger, being prone to the influence of floods from the Ord River in more recent times than the northern part of the plain. The clays are browner, more alkaline, better drained, finer structured, have a lower clay content and a higher phosphorus content than the soils of the northern section. Slopes are steeper in the south of the plain with gradients of 1:1500 to 1:2000 being common. At the junction of these two areas there are low gravelly rises and linear belts of highly calcareous soil, which are mostly near the research station.

The Ivanhoe Plain is mostly covered with cracking clay soils. The tropical climate has been conducive to the formation of these soils from the parent alluvium which was high in calcium and magnesium carbonates. These chemical conditions are ideal for the formation of the swelling, montmorillonite-based clays.

In seasonally inundated areas in the northern sections of the Ivanhoe Plain, and along the boundaries with sandy areas, heavier clay soils have developed. In some areas, wet season run-off from the sandy slopes has deposited sandy material over the margins of the clay plains. The accumulation of water in these areas has resulted in intense leaching of these soils with consequent low salinity levels. Increased sodium and potassium content is found at depth.

Coarse reddish soils occur in pockets (old levees) on the Ivanhoe Plain. These have been laid down in zones of greater river velocity. The coarse texture of these soils has permitted leaching of soluble salts and lowering of the pH. The texture of these soils is quite variable, and sandy and heavy textured phases can be recognised.

On the river frontage there are soils ranging from truncated cracking clays to sandy alluvial soils. The reddish alluvium underlying the Cununurra clays is often exposed. The soils of these areas have formed on recent deposits (levees) and recently exposed older alluvium and are younger than the inclusions of reddish soils in the clay plains.

The sandy soils that surround the plains have their origin in the erosion of the surrounding sandstone hills rather than in riverine deposits. These are the youngest soils of the ORIA and vary depending on erosion, drainage and stream action.

The soil maps

The soil maps of the ORIA show mapping units which cover soil differences and factors such as vegetation, stoniness, flooding, and the capacity to be eroded. The three maps have been compiled from several different soil surveys of the ORIA and, where appropriate, the terminology used in the Ivanhoe Plains survey (Aldrick *et al.* 1990) has been used. More detailed information is provided later about several of the more important soils considered representative of the range of major soil types encountered in the area.

Detail provided about the soils described relates mainly to the management implications for the soil in its use in irrigated agriculture. Permeability, drainage, moisture retention, inundation, susceptibility to erosion, pH, exchangeable sodium percentage, the possibility of the development of salinity, and tilth after cultivation are all factors of interest. The effect of soil chemical and physical factors on plant nutrition is considered where information is available. General characteristics are presented here as an introduction to the more detailed discussion of particular soils.

Physical properties

The most important physical attribute of the soils of the ORIA is the cracking nature of the main soils on the Ivanhoe and Packsaddle Plains. Water entry into the soils is mainly through cracks when the soil is dry. Subsoil drainage varies between locations in the valley. While in most areas the subsoil drainage is slow, there are some locations where the underlying gravel beds approach the surface and high rates of leakage of irrigation water have been reported. In a few small areas the water table has risen to within 4 m of the surface, but this has had no impact on surface salinity. Farmers, however, are increasingly conscious of the need to carefully manage water application. The highest risk soils are those with the lowest permeability, such that the drainage through the soil may be inadequate to prevent accumulation of soluble salts either from applied irrigation water or shallow ground waters. As yet, no problems have arisen. Only restricted areas in the north of the Ivanhoe Plain are considered at risk since over most of the plains water tables are well below the surface and subsurface drainage towards the Ord River is adequate.

The cracking clay soils have a low permeability when wet and this can lead to temporary problems in obtaining adequate internal drainage. Internal waterlogging can be a problem for plant growth for some days following irrigation. Soil trafficability is poor after irrigation. Also, when dry, the soils may be very hard, resulting in increased cultivation costs. The cracking permits evaporation of moisture from deep in the soil, accelerating the drying of the profile.

The shrinking and swelling of the soils leads to engineering problems for buildings and earthworks. Specially designed foundations are required for buildings. The non-cracking sands and loams are far more stable and have generally been the preferred sites for the construction of buildings. Channels and dams are constructed on the heavier textured soil, but occasionally these are prone to piping failure and leakage.

Chemical attributes

Chemical properties of the ORIA soils might be expected to affect plant growth through the presence or development of excess salinity, excess sodicity, excess bicarbonate, variations in soil pH, and deficiencies of micro- or macro-nutrients. Clearing and irrigation are likely to cause changes in the chemical status of the soils over time. Studies on the effect of irrigation in the area have shown that, at some sites, accumulation of salt in the surface layer of the soil and rises in pH may occur. Management practices and crops grown may need to change in response to changes in the soil. Nutrient availability will change with shifts in pH.

While problems associated with high salinity, high exchangeable sodium percentage, and high bicarbonate concentrations have been predicted, no such problems occurred in the first 25 years of farming in the ORIA. However, many of the soils, particularly in the southern part of the Ivanhoe Plain, have high pH and associated nutritional problems. All soils have low organic matter content and the carbon to nitrogen ratios are high. The nutrient requirements of crops are high as indicated by the removal of nutrients in the harvested product (Table 1). Fertiliser management has been shown to be particularly important for crops on the clays as both insufficient and excessive nitrogenous applications will reduce yields. Soil tests have been used to develop fertiliser programs for phosphorus and zinc in field crops. The soil tests have not been calibrated for other elements and no recommendations for these can be made from soil tests. Foliar nutrient analysis is becoming an important tool in monitoring crop nutrition.

Table 1. Typical removal of mineral nutrients in the fruit, seed or grain of some crops in the ORIA.

Nutrient removed (kg)	Banana* (*Musa* sp.) yield 50 t/ha	Maize (*Zea mays*) yield 10 t/ha	Chickpea (*Cicer arietinum*) yield 2.5 t/ha
Nitrogen (N)	189	160	75
Phosphorus (P)	29	30	9
Potassium (K)	778	40	30
Calcium (Ca)	101	5	3
Magnesium (Mg)	49	9	4
Zinc (Zn)	0.5	0.3	0.1

* Lahav and Turner, 1983

There is a strong interaction between soil chemical properties, nutrient status and the requirement for some nutrients, particularly phosphorus and zinc. Zinc is generally required as a trace element for crops in the ORIA, and frequent small applications are practised, with 4-8 kg/ha being applied each two to three years to cereal or legume crops. Zinc deficiencies may still occur seasonally during spells of cool and wet conditions. Deficiencies of phosphorus and zinc are commonly associated with soils having high pH values and the zinc deficiency may be exacerbated by high soil phosphorus levels. More detail on the soil fertiliser requirements and interactions may be found in the proceedings of the 'Soil and plant nutrition update' held in 1988, as well as in the soil descriptions below.

