SOIL PROPERTIES IN RELATION TO CANE GROWING

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Soil is a term that can be used to refer to the loose upper section of the Earth's crust. However, this broad description does not allow us to recognise that soils can differ markedly from place to place and that they are variable in appearance and/or properties. Soils are a product of various formation and development processes. Their composition and properties (physical and chemical) reflect the processes that have occurred with time, and the original (parent) material from which they have formed. Some soils need to be managed differently to others, particularly in relation to cane growing. It is important to be aware of the various constituents, basic properties and fundamental processes that are associated with specific soils.

The first step towards understanding soils and their properties is to dig a pit or clear an area along a road cutting or ditch and look at the vertical faces that are exposed. The depth of the exposed face will be determined by the nature of the soil, but it could be as shallow as a few centimetres or as deep as a few metres. The vertical faces will reveal a layered pattern that could be well defined or relatively diffuse. The individual layers are called horizons and the sequence of horizons is known as the soil profile.

SOIL PROFILE DESCRIPTION

A soil profile allows the opportunity to observe, recognise and/or describe the properties of a soil in the field. Such a profile should be seen as a 'snapshot' of a more or less continuous blanket that covers the Earth's land mass. This blanket changes either abruptly or gradually in its continuum in terms of variable characteristics such as depth, colour, texture, structure, etc. The organisation and/or reorganisation of soil material due to soil formation factors (climate, drainage and topography, age, parent material and living organisms) result in a sequence of layers or soil horizons that reflect the processes involved. The importance of these horizons is that they can be reproduced if similar soil-forming conditions exist and they become increasingly characteristic with age.

A soil profile may, therefore, be divided into a number of layers or *horizons* (Figure 1) that may or may not be present at any particular site.

ORIGIN OF SOILS

Soil forming factors

Soil and the sequence of soil horizons are the result of the interaction of a number of variables or soil forming factors. These include parent material, climate, relief (and drainage), time and living organisms. By being aware of the role of each of these factors and their interaction in soil formation, growers and their advisers will have improved understanding of why a soil is located where it is, and be able to make better management decisions regarding its limitations.

Parent material is essentially the material from which soil is derived. It may also be more specifically defined as the unconsolidated and more or less chemically weathered mineral (and organic matter) from which soils are developed. Even though the parent material is destroyed during soil formation, the resulting soil is closely related to the original material and is often identified by reference to its parent material, e.g. granitic, schist, basaltic, sandstone soils.

Basaltic soils, for instance, are dark red or brown in colour, are rich in clay (loam or clay loam surface textures), are highly alkaline and are base saturated with little exchangeable aluminium. Granitic soils, on the other hand, have coarse textures, are friable, and are generally acidic with low base status and low mineral reserves. Such soils are formed 'on-site' and are directly related to the underlying material. Other soils may be formed from material transported from elsewhere (alluvium).

Climate, which essentially involves moisture and temperature, has a major effect on the formation, distribution and sequence of soils on a regional scale. In dry areas, chemical weathering and therefore soil development are slow. As chemical reaction rates generally double with each 10°C increase in temperature, soil development increases dramatically in the wet tropics. In dry tropical areas of Queensland, such as the Burdekin, soils are, however, less weathered. This is because, although temperatures are high, chemical weathering is slower due to low rainfall. These areas often contain substantial amounts of swelling clays.

Soil formation also depends on other factors associated with moisture. These include seasonal rainfall variability, the form and intensity of precipitation, and evaporation rate. In the wet tropics and humid sub-tropics, soils are usually acidic, and cation and anion concentrations are low

Top soil	O	Fresh and/or partly decomposed organic matter.
	A	An horizon at or adjacent to the surface and consisting predominantly of mineral particles intimately mixed with a greater or lesser amount of decomposed organic matter
Sub soil	B	An horizon lying between the A and the C or R horizons which is characterised by a concentration of silicate clay, sesquioxides or organic matter, alone or in combination
Substratum	C	An horizon consisting of unconsolidated material or weathering rock, not having properties of the previous horizon
	R	Consolidated bed rock

Figure 1. *Arrangement of general soil horizons.*

due to on-going leaching. Clay particles also tend to be washed down through the profile resulting in lighter textured top-soils and heavier textured sub-soils.

Relief refers to the shape, slope and aspect of the Earth's surface. These three factors have a marked effect on soil development and the sequence of soils in the landscape. As a result, a range of different soil types can develop near to each other. Drainage, which is closely associated with relief, is also important in soil formation. Moving water affects the processes of weathering and erosion, and hence soil formation. Stagnant water or water with restricted movement may give rise to waterlogged soils. Such soils behave, and should be treated, very differently to soils found in well-drained positions.

