KNOW YOUR SOILS

Part 1

Introduction to Soils

Centre for
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Natural Resources and Environment

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KNOW YOUR SOILS

Part 1 **Introduction to Soils**

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Agriculture Victoria - Bendigo

Centre for Land Protection Research

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PREFACE

The soil is the lifeblood of your crop or pasture. This important asset supplies nutrients, water and oxygen to plants, supports machinery and animal traffic, and provides a medium for the decomposition of crop and pasture residues.

Soil management will affect land productivity and environmental sustainability. Maintaining the health of your soil to maximise productivity will require an awareness of soil characteristics and how they should be managed.

Farms may have a variety of soil types that require specialised management to optimise productivity and prevent land degradation. Different soil types occur for a variety of reasons, such as different geology, position in the landscape and drainage.

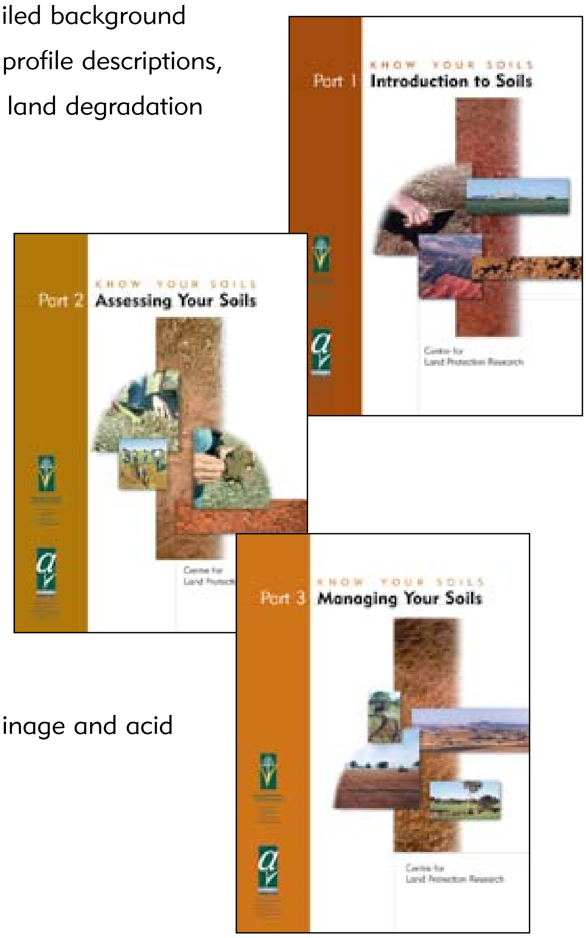
This booklet is the first in a series of three booklets called 'Know Your Soils'. The three booklets provide an easy and informative way for you, the farmer, to assess and understand your soil.

All three booklets are inter-linked and should be used together to achieve an understanding of the way your soil behaves and how it should be managed.

Part 1: Introduction to Soils - This booklet provides detailed background information on soil, including soil forming processes, soil profile descriptions, physical characteristics of soil, and soil management and land degradation issues.

Part 2: Assessing Your Soils - This booklet details eight exercises for you to carry out to assess some characteristics of your soil. The topics covered include: soil classing, the hole, soil colour and depth, stone size and percentage, soil texture, friability, soil slaking/ dispersion and soil pH.

Part 3: Managing Your Soils - This booklet allows you to use the information you have collected in Part 2, to interpret the behaviour and physical characteristics of your soil. Part 3 also provides management options for some limitations such as poor structure, poor internal drainage and acid soils.



When used together, all three booklets provide you with a logical way of assessing the characteristics of your soil, and most importantly, enable you to gain an understanding of your soil and how to manage it better.

You can use the 'Know Your Soils' booklets to monitor changes in the condition of your soil over time. Part 2 will help you describe your soil and Part 3 will assist you in understanding and managing your soil.

It is recommended that you do not use this series as a 'one off'. The routine use of 'Know Your Soils' every three to five years will allow you to observe patterns and changes.

By assessing two or three paddocks each year you can develop baseline information for each paddock and then re-sample to start the monitoring process. If you intend to monitor paddocks, it is important to re-sample as close as possible to the original sampling point. Early detection of changes through regular monitoring will enable problems to be managed and even prevented. This will reduce the detrimental effects of soil degradation on productivity and the environment.

It is also a good idea to independently monitor the chemical conditions of your soil in conjunction with this series. This will help you manage the application of fertilisers and allow you to work out if you have any chemical problems.