Descriptions of nine particular soils and their management characteristics

Cununurra clay - normal phase

Introduction

A significant area of the Packsaddle and Ivanhoe Plains is covered by cracking clay soils, of predominantly the Cununurra clay family. The normal phase of this family comprises the largest single soil unit found on the Packsaddle Plain, covering about 1200 ha. It also occurs occasionally on the Ivanhoe Plain and extensively in the Keep River area. The surface of this soil is slightly gilgaied with moderate cracking hidden by a surface crust. Topsoil pH is neutral to slightly alkaline, increasing to moderately alkaline with depth. Topsoil pH is higher than for leached phase soils, and lower than for alkaline phase soils of the Cununurra clay family. The normal phase soils are used predominantly for field cropping and for annual horticultural crops.

Natural vegetation

Vegetation comprises very open woodland of *Lysiphyllum cunninghammi* (bauhinia) with a grass cover of *Chrysopogon fallax* (ribbon grass), *Aristida sp.* and *Astrebla squarrosa* (bull Mitchell grass).

Physical properties

The normal phase soils are 'dark' clays, have mild gilgai relief, (20-25 cm amplitude) and are about 120-150 cm deep over reddish parent alluvium. Since only minimal differences occur between mounds and depressions of gilgai, levelling of gilgai should not adversely affect subsequent cropping. Structure and physical composition of the topsoil is generally intermediate in character between soils of the leached and alkaline phases. Some small carbonate nodules are visible in the upper profile but are more prevalent at depth. Drainage is classified as poor, and the soil is regarded as having potential for development of a medium tilth following cultivation. A typical profile of the normal phase is as follows.

0-5 cm	Dark greyish brown 'self-mulching' clay, pH 7.5
5-25 cm	Dark, greyish brown medium to heavy clay, very hard, strongly structured, some carbonates, pH 8.5
25-125 cm	Dark greyish heavy clay, extremely hard, strongly structured, some carbonates, pH 8.5
125-140 cm	Brownish medium to heavy clay, weakly structured, increasing carbonates, pH 8.6
140-160+ cm	Reddish medium clay, micaceous, with abundant carbonate nodules, pH 8.5

Physical attributes are largely intermediate in character between soils of the alkaline and leached phases and management requirements are influenced accordingly. Soils of the normal phase generally require more careful water management than the alkaline soils because of poorer drainage characteristics and they require increased cultivation for achieving a similar degree of tilth.

While drainage is classified as poor, it is regarded as adequate and better than for leached phase soils. Water logging is unlikely to be a problem during the dry season except for highly susceptible crops and for less susceptible crops during the wet season. Slopes are usually adequate with only limited areas of <1:2500. Most crops on these soils are flood irrigated with only small areas of trickle irrigation or micro-sprinklers. There are no unusual limitations on use of these soils for irrigation and cropping on them has proven very successful.

Chemical attributes

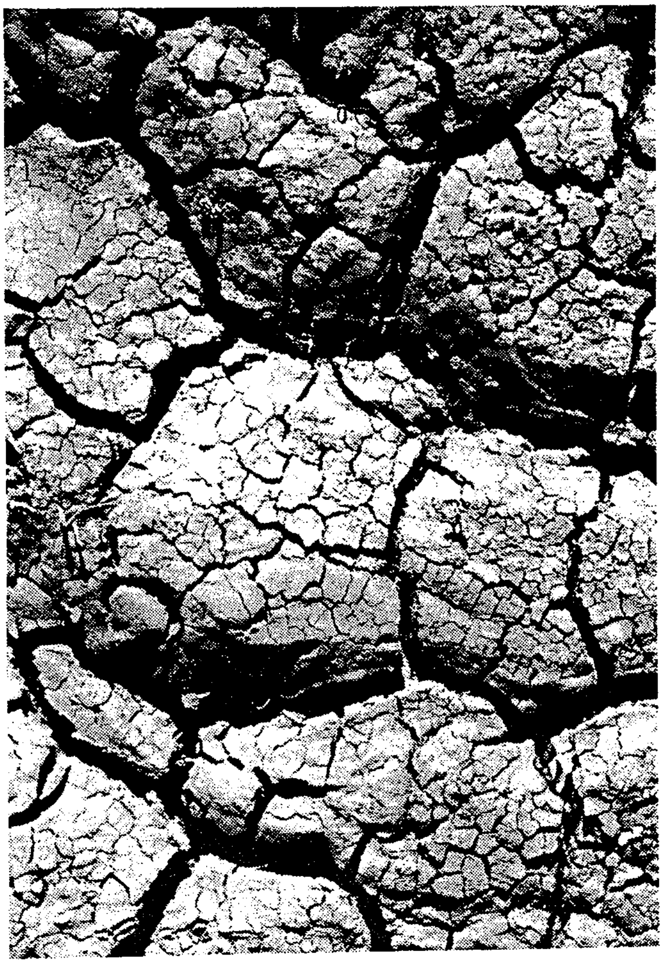
Throughout the period of development of the soil, moderate leaching of the parent material to a depth of about 1 m by incident rainfall has reduced the topsoil pH to neutral to slightly alkaline. Under these conditions, crop nutritional problems are not expected. Increases in pH occur down the profile with small carbonate nodules more prevalent at depth. Soil disturbance to depth by levelling or cultivation can result in increases in topsoil pH as can periods of irrigated agriculture with water and fertiliser application. Nutritional disorders can be induced under these conditions.

In the natural state, levels of nitrogen, phosphorus and zinc are inadequate for crop production. Without replacement, sulphur is also likely to become marginal after an extended period of cropping or with more sensitive crops. Neutral to slightly alkaline soil pH levels found in the natural state are unlikely to adversely influence plant nutrition, although increases in topsoil pH observed after cropping are likely to disturb the nutritional balance. Availability of zinc is most likely to be affected by increased pH levels, resulting in zinc deficiency. High rates of phosphatic fertiliser application can also reduce zinc availability. Increased applications of zinc will usually overcome this problem.

Iron deficiency can also be induced in sensitive crops with increased topsoil pH. Consideration should be given to management strategies likely to prevent or minimise increases in topsoil pH (see discussion under Cununurra clay leached phase). As with other soils of the Cununurra clay family, potassium levels are usually adequate for crop production.

Summary

The normal phase of the Cununurra clay is the largest single soil unit found on the Packsaddle Plain. It occurs occasionally on the Ivanhoe Plain and extensively in the Keep River area. The surface is slightly gilgaied with a topsoil pH neutral to slightly alkaline, and increases in pH with depth. These soils are used predominantly for field crop and annual horticultural crop production. Physical and chemical attributes are intermediate in character between the leached and alkaline phase soils of the Cununurra clay family. Drainage and soil structure are generally better than for the leached phase soils while pH is lower than for the alkaline soils resulting in fewer nutritional problems usually associated with high pH soils. With careful water and fertiliser management, these soils, as with the other Cununurra clay soils, can be highly productive.