Time affects weathering and the soil-forming processes. Some soils are old, having been formed over many thousands or tens of thousands of years. Other soils are young, having been deposited during the last flood. As the chemical, physical, mineralogical and biological processes continue with time, soil development becomes more pronounced and the soil profile features become more apparent.

Living organisms, such as micro-organisms, plants, insects, other animals and people generally affect soil formation by contributing both positively and negatively to the weathering process. For instance, plant roots can stimulate soil formation by forming or enlarging cracks in rocks and decomposing parent material. They also retard erosion as they tend to hold soil and peds together. Once they have died, they also result in channels for water and air movement in the profile. Animals, such as termites and earthworms, perform important tasks of assisting in the decomposition of organic matter. People may affect soil formation by agricultural activities crop production.

A large range of soil types is possible when the above-mentioned soil forming factors interact, particularly when some have played a more dominant role than others.

BASIC SOIL PROPERTIES AND THEIR ASSOCIATION WITH SECONDARY PROPERTIES

Basic soil properties are the fundamental characteristics associated with a soil or a soil horizon that can be used to separate one soil or horizon from another. Generally, they are colour, texture, structure and depth. In turn, these basic properties influence or give rise to secondary soil properties. Knowledge of basic soil properties enables better management of specific soils.

Colour

The most striking feature of a soil or soil profile is its colour. Colour is a good indicator of some of the general properties and processes associated with a soil. It is usually determined by the amount and state of the organic matter, the amount and state of iron oxide in the soil as particles or as particle coverings, and the degree of aeration of the soil.

A large range of colours is possible, from black or dark brown to red, yellow to yellow brown, light grey to dark grey and even some greyish-blue to blue/green colours.

Black and dark brown are often associated with the accumulation of organic matter. However, in some circumstances the minerals that make up the soil can also be dark. Two simple 'rules of thumb' worth remembering are that: the darker a soil is, the more organic matter it contains; and a dry soil that leaves your hands 'dirty and dusty' has a high organic matter content.

A red or brown colour indicates that the soil is well drained. Here, the iron compounds are in their oxidised form, i.e. the presence of air will result in a 'rusty' appearance. Again, this colour may be somewhat 'darkened' by the presence of organic matter. Red soils are often found in 'crest' positions in the landscape.

Yellow and yellow/brown colours indicate somewhat less well-drained conditions than with red soils. The iron compounds are in a hydrated form, i.e. water is present as part of the molecule, but the soil is certainly NOT waterlogged.

Grey and blue grey colours are mostly associated with waterlogged and poorly drained conditions. The colours relate to the iron and manganese compounds that are in their reduced form (not oxidised) due to the lack of air.

Light grey colours are associated with bleached or 'washed out' conditions. Here the iron and manganese colours have been intensely leached from the soil by vertical or lateral drainage. In some cases, this 'washing out' also affects the clay particles, leaving a residue of coarser sand particles (See section referring to Texture).

The way in which the various colours manifest themselves in the profile can also be indicative of certain conditions. Uniform colours throughout the profile indicate well-established conditions. Such soils will be considered 'old' and the soil forming processes have reached a high degree of maturity. Stratified colours, on the other hand, are associated with 'young' soils that are still in the process of forming and are mainly found where deposition is actively occurring, e.g. alluvial flood plains. Mottled colours indicate imperfectly drained conditions where periodic periods of waterlogging give rise to alternating oxidising and reducing conditions. Mottles should be thought of as blobs, blotches or streaks of sub-dominant colours within a matrix of a different colour. Segregated colours are associated with the presence of segregations in the soil profile. Segregations are nodules or concretions that form by the accumulation of products from chemical and/or biological reactions. Iron and/or manganese nodules (black, yellow or orange) often form when there are cycles of wetting and drying. Carbonate concretions (white, light grey) are found in alkaline soils in low rainfall areas.

By taking note of the presence of the above colours in soil, growers or their advisers can make important deductions about certain secondary soil properties such as drainage, susceptibility to water-logging, and nitrogen mineralising potential (Table 1). For instance, while a red soil would be well drained and have moderate organic matter accumulation, it would also have moderate to low leaching of nutrients and very low water-logging potential, with minimal chances of nitrogen losses by denitrification. On the other hand, a grey to blue grey soil will be poorly drained and subject to water-logging, there will be low accumulation of organic matter and, although little leaching of nutrients will occur, losses of nitrogen by denitrification will be high.

Texture

Texture refers to the relative proportion of the different sized mineral particles in soils. These mineral particles vary considerably in size and are divided into categories or fractions according to their diameter ranges (Table 2). Coarse sand particles are relatively large in size (2.0-0.2 mm diameter). One gram of sand contains about 650 sand particles, with a total surface area of about 0.0035 m^2. Clay particles are much smaller (<0.002 mm in diameter), so one gram of clay contains about 90 billion particles, with a surface area of about 800 m^2. While the influence of sand particles on soil properties is relatively small, clay particles have a major effect on chemical and physical reactions of soils.