In Part 3 you will identify limitations that can be managed. Limitations, such as subsoil acidification, are likely to change over time and are costly and difficult to treat. Monitoring pH, particularly at depth, will enable the early detection of subsoil acidification and provide an opportunity for prevention.

Recording sheets are located at the back of Part 2. These sheets will allow you to record the information you collect so you can refer to them when you re-sample. You can independently do the same with your chemical analysis.

Cross referencing between booklets

Each of the three booklets in the 'Know Your Soils' Series is numbered for ease of reference. All sections found in Part 1 have the prefix '1'. For example, 1.1 Introduction to Soil and 1.5.5 Wind Erosion. Whereas 2.7 Soil Slaking/Dispersion Exercise is a practical activity found in Part 2; and Section 3.6 Determining Soil Drainage can be found in Part 3.

1.1 INTRODUCTION TO SOIL

1.1.1 SOIL AND AGRICULTURE

Agricultural viability depends upon a healthy soil. A healthy soil is obtained through knowledge of the soil and the application of appropriate management practices. Poor management practices can lead to soil degradation, which can reduce productivity. Soil is not a renewable resource. The loss of 1 mm of topsoil can take 3000 years to replace.

Soil has a number of functions important for agricultural production, these being:

- A medium for plant growth supplying and retaining nutrients, oxygen and water
- A medium for the decomposition of crop and pasture residues
- An anchor for plants
- A medium that should support machinery and animal traffic under most soil conditions without degradation.

Soil is essentially made up of four main fractions, but the fractions vary greatly in arrangement and form, hence soils can be physically and chemically quite different. Understanding why soil can be so varied, and how different soils require different management is important for an effective farming enterprise.

1.1.2 WHAT IS SOIL?

Soil is the unconsolidated outer layer of the Earth's crust. It appears in a variety of forms (different textures, colour, structure and nutrient content) depending on a number of factors outlined further in this booklet.

Although soil is highly variable, there are four main ingredients (fractions) that are consistent with all types of soil: mineral, organic matter, water and air. These four fractions fall into two categories: solid (mineral and organic matter) and non-solid (water and air).

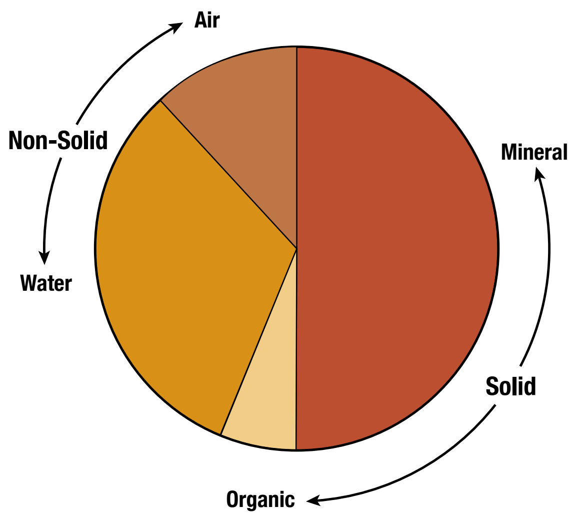


Figure 1 *Approximate proportions of the four soil fractions in a typical soil.*

The solid category

The solid category makes up approximately 50-70% by volume of the total soil and consists of the mineral and organic matter fractions. Combined, the mineral and organic matter fractions give the soil a characteristic known as texture.

i) Mineral fraction
   The mineral fraction makes up about 95-99% of the solid category. It is comprised of the weathered remains of parent rocks that are broken down over many thousands of years.

As the mineral fraction is such a large percentage of the total soil volume, the characteristics of soil are generally determined by the type of parent rock (geology) from which it was formed.

The mineral fraction is made up of four main particles that are defined by the diameter of the particle:

Gravel	> 2 mm
Sand	0.02-2 mm
Silt	0.002-0.02 mm
Clay	< 0.002 mm

The proportion of these particles plays an important role in the fertility of the soil and its response to management.

Clay particles are the smallest particles of the mineral fraction. They are an important component of soil as they have a negative electrical charge. This enables them to hold and exchange nutrients (which also have an electrical charge). Clay particles in soil provide an exchange site for plant nutrients. Clay soils are normally more fertile than sandy soils.

The type and quantity of clay in the soil can affect the amount of nutrients held for plant use and the ease at which these nutrients are released to the plant. The electrical charge on clay particles enables them to stick to other clay particles and also to sand and silt particles (this is the reason why clays are so sticky). This can be good and bad in terms of soil management as will be explained in Section 1.5 of this booklet: Soil Management and Land Degradation.