Cununurra clay characteristically cracks on drying

Cununurra clay - alkaline phase

Introduction

Most of the irrigable land found on the Ivanhoe and Packsaddle Plains consists of Cununurra clay. Soils of this family include the normal, alkaline, leached, and wetter phases. The alkaline phase is a brownish, cracking clay with finely structured, high pH top soil, and is largely confined to the more recent alluvial deposits of the southern province of the Ivanhoe Plain, and to small areas on Packsaddle Plain. Minor areas of highly calcareous clay soils (Walyara clay) commonly occur in association with the alkaline phase.

Natural vegetation

Natural vegetation consists of largely *Lysiphyllum cunninghammi* (bauhinia) woodland with occasional *Carissa lanceolata* (conkerberry) and *Terminalia oblongata ssp. volucris* (rosewood). The grasses include *Aristida latifolia* (feathertop wiregrass), which dominates with over-grazing, *Astrebla squarrosa* (bull Mitchell grass) and *Brachyachne sp.* (native couch).

Physical properties

The alkaline soils have formed on relatively young, recently reworked alluvium of the Ord River flood plain. These soils, having undergone only relatively minimal leaching, have carbonate nodules and fine amorphous carbonates which are visible in the top soil in many locations. Small areas of soils even more calcareous in nature (Walyara family) are interspersed throughout. A typical profile of the alkaline phase is as follows.

0-10 cm	Dark brownish self-mulching clay with a fine tilth. Some small carbonate nodules, pH 7.8
10-35 cm	Dark brownish medium to heavy clay, very hard and strongly structured. Some carbonate nodules, pH 8.4
35-135 cm	Dark brownish medium to heavy clay, very firm and strongly structured. Moderate amounts of carbonate nodules, pH 8.7
135-145 cm	Brownish medium clay, increasing carbonate content (mainly nodules) pH 8.7
145-160+ cm	Reddish light to medium clay with abundant carbonate nodules, pH 8.5. Some micaceous material.

Slopes in the southern province of the Ivanhoe Plain are greater than in the north, with gradients broadly ranging between 1:1500 and 1:2000. Drainage, although classified as imperfect to poor is better than for the northern province soils. These characteristics, together with a finer structured top soil and lower clay content generally allow for easier physical management of the alkaline soils. These soils produce a fine tilth with cultivation.

The soil is suitable for a range of field and annual horticultural crops. Available water is about 120 mm in the top 1 m of soil, although access is limited for some crops as root depth is restricted because of high clay content. Available water and infiltration rates have been observed to decline over a number of seasons with flood irrigation and perennial cropping. Flood irrigation is commonly practised with small areas under trickle and sprinkler irrigation.

Problems associated with waterlogging should be minimal for irrigated dry season crops while susceptible crops should be avoided during the wet season. Appropriate cultural practices are important in avoiding soil structural degradation which results largely through compaction by farm machinery.

Chemical attributes

A relatively high carbonate content in the top soil has resulted in the pH being typically within the range 7.5 to 8.0. These readings increase with depth and have been observed to rise after extended periods of irrigated cropping.

The low organic matter content of these soils is associated with reduced mineralisation and widespread nitrogen deficiency. Both total and available phosphorus are low in the native state, around 3 ppm bicarbonate extractable phosphorus and less than is present in soils of the northern province.

High soil pH probably reduces the availability of applied phosphorus through its precipitation as calcium phosphate. Careful management of zinc nutrition is important since deficiency can be induced with high pH and as a result of higher levels of phosphorus application. Iron deficiency is also likely in sensitive crops, induced by high soil pH.

Soil sulphur levels may also be inadequate under some management conditions and will be dependent on applied sulphur levels since the alkaline cracking clays have minimal capacity for sulphur adsorption. Levels of potassium are usually adequate for crop production.

The relatively high pH has important implications for crop fertiliser management. Management strategies which will minimise the detrimental effects associated with high soil pH, and which will prevent further pH increases are essential (see discussion under Cununurra clay leached phase).

Fertiliser form is important in producing a localised soil pH effect, particularly its effect on seedling development when placed close to the seed at planting. Most crops will require nitrogen, phosphorus and zinc application with other crops responsive to addition of sulphur. Interaction between these nutrients influences their availability and plant uptake. High levels of applied phosphorus can further induce zinc deficiency while inadequate levels of sulphur can reduce the plants responsiveness to nitrogen. Zinc and phosphorus deficiency, are both more likely to occur under cooler dry season conditions and with waterlogging, especially during crop establishment.

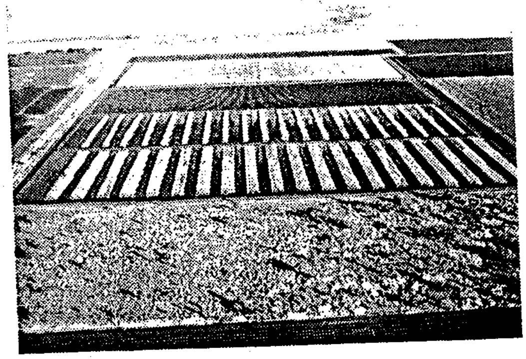
Summary

The alkaline phase of the Cununurra clay is the predominant soil of the southern province of the Ivanhoe Plain and is found in small areas on the Packsaddle Plain. These soils have a finer structured top soil, lower clay content, and better drainage than soils of the northern province, and are generally easier to work. They are relatively flat and well suited to flood irrigation.

Drainage, while imperfect, is adequate for most dry season crops. The alkaline phase is characterised by high topsoil pH which increases with depth and following extended periods of irrigated agriculture. Soil pH is sufficiently high to induce nutrient deficiencies of iron and zinc in the native state, and to reduce availability of applied phosphorus.

Sulphur levels are also likely to be quickly depleted with continued cropping as adsorption is minimal on alkaline cracking clays. Application of nitrogen, phosphorus and zinc are usually required for crop production on these soils. Iron and sulphur may be required in some situations. With adequate water and fertiliser management, cropping on the alkaline cracking clays has proven to be highly productive.

Harvesting beans



Hybrid seed production on Cununurra clay

Cununurra clay - leached phase

Introduction

Soils of the Cununurra family are distinguished largely on the basis of soil pH which is related to the amount of leaching that has taken place in the virgin state. This depends largely on the age of the soil and its position in the landscape. The more leached soils tend to have lower surface soil pH and increasing pH with depth. Soils of the leached phase occur to the north and east of the Frank Wise Institute of Tropical Agricultural Research and are the most extensive of the soil types found on the Ivanhoe Plain. In its natural state this area is largely a treeless plain.