In the laboratory, the amounts of sand, silt and clay (particle size distribution) can be measured. These relative proportions can be used to determine the 'texture' of the soil. In the field, soil texture can be estimated by observing the characteristics of a small handful of moist soil that has been kneaded into a ball (bolus) and then pressed out into a ribbon between thumb and forefinger (Table 3). Soils that contain more or less equal proportions of sand, silt and clay are called loams. The naming of soils according to

Table 1. Secondary soil properties related to soil colour.

Soil property	Black	Light grey	Red	Brown	Yellow	Grey / Blue grey
Drainage	Often slow	Well drained	Well drained	Well to moderately well drained	Less well drained	Poorly drained
Potential for water-logging	Medium	Low	Low	Low	Low-medium	High
Organic matter accumulation	High	Low	Medium	Medium-high	Medium-low	Low
Leaching of nutrients	Low	High	Moderate	Moderate	Moderate	Low
Loss of nigrogen by denitrification	Medium	Low	Low	Low	Low-medium	High

Table 2. Soil texture categories.

Fraction	Particle diameter (mm)	Approximate number of particles per gram	Approximate total surface area in 1 g (m^2)
Coarse sand	2.0–0.2	650	0.0035
Fine sand	0.2–0.02	46 000	0.009
Silt	0.02–0.002	6 000 000	0.045
Clay	<0.002	90 000 000 000	800

field texture indicates a predominance of a particular fraction, with the emphasis on the last word of the description. For instance a 'loamy SAND' is more like a sand than a loam, and a 'sandy LOAM' has more loamy characteristics than a sand.

Soil texture influences a number of secondary soil properties (Table 4). These are often related to the interaction between the soil particles, water and air and have implications for plant growth. Soils with different textures will have varying water-holding capacities and porosities. Porosity refers to the percentage of soil volume that is not occupied by solid particles. Whereas in dry soil the total pore space is filled with air, the pore space in moist soil will contain both air and water.

A loam has a porosity of about 50%, while the porosity of sands will usually be lower and the porosity of clays higher. As sandy soils have a small number of large pores (macropores), they have low water-holding capacities and rapid drainage (Table 4). Conversely, clay soils have large numbers of small pores (micropores) that contribute to a high water-holding capacity and slow permeability. Likewise, in terms of the other secondary properties associated with texture, sands can be thought of as having light drawbar pull and low storage and high leaching of nutrients. Clay soils are difficult to work, but have a high storage capacity for nutrients with low leaching potential.

Soils with distinct textural differences between horizons behave somewhat differently to soils that are characterised by gradual textural changes with depth. Water infiltration and root penetration can be affected severely by abrupt changes in texture.

Table 3. Summary of field guide for determining texture*.

Ribbon length (mm)	Behaviour of moist bolus	Texture grade
Nil	Little or no coherence; cannot be moulded; single sand grains apparent	Sand
5	Sandy with slight coherence	Loamy sand
5-15	Sticky with slight coherence; can just be moulded	Clayey sand
15-25	Sandy, just coherent, moulded bolus will form	Sandy loam
25	Spongy, coherent	Loam
25-40	Distinctly sticky but presence of sand obvious	Sandy clay loam
40-50	Smooth and strongly coherent, no obvious sand grains	Clay loam
40-50	Smooth and coherent	Silty clay loam
50-75	Plastic and coherent	Light clay
>75	Plastic and coherent	Medium to heavy clay

Note: The presence of silt gives the bolus a silky feel.
* Adapted from the Australian Soil and Land Survey Field Handbook.

Table 4. Secondary soil properties as influenced by texture.

Soil property	Sand	Loam	Silty clay loam	Sandy clay loam	Clay
Internal drainage	Excessive	Good	Fair	Fair	Fair to good
Plant available water	Low	Medium	High	Medium	Medium-high
Suitability for flood irrigation	Low	High	High	Medium	High
Stable structure	Low	Medium	Medium	Medium-high	High
Potential for compaction	Low	Low	Medium	Medium	Low
Run-off potential	Low	Low-medium	High	Medium	Medium-high
Erodibility	Low	Medium	Medium	Medium-high	High
Drawbar pull	Light	Light-medium	Medium	Medium	Heavy
Workability	Easy	Easy	Medium	Medium	Difficult
Timing range for cultivation	Long	Long	Long	Medium	Short
Leaching of nutrients	High	Medium	Medium	Low	Low
Nutrient reserve capacity	Low	Medium	Medium	Medium-high	High