Gravel, sand and silt particles do not have an electrical charge and have minimal ability to hold and exchange plant nutrients. They do, however, have other important roles such as aeration of the soil. Gravel and coarse sand particles are larger than clay, silt and fine sand particles, and they have bigger gaps between them. Therefore more space is available for movement of water and air through the soil.

A good mix of sand, silt and clay particles will allow the soil to hold sufficient nutrients as well as allowing adequate exchange of air and water essential for plant growth.

ii) Organic matter fraction

Organic matter is the other part of the solid soil category. It consists of the remains of living organisms in various stages of decomposition as well as living micro-organisms. In agricultural soils in Victoria, organic matter can comprise up to 6% of the solid soil fraction however it is more common for agricultural soils to have between 0.5 and 3% organic matter. In forest soils, organic matter can comprise up to 20%.

Organic matter occurs in various forms from undecomposed to completely decomposed (humus), and all forms provide benefits for the soil. Like clay particles, humus is also electrically charged and is able to store and release nutrients. Humus is also able to increase the water holding capacity of the soil. This is particularly important for sandy soils which have a low water holding capacity.

Micro-organisms form the living component of the organic fraction. They feed on organic matter decomposing it to humus. Micro-organisms also live on products of living plants, some providing benefits to the plant, others creating disease. Most soil organisms decompose organic matter and release nutrients for plant growth as well as improving soil structure. Micro-organisms in the soil are important for soil health.

The non-solid category

The non-solid category can be divided into two fractions: water and air.

Water and air should comprise around 30-50% of an agricultural soil. This depends on the time of year and the soil type. Water and air are essential for plant growth. In particular, oxygen and carbon dioxide need to be exchanged between the soil and the atmosphere for root respiration to occur.

1.2 CHARACTERISTICS OF SOIL

There are three characteristics of soil that are important for plant growth and productivity: physical, biological, and chemical. A change in one characteristic is likely to affect another.

Physical

The aspects of the soil that you can see and touch. Physical charactersitics include: soil texture, soil colour, soil depth, soil structure, porosity (spaces between particles) and stone content. The role physical properties play in soil health are:

- To supply water and air to plant roots and allow adequate water and air movement into and through the soil profile.
- To store water for plant growth.
- To support machine and animal traffic.

Chemical

The ability to supply nutrients for plant growth and store nutrients in the profile without loss by leaching. The ability to keep clay aggregates chemically stable which impacts on soil structure.

Biological

The ability to support a healthy microbial population for organic matter breakdown (faeces and crop and pasture residues), nutrient cycling and the growth of nitrogen fixing bacteria.

1.2.1 PHYSICAL CHARACTERISTICS

Soil texture

As mentioned above, soils are partially made up of a mineral fraction (gravel, sand, silt and clay particles) and an organic matter fraction. It is these two fractions combined (minus the gravel particles) that give the soil a characteristic known as texture. There are many different texture grades depending on which particles (sand, silt, clay or organic matter) are dominant (if any). Soil texture provides a good way of characterising soils and can be described through the behaviour of a moist lump of soil when rubbed between your thumb and forefinger (refer to 2.5 Soil Texture Exercise). Some examples of texture and their characteristics are as follows.

Soils of one particle size

Sand -	Particles are visible to the eye, feels gritty and sand grains can be heard when rubbed. Sticks together only when moist e.g. beach sand.
Silt -	Particles not visible to the eye, feels silky (like talcum powder) and can be rolled when moist to form short rods. Sticks together when moist or dry.
Clay -	Particles not visible to the eye, feels smooth and plastic and can be rolled to form long rods when moist. Sticks together when moist or dry e.g. pottery clay.

Soils having a range of particle sizes and types

Loam -	About 20 - 25% clay with the remaining fraction composed of sand, silt and organic matter.
Sandy loam -	Loam with sand dominating.
Silt loam -	Loam with silt dominating.
Clay loam-	Loam with clay dominating.

Many other texture grades can be described and all differ due to the proportion of each primary particle size and the amount of organic matter. Soil textures are often referred to as light textured (sand dominant) or heavy textured (clay dominant).

The texture of the soil can change with depth. Obvious changes in texture through the soil profile can provide an easy way of assessing the different horizons (layers). Determining how the soil texture changes (if at all) at depth is important in understanding what plant roots have to contend with. In some cases the soil texture can differ markedly through the soil, ranging from a light texture (e.g. sandy loam) and changing abruptly into a heavy texture (e.g. clay). This is known as a texture contrast or duplex soil (refer to 1.3 Soil Profile). This could be a problem for some plants. The ideal situation for plants is gradational soils, that is a soil texture that gradually becomes heavier down the profile. Some soils do not change textures, that is, they are the same texture throughout the soil (uniform soil). If the soil is clay all the way down, it will often drain quite slowly, so plants that can cope with wet roots will grow best in this soil type. Soil that is sandy all the way down will drain very quickly and plants that can deal with dry conditions will be suited to this soil type.