Natural vegetation

Vegetation is almost a grassland with some *Lysiphyllum cunninghamii* (bauhinia). The density of *L. cunninghamii is* markedly lower than on the younger Cununurra clays, the normal and alkaline phases. The grasses include *Chrysopogon fallax* (ribbon grass), *Aristida sp.* and *Astrebla squarrosa* (bull Mitchell grass).

Physical properties

Because of the more complete leaching these soils are greyer than the normal and alkaline phases. Differences are difficult to detect unless careful standards are applied. Soil structure is coarser than in the alkaline phase, especially in the upper parts of the profile. On cultivation these soils tend to produce a coarse, cloddy tilth, less desirable than the fine tilth of the alkaline phase. Clay contents are higher and drainage is poorer than with the alkaline phase. Within the spread of the leached phase soils there are small areas of relatively poorly drained soils. These are mapped separately as a Cununurra clay (wetter phase). A typical profile of the leached phase is as follows.

0-5 cm	Dark greyish self-mulching clay, pH 7.0
5-25 cm	Dark greyish heavy clay, extremely hard and strongly structured, pH 7.6
25-130 cm	Dark greyish heavy clay, very firm and strongly structured, traces of carbonates, pH 8.5
130-145 cm	Dark yellowish brown heavy clay, traces of carbonates, pH 8.8
145-160+ cm	Dark brown medium to heavy clay, small amounts of carbonate nodules, pH 8.9

Slopes on the northern end of the Ivanhoe Plain (1:2500 to 1:3500) are lower than at the southern end (1:1500 to 1:2000). When this is combined with the poorer subsoil drainage of the heavier textured leached soils the establishment of an adequate irrigation and surface drainage system is the main factor in successful farming. The limitation imposed by the restricted drainage has not proved to be a major constraint to production and the most actively farmed area in the valley is located on these soils. Waterlogging is unlikely to be a problem in other than very wet years, and cropping activity is less intense in the wet season than in the dry. Soil tilth following the initial cultivation tends to be cloddy and numerous secondary workings may be necessary to achieve an acceptably fine seedbed tilth.

Chemical attributes

Cununurra leached soils have a surface soil pH about neutral in the virgin state and nutritional problems are not expected under these conditions. However, after a period under irrigated cropping, soil pH has been seen to rise substantially in the cultivated topsoil. Subsequently, nutritional problems similar to those encountered on the alkaline phase may result.

Large areas of these soils have been developed for irrigated agriculture and a shift from a neutral surface soil pH to higher pH values at the soil surface is now suspected. Little research work has been done on the rate of change of soil pH with irrigated farming. Some farmers have considered the possibility of applying acidifying chemicals to reduce the pH and hopefully reduce nutrient deficiency problems (particularly zinc). However, buffering capacities have not been determined and the required rates of acidifying material such as mineral sulphur and its likely effectiveness are not known. Farmers should exercise caution in the application of such uncertain technology until more data are available; test strips on their own farm should be considered.

Regular testing of soil pH, phosphorus and zinc will serve to characterise the trends on particular farmed areas and the likelihood of deficiencies such as zinc and phosphorus may be determined. No soil standards exist for other nutrients, but plant analysis is available to determine the status of plants growing on areas already characterised for soil pH, phosphorus and zinc. Regular monitoring should help improve the understanding of the chemical requirements of the land.

Summary

The leached phase of the Cununurra clay is the most extensive soil on the Ivanhoe Plain and there are small occurrences of an equivalent acidic phase on the Packsaddle Plain. In its virgin state it has a neutral soil pH, but this rises with farming and irrigation. While there are unlikely to be pH induced nutrient deficiencies in the virgin state the soil is likely to be deficient in nitrogen and phosphorus. With farming, this is likely to extend to include zinc and iron, and the zinc problems are exacerbated by moist, cool conditions and by high levels of applied phosphorus.

Physical conditions are determined largely by the heavy texture and resultant poor internal drainage. Careful preparation of the irrigation and drainage system has allowed successful farming of this land system.

Furrow irrigated maize on Cununurra clay

Aquitaine clay

Introduction

Soils of the Aquitaine family have been strongly influenced in their formation by extensive periods of inundation. They occur in depressed, contained areas such as swamps and 'junction complex' areas around the margins of the plains. Annual inundation is a significant feature, with the source being local run-off from the adjoining sandy country and the nearby clay plain. The differing degrees of seasonal inundation result in recognisable differences in soils of this family and colour has provided the basis for subdivision of the soils.

Natural vegetation

Native tree species grow particularly densely on the 'bluish' phase. *Eucalyptus microtheca* (flooded box) and *Exoecaria parvifolia* (gutta-percha tree) are common on this soil, and less densely on the soils of the 'greyish' phase, but the 'olive-yellow' phase is normally treeless.

Physical properties

Soils of the 'bluish' phase have a distinctive colour when dry and have been more extensively subjected to inundation than the other phases. Leaching has been more pronounced and soil pH is lower in the upper profile than for Cununurra clays. Free carbonates are not common and the underlying 'reddish' parent material is paler and yellower than for Cununurra clay soils. It also contains a few mottles, indicating the effect of inundation. A typical profile of the 'bluish' phase is as follows.

0-8 cm	Greyish (bluish when disturbed) structured medium clay, weakly self-mulching, pH 6.0 to 7.0
8-30 cm	Grey (bluish when disturbed) medium to heavy clay, extremely hard, structured, and sometimes mottled, pH 6.5 to 7.5
30-135 cm	Grey or olive-grey medium to heavy clay, weakly structured, very firm, usually distinctly mottled, pH 7.5 to 8.0, some carbonate nodules and sand lenses.
135-150 cm	Brownish or yellowish medium clay, some mottles, some carbonate nodules, pH 8.5 to 9.0.

Soils of the 'greyish' phase are inundated to a lesser depth and for a shorter time than soils of the 'bluish' phase. They occur mainly in swamps and some parts of the junction complex, and towards the main body of the plain merge with the soils of the wetter phase of Cununurra clay. Subsoils are not as pale or as mottled as those of the 'bluish' phase. A typical profile of the 'greyish' phase is as follows.

0-8 cm	Dark grey structured medium clay, weakly self mulching, pH 6.5 to 7.5
8-30 cm	Dark grey medium to heavy clay, extremely hard, coarsely structured, pH 7.5 to 8.5
30-130 cm	Dark grey heavy clay, very firm, weakly structured, distinctly mottled, pH 8.0 to 8.5, some carbonate nodules and sand lenses
130-150+ cm	Brownish or reddish medium to heavy clay, some mottles and some carbonate nodules, pH 8.5 to 9.0.

There is also an 'olive-yellow' phase which occurs near the 'junction complex' along the eastern margin of the Ivanhoe Plain. The colour, when dry, is a distinctive yellow or olive. The colouration is likely to result from the influence of run-on water from nearby sandier country. Sand is commonly found in the profiles, but they are not common soils.