Structure

Structure is the natural aggregation of primary soil particles (sand, silt and clay) into secondary units or peds. When soils are examined microscopically, the sand and silt particles are seen to be held together by arrangements of clay particles and/or organic matter in a way similar to the schematic representation in Figure 2. The presence of structure can have both positive and negative effects on secondary soil properties such as erodibility, plant available moisture, root penetration, and nutrient accessibility (Table 5). Such effects are primarily due to the type, development and size of structural units in the profile. The type of structure is described in terms of the overall shape of the peds present. These range from crumb to prismatic

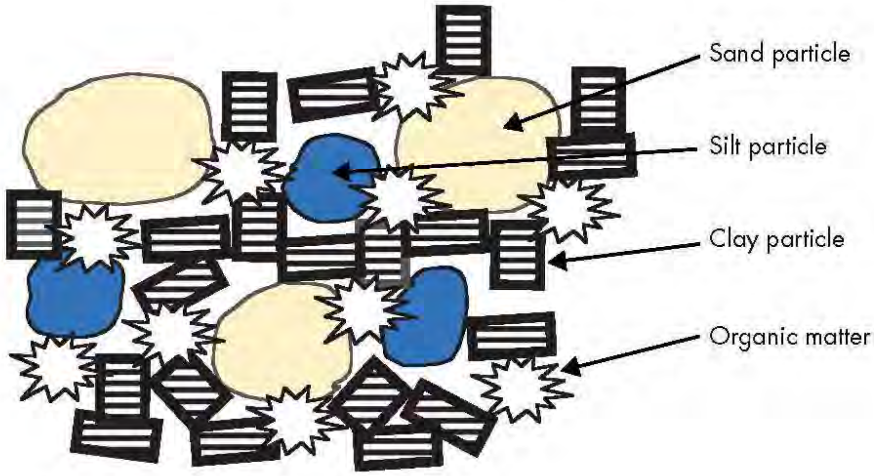


Figure 2. *A microscopic representation of soil structure.*

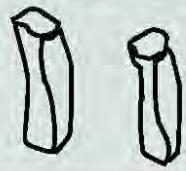
Table 5. Secondary soil properties as influenced by structure.

Soil property	Structure-less	Weak	Moderate	Strong blocky	Strong prismatic
Cohesion	None	Little	Medium	Strong	Strong
Erodibility	High	Medium-high	Medium	Low	Low
Aeration	Good	Good	Good	Good	Poor (within)
Plant available water	Low	Low-medium	Medium	Medium-high	Low
Internal drainage	Good	Good	Medium	Medium	Poor (within), Good (between)
Root penetration	Easy	Easy	Moderate	Moderate	Poor (within)
Nutrient accessibility	High (if present)	High (if present)	Medium	Medium	Low

(Table 6). In terms of size, peds are described as fine, medium or coarse. In describing the development (or distinctness) of peds, structure is classified as weak, moderate or strong. With weak structure, peds can easily be broken by hand. With strong structure, the cohesion within the peds means that considerable mechanical pressure is needed to rupture the individual units. Soils that have no structure are referred to as structureless. Beach sand or young dunes are good examples of structureless soils. Soils may also be described as apedal. Here the structure is present but not visible to the naked eye.

The cohesion between particles produces stable units that are not as vulnerable to erosion as individual particles. Structure also ensures the presence of both micro- and macropores. Micropores are the spaces between the sand, silt and clay particles as they pack together into peds (Figure 2). These smaller pores are essential for ensuring that a soil is able to hold water. Macropores are a result of the spaces (lines/faces of weakness) between the peds in a profile. These bigger pores allow movement of air, water and/or nutrients. If structure is exceptionally strong, roots and shoots will

Table 6. Types of structure and their descriptions.

Type of structure	Description	Illustration
Crumb	Porous to relatively non-porous units that fit together imperfectly.	
Blocky	Units have similar vertical and horizontal dimensions.	
Platy	Peds are arranged in a horizontal plane with the horizontal dimensions larger than the vertical dimensions.	
Prismatic	Column shaped peds, with vertical dimensions exceeding the horizontal dimensions.	

not be able to penetrate the individual peds, but will only be able to grow through the macropores. This may result in poor shoot emergence and/or retarded root growth. In contrast, structureless sand will have little or no cohesion between the individual grains and a predominance of macropores, so water infiltration, aeration and root penetration will be good. However, due to a general absence of micropores, plant available water will be low. As will be explained later, the natural fertility of these soils is low, but, if nutrients were present, they would be easily accessible for plant uptake.

Effective depth

Effective depth is the depth of soil that can be exploited by roots for water and nutrients or for physical support. The presence of an impermeable layer or a perched water table will contribute to a shallower depth.