The problem associated with the irrigation of the intensely leached Aquitaine soils is their low permeability, because additional alluvial clay has been deposited in the already fine pores. Under these conditions solutes may accumulate and the exchangeable sodium percentage may rise, further leading to the risk of salinity, because of the lower permeability that may result. Surface drainage works are considered necessary before the largest expanses of these soils could be developed. They have been recognised as potential areas for future development and small areas are already being farmed successfully.

Chemical attributes

Surface soil pH values are near neutral, but pH rises quickly down the profile. As with the Cununurra leached phase, the possibility of increasing pH with irrigation and the cultivation associated with farming means that the nutrient status of the soils may change over time. As yet only small areas of the soils of the 'bluish' phase have been extensively farmed, mainly to grain and seed crops (sorghum and sunflower). There has been no detailed monitoring of the changes imposed by farming and irrigation, and so no records exist of the changes of soil pH that may have occurred. Cultivation and irrigation are both likely to lead to higher soil pH and the associated problems of zinc and iron deficiency. The soils are inherently deficient in nitrogen and phosphorus.

An awareness of the changes that are likely to occur with irrigated farming is critical in developing these soils for agriculture. The poor internal drainage may lead to problems with salinity or sodicity, but this has not been encountered on the farmed areas to this stage. Changing soil pH with farming, introduces the need to monitor pH in the root zone as well as sodicity and salinity.

Summary

As yet only small areas of the Aquitaine soils have been developed, but substantial areas can be developed by a simple extension of the existing channel system. Drainage is recognised as an essential pre-requisite for the successful farming of the new areas.

Those areas presently farmed have not yet experienced the problems of salinity or sodicity potentially associated with the poor internal drainage. Farmers should be aware of the changes of surface soil pH that may occur with irrigation and cultivation. Because of the hard nature of the soils when dry, cultivation is likely to be difficult unless moisture conditions are ideal. Regular monitoring of the soil chemical status will help the planning of a fertiliser program. Further characterisation of the soils and changes resulting from farming are required.

Natural vegetation on Aquitane clay

Walyara clay

Introduction

Walyara soils are calcareous soils with gradational profiles that occur on low gravelly rises and in linear belts on the Ivanhoe Plain. Their parent material is river alluvia. They are thought to be the remnants of old levees and channels and to have developed under conditions of minimal leaching. They have been mapped in three units according to the relative proportions of Walyara to Cununurra clay (40 per cent, 20 per cent and 2 per cent Walyara clay) and occur on about 400 ha of the ORIA. Only small areas of Walyara clay associated with more suitable soils have been developed.

Natural vegetation

The native vegetation includes populations of *Lysiphyllum cunninghamii* (bauhinia) and *Carissa lanceolata* (conkerberry). *Eucalyptus clavigera* (apple gum) grows on these soils in the older northerly province on the Ivanhoe Plain.

Physical properties

The Walyara soils are characterised by their dark surface crust and occur on low gravelly rises. After levelling and cultivation they are not readily distinguished visually from the Cununurra clay soils. In some areas, the proportion of Walyara soil patches reaches 40 per cent with individual patches typically 20 m wide, in other areas, Walyara soil patches represent about 20 per cent in linearly orientated patches about 3 m by 6 m. The land unit with the least Walyara soil has only 2 per cent in weakly gilgaied areas with the Walyara soils on the mounds. A description of a typical Walyara profile is as follows.

0-10 cm	Dark brown clay loam with a thin dark curled surface crust and some siliceous gravel, pH 8.0, calcareous
10-20 cm	Dark brown light clay, very hard, some finely divided carbonates, pH 8.5, calcareous
20-100 cm	Dark brown medium clay, extremely hard, with weak structure and 20 per cent finely divided carbonates, pH 8.8, calcareous
100-160 cm	Dark yellowish medium to heavy clay, extremely firm, weakly structured, some finely divided carbonates and pale mottles, pH 8.8, calcareous

As Walyara soil often occurs on low rises or gilgaied areas levelling would be required for furrow irrigation. The chemical limitations of this soil type may preclude its use if there is a large proportion of Walyara soil at the site. Otherwise, the management recommendations that apply to Cununurra clay soils would apply to Walyara soils.

Chemical attributes

The Walyara soils are calcareous, have a high pH and exchangeable sodium percentage above 15 per cent in the subsoil. Being calcareous and of high pH, these soils are likely to have nutritional problems such as poor phosphorus and micronutrient availability and uptake in crops. The high exchangeable sodium in the subsoil is likely to reduce drainage. Levelling of these sites exposes the lower layers of the profile thereby increasing the chemical problems.

Development of these soils for irrigation would present difficulties. They would fix phosphorus and zinc more readily than the adjacent Cununurra clay soils and, because of their patchy nature, would preclude the development of uniform irrigation bays, particularly as levelling would accentuate the problems. Where the proportion of Walyara soil at the site is low the area could be developed as recommended for Cununurra soils, but small patches with crop nutritional problems are to be expected. Along with phosphorus and zinc, iron deficiencies may be encountered.

Summary

The Walyara soils are a minor soil family in the ORIA. They are calcareous and of high pH with high exchangeable sodium levels in the subsoil. Inherent nutrient deficiencies and poor use of applied nutrients would limit their use. Some areas with a low proportion of Walyara soil could be cropped after levelling, however, some patchy crop nutritional problems should be expected.

Sunflower crop on the ORIA

Packsaddle sandy loam

Introduction

Packsaddle sandy loam occurs on the Packsaddle Plain and is sometimes called Packsaddle red soil. Clay content increases with depth. A major feature is the powdery or 'bull-dusty' nature of the surface soil which causes difficulties in land preparation when excessively dry. It is often interspersed with transitional soil types requiring variable management within localised areas.

Natural vegetation

Vegetation is typically a eucalypt woodland, mainly *Eucalyptus pruinosa* (silverleaf box) with *Eucalyptus clavigera* (apple gum), *Eucalyptus arenaria* (bloodwood) and occasional *Carissa lanceolata* (conkerberry) shrubs. The associated grasses are *Heteropogon contortus* (black speargrass) and *Eriachne obtusa* (northern wandarrie grass). In shallow areas of Packsaddle sandy loam, with a marked increase in clay content at only 25 cm, there are commonly dense stands of *Melaleuca minutifolia* with some *Terminalia platyptera* (wing-seed terminalia) and a few *Eucalyptus pruinosa.*

Physical properties

A typical profile of the Packsaddle sandy loam is as follows.

0-10 cm	Dusky red loamy sand to sandy loam surface, firm, coherent, slightly cracked, powders to bulldust. pH 5.7
10-45 cm	Dark red sandy loam. pH 5.6
45-60 cm	Dark red sandy clay loam. pH 5.6
60-145 cm	Dark red light clay, slightly micaceous. pH 7.0
145-180 cm	Reddish brown light clay, slightly micaceous, and with a few carbonate nodules. pH 9.0

Clay content increases from 27 per cent in the top 30 cm to 34 per cent at 100 cm depth while the coarse sand fraction decreases from 21 per cent to 15 per cent.

A small area of a shallow phase of eroded Packsaddle sandy loam also exists in which dark red sandy clay loam occurs within 25 cm of the surface and the dark red clay within 40 cm. Clay content towards the surface is 34 per cent increasing to over 40 per cent at 60 cm depth. This soil is noted for its blocky structure.

Infiltration rates on the more typical Packsaddle sandy loam are intermediate in character between the Cununurra clay and levee soils. Very low rates occur on the shallow phase. Horticultural production on these soils uses both flood and micro-sprinkler irrigation although better control of soil moisture levels is achieved with micro-sprinklers because of the relatively low infiltration rates and imperfect drainage.

Transitional soil types associated with Packsaddle sandy loam may require separate production units within one farm to be managed individually.

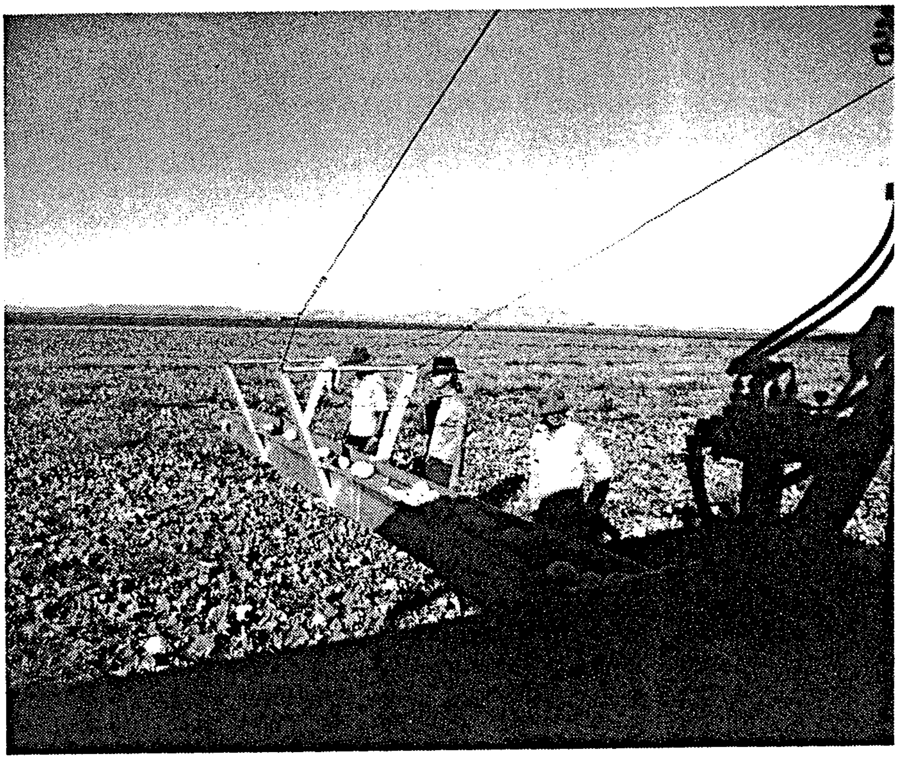
Chemical attributes

Packsaddle sandy loam is the most acidic of the main soils of the ORIA. It is low in organic matter and most nutrients.

Regular addition of macro-nutrients will be required for crop production on this soil. High rates of phosphorus application are usually needed. Nutrient availability should not be a problem given the slightly acidic pH. Responses to zinc have been observed in horticultural crops. High levels of manganese have been recorded in some crops. The permeability of Packsaddle sandy loam is less than for the levee soils, but may be adequate to allow leaching of applied nutrients.

Summary

Packsaddle sandy loam is a moderately fertile soil suitable for horticultural crops. It powders when dry making it difficult to work under those conditions. It has a low water holding capacity compared with the levee soils.



Harvesting melons on the ORIA

Cockatoo sand

Introduction

The Cockatoo sands are a group of soils derived from the ferruginous sandstone parent material of the hills surrounding the ORIA. They are the youngest soils of the area and are located at the higher landscape positions. They were mapped in a survey undertaken in 1979 to identify areas suitable for peanut *(Arachis hypogaea)* production (Dixon and Petheram 1979). Commercial peanut production on these soils commenced in 1981 and other crops such as maize and vegetables have been occasionally grown as the dry season rotational crop with peanut.

Other sandy soils in the ORIA include the soils in the Pago, Cajuput, Cullen, Elliot and Steeple Peak families. These soils have similar parent material and have formed in different landscape positions. The Pago soils are considered suitable for peanut production with most of the other sandy soils potentially suitable for some form of agriculture.

Natural vegetation

These soils support a variable woodland of small trees. The *Eucalyptus* component is an association of *Eucalyptus miniata* (northern woolybutt) and *Eucalyptus tetrodonta* (Darwin stringybark), the former being dominant in some sites. Other minor species include *Erythrophleum chlorostachys* (Cooktown ironwood), *Buchanania obovata* (wild mango), *Grevillea agrifolia* (blue grevillea), *Persoonia falcata* (wild pear) and *Owenia verincosa* (emu apple). The ground flora consists mainly of coarse grasses.

Physical properties

There are three phases of Cockatoo sand recognised; sandy, normal and heavy phases. These differ mainly in their clay content. The sandy phase has minimal increase in clay with depth whereas the B horizon of the normal phase is a loamy sand. The heavy phase is a loamy sand on the surface and a clayey sand at depth. A typical profile description of the normal phase is as follows.

0-10 cm	Reddish brown loamy sand, pH 6.5, dry slightly hard consistency, with an earthy fabric and massive structure
10-35 cm	Dark red loamy sand, pH 6.0, dry slightly hard, earthy, massive
35-150 cm	Red loamy sand, pH 6.0, moist, friable, massive earthy.

These soils have rapid infiltration rates and high subsoil permeability with extremely low to low moisture availability. They have slopes of one to two degrees with moderate surface drainage and very high potential for erosion. They are virtually devoid of stones.

As moisture availability is low and the soils are free draining they are only suited to sprinkler or micro irrigation. Given their position in the landscape, the pumping cost for irrigation can be significant. These sands are trafficable within a day or so after heavy rain, but are subject to compaction if worked too wet or too often. Given the slope and ease of erosion of these soils they should be worked on the contour and some erosion control works may be necessary. The light texture and lack of stones suits these soils to peanut production.

Chemical attributes

These are neutral to slightly acidic soils with extremely low to low organic matter, available nutrients, buffering capacity, salinity and reserves of weatherable materials. A typical available nutrient analysis for virgin cockatoo sand top soil is 2 ppm phosphorus, 50 ppm potassium, 200 ppm calcium, 50 ppm magnesium, 0.2 ppm copper, 0.5 ppm zinc. The cation exchange capacity is low at 1 - 3 me/100 g and conductivity of about 0.2 mS/m.