CHEMICAL PROPERTIES AND PROCESSES ASSOCIATED WITH SOIL

Cation and anion exchange

Because clay particles are so small, are present in such large numbers, have such a large surface area and are electrically charged, they form one of the most important components of any soil. The clay particles are structures made up of frameworks of silicon, aluminium, oxygen and hydrogen building blocks. These frameworks are often called clay minerals. Depending on the actual sequence of silicon and aluminium building blocks, clay minerals can either be 1:1 or 2:1 (ratio of number of silicon-based building blocks to aluminium-based building blocks). While 1:1 clays are not expandable, 2:1 clays are able to shrink and swell as they dry out and wet up. Associated with these clay minerals are negative electrical charges that allow nutrients [(positively charged cations such as potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+})] to be retained in soil and then released for plant uptake. This negative charge, which has a greater potential for occurring in the 2:1 clays than the 1:1 clays, is called the cation exchange capacity (CEC). In other words, CEC can be thought of as the ability of a soil to hold onto positively charged nutrients that are then potentially available for plant use. Likewise, but to a much lesser extent, positive electrical charge or anion exchange capacity (AEC) is associated with the edges of some clay minerals. This allows other nutrients [(negatively charged anions such as nitrate (NO_3^-), phosphate (HPO_4^{2-}) and chloride (Cl^-)] to be held in soil. The oxides and hydroxides of aluminium and iron and organic matter are also sources of CEC and/or AEC in soil.

Generally, less weathered soils (such as in the Burdekin region) are dominated by 2:1 clay minerals (smectites), while the highly weathered soils of the wet tropics contain a predominance of 1:1 clays (kaolin).

The oxides and hydroxides of metals, such as aluminium and iron, are present either in solution or as minerals. A range of iron oxide and hydroxide compounds is possible depending on soil aeration (or waterlogging) and other soil forming factors. The presence of specific iron compounds contributes to the colour of soils (as discussed in a previous section). In addition, metal oxides and hydroxides have a small charge that varies with pH and salt content. In soil, they tend to be positively charged, so that they are attracted to negatively charged clay minerals and organic matter. The soils of the wet tropics may have substantial anion exchange capacity due to this source of positive charge under naturally acidic conditions.

Of particular importance is the ability of some soils to adsorb phosphate so strongly that it is virtually non-exchangeable. Such 'fixed' phosphorus is released slowly and sparingly depending on other soil properties such as pH and concentration of other ions. Adsorption of phosphorus is particularly marked in acidic clay soils.

Soil pH and acidity

Soil pH is a measure of the amount of acidity or alkalinity in soil. As pH is expressed as the negative log of the hydrogen ion (H^+) concentration in solution, it ranges from 0 (highly acid) to 14 (highly alkaline). This means that the higher the amount of H^+ present, the lower the pH value. A pH value of 7 is considered to be neutral (neither acid nor alkaline). Alkaline conditions indicate that hydroxide ions (OH^-) predominate over the H^+ ions. Most often soils from wet tropical areas will have low pH values. In contrast, soils from drier regions will be alkaline. Soil pH is usually measured in the laboratory using a 1:5 soil to water extract, but it is possible to use a test kit to estimate soil pH in the field.

Soil acidity is a combination of H^+ ions and aluminium (Al^{3+}) ions in the soil solution and on the cation exchange sites. In soils that are more or less neutral or slightly alkaline, the predominant cations will be Ca^{2+}, Mg^{2+}, K^+ and Na^+. Such soils are often referred to as being base saturated. In acidic soils, the CEC will be dominated by H^+ and Al^{3+} ions. With soil weathering and crop production, there is a general trend for soils to become more acidic, i.e. the base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) are, with time, replaced by H^+ and Al^{3+} ions. This process is called soil acidification and, although it is a natural process, it may be enhanced by cropping due to nitrate leaching. Some soils are more susceptible to acidification than others. Sandy soils are not able to resist pH changes due to the low clay content, while other soils, particularly clays and those with relatively high organic matter content, do not easily undergo pH changes. Such soils are said to have a large buffering capacity.

Organic matter

Soil organic matter is generally defined as the total living (roots, micro-organisms, animals) and dead (decomposable and inert) organic material present in the soil profile. Although it is present in relatively small proportions, it has a large effect on soil properties. When fresh organic matter, such as sugarcane trash, is added to soil, some of it will decompose quite rapidly, while the more inert fraction will persist for extended periods. Organic matter can influence soil by affecting soil fertility, soil structure, and the ability of a soil to act as a buffer against sharp pH changes. In terms of soil fertility, organic matter can contribute substantial amounts of nitrogen and sulfur due to microbial breakdown processes. A substantial amount of phosphorus is also held in the organic phase. Organic matter can also act as a storage for cations such as potassium, calcium and magnesium, as it generally has a high CEC, which is particularly important in soils that have low clay content. Soil organic matter can also be an important 'sponge' capable of adsorbing heavy metal contaminants. Soil organic matter also fulfils an important role as a 'binding' agent in holding the primary particles together, and the porous nature of organic matter will also help to increase the amount of plant-available water in most soils.