The soils require inputs of mainly phosphorus, zinc and calcium for peanut production. A typical annual fertiliser application for peanut production would be 150 kg/ha double super phosphate with trace elements, zinc, boron and molybdenum and 1 t/ha gypsum. The surface pH of these soils generally increases slightly with irrigated production and availability of some nutrients may become limiting and should be monitored. For production of maize in rotation with peanut, nitrogenous fertiliser such as 100 kg/ha of urea would be required for the maize crop. In this rotation, substantial nitrogen input would be expected from the peanut crop. Inoculation of peanut seed is only necessary in areas where a peanut crop has not been grown previously.

Nutrient requirements for horticultural crops will be specific to particular crops and current recommendations should be obtained from the Department.

As these are soils are prone to leaching and have low buffering capacity they may be subject to nutrient deficiencies, toxicities and imbalances. It is advisable that the nutritional status of crops on these soils be regularly monitored. Agricultural practice to elevate the organic matter status of these soils would also be advisable as this would help improve structure and nutrient availability.

Other sandy soils

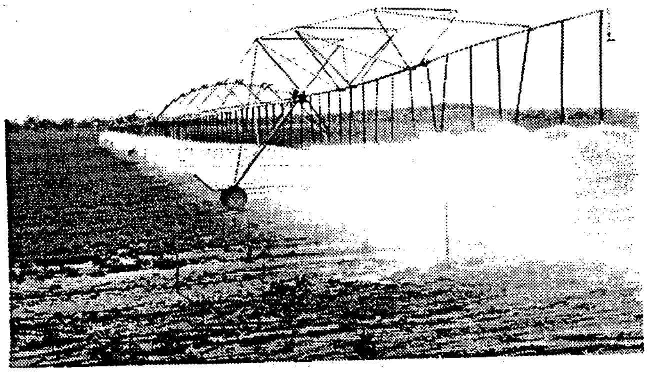
The other sandy soils of the ORIA have formed in landscape positions downslope from the Cockatoo sands. They differ in colour, texture and drainage. The Pago sands are found adjacent to the Cockatoo sands and are the potentially most useful of the others for peanut production after the Cockatoo sands. These are slightly lighter in colour and of a lighter texture throughout the profile.

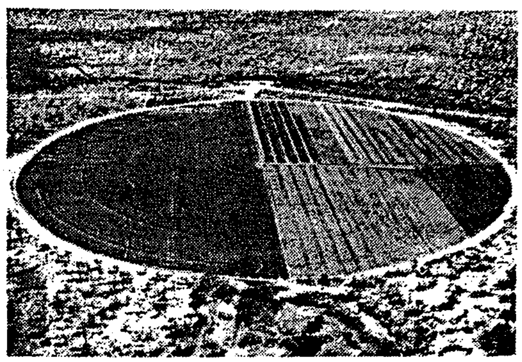
The remaining soils in the Cajuput, Cullen, Elliot and Steeple Peak Families are less suited to agriculture because of either their limited extent or restricted drainage. They may be successfully used for tree and vegetable crops.

Summary

The Cockatoo sands have limitations associated with their poor fertility and cost of irrigation compared with heavier soils in the valley, but are not as subject to access limitations in the wet season and have advantages for peanut production. Their future use may be largely for annual and perennial horticultural crops. Crops of high value, requiring more reliable access and light textured, free draining soils would be best suited to Cockatoo sands.

Similarly, there are a range of other light textured soil types in close proximity to the Cockatoo sands that have agricultural potential. The Pago sands may be suitable for field crops with the others more suited to intensive production.





Centre pivot irrigation on sandy soils

Ord sandy loam

Introduction

Ord sandy loam is a levee soil commonly found along the Ord River adjacent to the Ivanhoe Plain. It is some times called the Ord levee soil. It is a most acceptable soil for horticultural production with its loamy texture, neutral pH and good drainage characteristics. However, it is of limited extent on the Ivanhoe Plain. Larger areas of similar soils are found on the Mantinea Flats, Carlton Plain and in the Goose Hill area, down stream from the currently developed irrigation area (Burvill 1944, Stoneman 1988). The levee soils have generally been subject to erosion as cattle have preferred these areas, because of access to water. They permit easier movement when wet than the adjacent clays.

Natural vegetation

The levee soils support an open woodland, mainly of *Eucalyptus* spp. and grasses. The eucalypts include *Eucalyptus arenaria* (bloodwood), *Eucalyptus clavigera* (apple gum), *Eucalyptus pruinosa* (silverleaf box) and *Eucalyptus papuana* (ghost gum). Other tree species include *Gyrocarpus americanus* (helicopter tree), *Adansonia gregorii* (boab), *Owenia reticulata* (emu apple), *Planchonia careya* (mangaloo), *Brachychiton diversifolius* (northern kurrajong), *Ficus opposita* (sandpaper fig) and *Hakea arborescens* (common hakea). The common grasses are *Themeda australis* (kangaroo grass), *Heteropogon contortus* (black speargrass), *Dicanthium* spp. (blue grass) and *Sehima nervosum* (rat's tail grass).

Physical properties

A simplified profile of the Ord sandy loam is as follows.

0-20 cm	Grey brown or dull brown fine sandy loam. pH 7.0
20-200 cm	Brown fine sandy loam passing to fine sandy clay loam, and often becoming more sandy again with depth. Tight when dry. pH 7.2 to 7.9

The soil is predominantly fine sand with a clay content of 8-14 per cent at the surface increasing to 35 per cent at 100 cm depth. Fine sand decreases from over 70 per cent to less than 50 per cent over the same depth. The levee soil overlies clays similar to Cununurra clay. Away from the river and approaching the Cununurra clay, transitional soils with significantly higher clay content within 90 cm of the surface occur.

Water penetration to depth is satisfactory allowing adequate rates of infiltration during irrigation and adequate drainage of top and subsoil. Proximity to the Ord River and the presence of deeper sandy horizons allow natural subsoil drainage to readily occur. This also minimises the risk of developing water tables and salinity.

Field capacity for a typical Ord sandy loam has been reported at 22 per cent gravimetric water content in the surface 15 cm, decreasing to 17 per cent between 20 and 100 cm depth. In the same soil, 180 mm of available water occurred in the top 100 cm.

Chemical attributes

Ord sandy loam is of neutral pH and has low organic matter and mineral nutrients. The content of phosphorus in the topsoil is generally higher than in the clays and sands of the area.