Salinity

Salinity is a term describing the salt content of soils. It is measured in the laboratory by determining the electrical conductivity of a 1:5 soil extract. It is important because plants need to absorb water by a process called osmosis. This means that water will move into the roots in an attempt to balance the salt concentrations between the root sap and the soil solution. This works well when the root sap has a higher salt concentration than the surrounding soil solution. In circumstances where the soils are too saline, plants will suffer drought stress as water will not be moving into the roots. The effect of salinity on sugarcane growth is dependent on soil type (Table 7). For instance, a moderate growth restriction would be expected if an $EC_{1:5}$ value associated with a sand was 0.35. However, there would be slight effect with the same $EC_{1:5}$ value in a clay soil.

Sodicity

Sodicity is a chemical characteristic that affects the structure of soils. The primary soil particles (sand, silt and clay) more readily bind together to form structural units in soils that contain a predominance of the more highly charged cations such as Ca^{2+} and Al^{3+}. Soils with a relatively high percentage of the cation exchange sites dominated by sodium tend to have structure that is unstable. In these circumstances, the soils are said to be sodic (if the ESP (exchangeable sodium percentage) >6) and peds will easily break down or disperse. This not only influences the positive attributes associated with good soil structure, but it also can reduce cane yield. Cane yield in the Burdekin region was reduced by 2.1 t/ha for every 1% increase in ESP above the critical value of 6. This condition can be improved by the application of calcium-containing amendments that need to be leached through the soil profile.

OCCURRENCE OF SOILS IN THE LANDSCAPE

Apart from being able to identify soil characteristics in the field and being aware of soil properties and processes, it is also important to know the location of different soils on the farm. Knowledge of the main soil type found in a particular block of cane and how it differs from adjacent soils will enable more informed decisions and better management of inputs. To do this, growers should refer to published reports and soil maps from the Queensland Department of Natural Resources (DNR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). However, the information would often be inconsistent with

Table 7. Growth restriction to sugarcane due to salinity ($EC_{1:5}$, dS/m)*.

Soil type	Degree of restriction			
	None	Slight	Moderate	Severe
Organic	<0.32	0.32 - 0.65	0.65 - 0.97	>0.97
Clay	<0.28	0.28 - 0.55	0.55 - 0.83	>0.83
Clay loam	<0.21	0.21 - 0.42	0.42 - 0.62	>0.62
Loam	<0.19	0.19 - 0.39	0.39 - 0.58	>0.58
Sandy loam	<0.19	0.19 - 0.37	0.37 - 0.55	>0.55
Sand	<0.14	0.14 - 0.28	0.28 - 0.42	>0.42

* From CRC Sustainable Nutrient Management in Sugarcane Production short course manual.

the identification of soils at the farm or block level, as scales used were mostly in excess of 1:50 000. An exception is the soil mapping that has been undertaken in the Herbert River District at a scale of 1:5000. Despite this paucity of soil maps at an acceptable scale, it is still possible for growers and their advisers to identify and manage agricultural inputs by identifying soil differences according to basic soil properties and predicting the occurrence of soil type according to the landscape. The sequence of soils about the same age that have been derived from similar or related parent material, but that exhibit different characteristics due to variation in topography and drainage, is called a catena. This can be illustrated by means of the following example:

Considering a hypothetical case of a landscape from a river to the crest of a hill (Figure 3), assumptions can be made about the types of soils in various positions up the slope. This is based on the knowledge that:

Alluvial soils are expected in active depositional sites.

Depressions or flat areas that are not well drained may give rise to waterlogged conditions particularly in subsoil horizons. This is referred to as a gleyed horizon containing mottled, or a predominance of, grey and blue/grey colours.

Where large quantities of leaf litter are present and drainage is restricted, peaty humic soils can occur.

A fluctuating water table and/or the presence of an impervious sub-surface layer will cause lateral drainage and possible bleached (light grey) or washed-out conditions.

In moderately drained conditions soil will often have yellow to brown colours.

Red soils are most likely in well-drained positions.

A soil sequence from the Herbert River District (Figure 4) illustrates this. In a similar way, the occurrence of soil types can be predicted in other areas and regions.

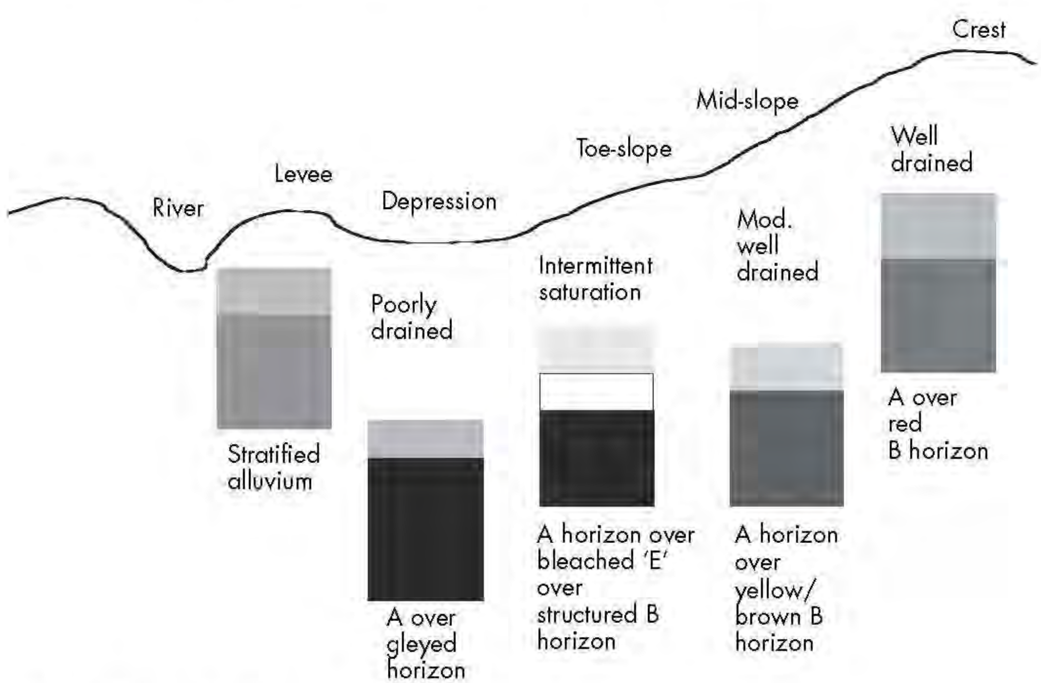


Figure 3. *An example of a catena.*

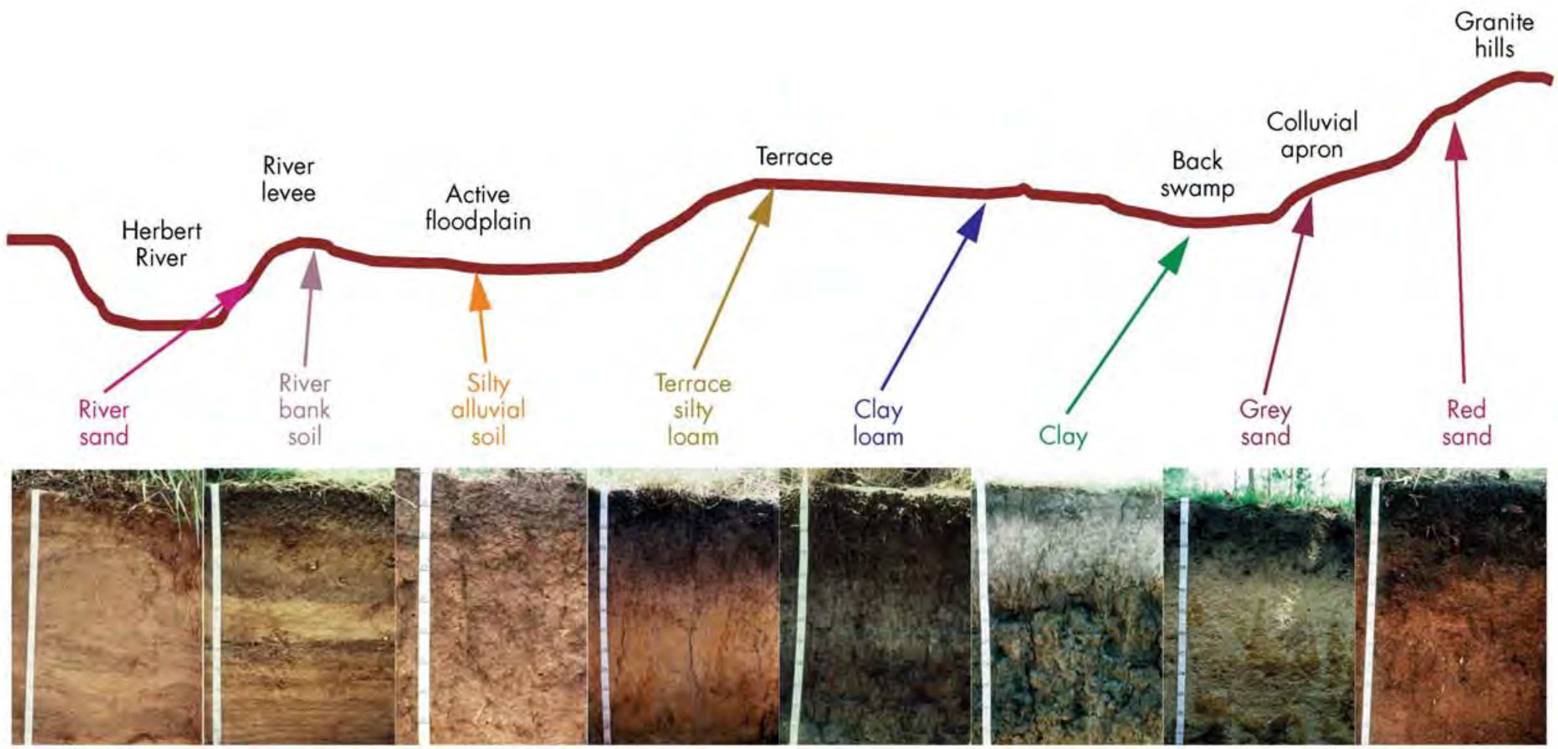


Figure 4. *A typical soil sequence in the Herbert River District (complied by A.W. Wood and B.L. Schroeder from photographs kindly supplied by P.R. Wilson, Queensland Department of Natural Resources).*

River bank soil

(a)

Field and chemical properties
- Found on river levees.
- Brown topsoil.
- Sandy loam surface horizon.
- Stratified alluvium in the subsoil that may range from a loamy sand to a clay loam, but generally described as having a yellow to yellow-brown colour.
- Weakly structured.
- Deeper than 1.2 m.
- Low to moderate CEC.

Implications for management
- Moderate to low N mineralising potential.
- Low to moderate nutrient status and storage.
- Low plant available water.
- Well drained.
- Easily worked.
- Productivity low in dry years.

Silty alluvial soil

(b)

Field and chemical properties
- Found on the active floodplain.
- Dark coloured, well structured topsoil.
- Fine sand or silty texture.
- High organic matter content.
- Weakly structured.
- Moderately high CEC.

Implications for management
- High N mineralising potential—reduced N rates needed.
- Moderately high natural nutrient status and storage capacity.
- Easy to cultivate, difficult to damage physically.
- Relatively high plant available water.
- Well drained, but prone to flooding.
- Sugarcane varieties suitable for 'richland' soils.
- Productivity high in most years.

Figure 5. *Soil types (a) River bank, (b) Silty alluvial from the Herbert River District showing field and chemical properties and implications for management (Compiled by A.W. Wood and B.L. Schroeder. Photographs supplied by P.R. Wilson, Queensland Department of Natural Resources).*

Clay

(c)

Field and chemical properties

- Found on terraces and back swamps.