Although levee soils are the most fertile in the area, because they are mostly used intensely for horticultural crops, they will require regular additions of the macro-nutrients. Given the neutral pH, nutrient availability should not be a problem and the native level of trace elements may prove adequate at many sites. Growers would be advised to monitor the soil for changes in pH and other chemical characteristics as this will change with extended cropping. There is minimal risk of salinity problems as infiltration and drainage are adequate.

Summary

Ord sandy loam is a medium textured soil found on the levees of the Ord River. These areas have been subject to over grazing in the past and some erosion of these areas has occurred. The soil is well suited to crop production given its texture, water holding capacity and naturally fertile state. However, it is of limited extent. High value and/or perennial horticultural crops, especially those requiring better access in the wet season, would be best grown on Ord sandy loam.

Banana production on the loamy soils of the Ord River levees

Ord loamy sand

Introduction

This soil is located along the rivers, major creeks, and associated steep banks of the Packsaddle Plain. Ord loamy sand is sometimes called the Packsaddle levee soil. It is light textured to depth, but with small increases in texture down the profile. It is formed from recent alluvial deposits and is frequently eroded. Ord loamy sand is slightly coarser in texture and more acidic than the Ord sandy loam which is more commonly found on the Ivanhoe Plain.

Natural vegetation

Vegetation is an open eucalypt woodland of *Eucalyptus arenaria* (bloodwood) and some *Eucalyptus clavigera* (apple gum), with a grass understorey dominated by *Aristida hygrornetrica* (northern kerosene grass) and some *Heteropogon contortus* (black speargrass).

Physical properties

A typical profile of Ord loamy sand is as follows.

0-48 cm	Dark reddish brown loamy sand. pH 6.7
48-55 cm	Dark red sandy loam. pH 6.6
55-165 cm	Yellowish red sandy loam. pH 7.3
165-180 cm	Red sandy loam. pH 7.5

The soil is slightly micaceous throughout. Clay content increases from 10 per cent in the top 30 cm to 14 per cent at 100 cm depth, while coarse sand content decreases from 43 per cent to 16 per cent.

The soil is relatively permeable being light textured to depth. It is well suited to irrigation by micro-sprinkler and can be flood irrigated. Natural drainage from the Packsaddle Plain is either towards the Ord River or Packsaddle Creek, with sub-surface drainage generally adequate. A sand horizon below the plain ensures that drainage water should not build up a water- table or result in salinisation.

Ord loamy sand is associated with transitional soil types so production units within the one farm may need individual management.

Chemical attributes

Ord loamy sand is slightly acidic with increasing pH to depth. In its native state it is low in most nutrients and organic matter. The relatively free draining nature of this soil makes it prone to leaching. Variation in sand content and pH between sites is common for this soil. Management characteristics

Regular addition of most macro-nutrients will be required to grow horticultural crops. Given the slightly acidic pH at most sites nutrient availability should not be a problem. However, topsoil pH can be as high as 8.0 at some sites thus requiring zinc application. The benefit of zinc application has proven to be short term and regular application is required.

Summary

Ord loamy sand is a coarse textured levee soil occurring mainly on the Packsaddle Plain. It is suited to horticultural production and is generally better suited to agriculture than the clays of the area and the sands of the Cockatoo land system, however, it is only of limited extent.

Acknowledgements

The material for this publication has mostly been taken from the original soil surveys and other reports listed in the bibliography. The comments and advice of local farmers and officers of the Department of Agriculture is acknowledged.

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Map keys

The soils of the Kununurra area were not always mapped as soils, but as soil/landform/vegetation combinations. Nevertheless, soils did play a major role in determining the map units.

There is also a degree of overlap between surveys and units. It will be noted in the following lists that some of the map unit numbers are not continuous sequences. This is because the 'missing' numbers were used for the mapping of the Keep River and Lower Weaber Plains, by Aldrick *et al.* (1977).

The chronology of surveys on the accompanying maps was: Packsaddle, 1972; Ivanhoe, 1974; Groundnut survey, 1979 and Packsaddle Farm 6, 1981. The actual reporting dates often varied considerably from the date of survey, and in a couple of cases, the same symbol has been used in different areas, for example, 'R' is used on the Packsaddle to denote 'Recent alluvial soils' while elsewhere 'R' denotes a rock outcrop.

SOIL TYPES ACCORDING TO MAP UNIT, ON THE WEABER, PACKSADDLE, AND IVANHOE PLAINS, AND SANDY AREAS ADJACENT AND TO THE EAST OF THE IVANHOE PLAINS.

IVANHOE PLAIN (Aldrick *et al.* 1990)

Map unit	Major soil type
la	Cununurra Clay (alk)
lb	Cununurra Clay (leached)
2c	Weaber (normal)
2e	Weaber (heavier)
4c	Keep (normal)
4f	Cununurra Clay/Weaber mix
5a	Aquitaine (blue)/ Keep (flooded)
5b	Aquitaine (grey)
5c	Aquitaine (blue)
5d	Cununurra Clay (wet)
7a	River banks
7b	Cununurra clay (eroded)
8a	Heavy clays (mixed)
8b	Duplex soils (mixed)
9a	Walyara/Cun. clay (alk) 40% : 60%
9b	Walyara/Cununurra clay (alk) 20% : 80%
9c	Walyara/Cununurra clay (alk) 2% : 98%
10a	Cununurra clay (leached) with coarse sand
10b	Cununurra clay (leached) some coarse sand
R	Rock outcrops
Cc	Cockatoo land system

SANDY AREAS ADJACENT TO IVANHOE PLAIN (Dixon and Petheram 1979)

Map unit	Major soil type
CS	Cockatoo sand
P	Pago sand
C	Cajaput sand
SP	Steeple Peak
E	Elliot
Cu	Cullen
J	Jones
A	Aquitaine
PCS	Pago/Cockatoo sand intergrade
JC	Junction complex - variable soils
SLC	Sandstone/laterite complex
LC	Lateritic complex
DL	Drainage lines
R	Rock outcrops
SL	Swamps and lagoons
CSL	Colluvial slopes.

PACKSADDLE PLAINS (Stoneman1980, Clark 1981)

Map unit	Major soil type
Cc	Cununurra clay (normal phase)
Cc(acid)	Cununurra clay (acid phase)
Cc(alk)	Cununurra clay (alkaline phase)
Cc(g)	Cununurra clay (gilgaied phase)
Psl	Packsaddle sandy loam
Psl(s)	Packsaddle sandy loam (shallow phase)
Ols	Ord loamy sand
A	Unnamed soil 'A'
B	Unnamed soil 'B'
B (d)	Unnamed soil type B (deep phase)
C	Unnamed soil 'C'
D	Unnamed soil 'D'
R	Recent alluvial soils
E	Eroded soils near Packsaddle Creek
F	Unnamed soil type F
G	Unnamed soil type G
H	Unnamed soil type H
L	Unnamed soil type L
R	Recent alluvial soils
W	Swamps and flooded areas.
Complex	Complex area of unidentified soils