- Moderate to dark brown, well structured topsoil.
- Silty clay topsoil.
- Grey to grey-brown mottled subsoil.
- Clay subsoil.
- Moderately high organic matter.
- High CEC.

Implications for management

- Moderate N mineralising potential.
- Well supplied with nutrients and high nutrient storage capacity.
- Imperfect drainage with seasonally high water table.
- Good surface drainage required.
- Moderate plant available water.
- Narrow moisture range for cultivation.
- Denitrification possible in wet years.
- Productivity high in dry years, but low in wet years.

Grey sand

(d)

Field and chemical properties

- Found on bottom slopes of granitic hills.
- Grey top soil.
- Pale grey to yellow subsoil.
- Coarse sandy loam texture.
- Subsoil often wet due to seepage from hills.
- Low CEC.
- Low organic matter content

Implications for management

- Low N mineralising potential—N to applied at highest recommended rate, splitting should be considered.
- Low to very low natural fertility.
- Poor internal drainage, sub-surface drainage needed.
- Low plant available water.
- Productivity low in most years.

Figure 5. (continued) *Soil types (c) Clay and (d) Grey sand from the Herbert River District showing field and chemical properties and implications for management (Compiled by A.W. Wood and B.L. Schroeder. Photographs supplied by P.R. Wilson, Queensland Department of Natural Resources).*

IMPLICATIONS FOR MANAGING SOILS ACCORDING TO THEIR PROPERTIES

It is important that on-farm management reflects the differences in soil type that have been explained above. Selected soils from the soil sequence in the Herbert River District (Figure 4) are shown in Figure 5 to illustrate how soil field properties can be used to highlight important implications for good soil management.

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