Refer to 2.5 Soil Texture Exercise.

Water and nutrient holding capacity

In conjunction with soil depth and structure, the texture of a soil will determine the potential water and nutrient holding capacity. Sandy soils, due to their large primary particle sizes, have poor nutrient and water holding capacities. Clay soils, on the other hand, are able to hold high levels of nutrients due to electrical charges. Clay soils are able to hold more water but generally do not drain as well as sands.

The amount of water available to plants, known as Plant Available Water (PAW), depends on the texture and depth of the soil. Clay soils hold a lot of water but they hold onto water very tightly. Some of the water held in clay soils is therefore unavailable to plants. Table 1 indicates that although clay soils typically hold 280 mm of water over a one metre depth, only 70 mm of this water is available for the plants. That is, just 25% of the water held in the profile can be utilised by plants. Sands hold less water than clays and because they drain very quickly, only 10% of that water is available to plants.

Table 1 *The effect of soil depth and texture on plant available water holding capacity.*

Depth	Soil Water Holding			Plant Available Soil Water		
(cm)		**Capacity** (mm)		**Holding Capacity** (mm)		
	Sand	Sand to 10 cm over clay	Clay	Sand	Sand to 10 cm over clay	Clay
0 - 10	10	10	30	1	1	7
10 - 60	60	140	140	6	35	35
60 - 100	45	110	110	4.5	28	28

Refer to 2.5 Soil Texture Exercise.

Soil structure

The solid category of soil, which consists of individual particles (sand, silt, clay and organic matter) can cement together to form aggregates (also referred to as peds). (Refer to Figure 2).

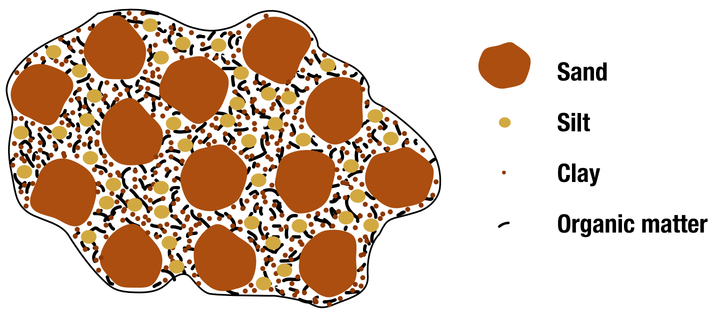


Figure 2 *Soil aggregate*

Sand, silt, clay and organic matter are cemented together by the clay particles and organic matter (due to electrical attraction). Organic matter is one of the major cementing agents for soil aggregates (particularly in topsoils) and one that is strongly affected by soil management.

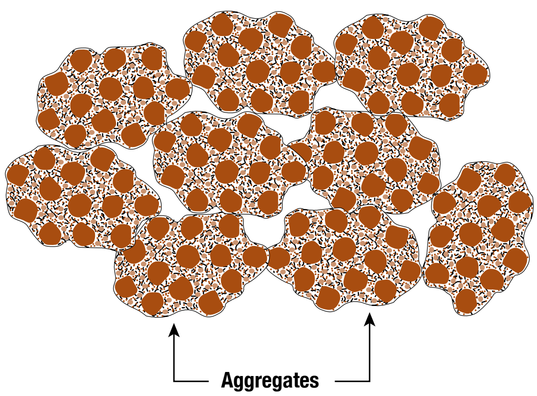


Figure 3 *Aggregates join together to give the soil a characteristic known as structure.*

Organic matter and clay also bind aggregates together. The arrangement of aggregates, along with their size and shape, gives soil a characteristic known as soil structure. (Refer to Figure 3).

Sandy soils do not tend to form aggregates and remain as primary sand particles with poor structure. Soils that have enough clay and organic matter to bind the soil particles together to form many small aggregates have good structure. (Refer to Figure 4).
Refer to 2.5 Soil Texture Exercise or 2.6 Friability Exercise and 3.5 Establishing Soil Structure.

Aggregates held together by clay particles that are unstable in water can be very weak and may collapse when wet or over cultivated to form larger aggregates or clods. Good soil structure should have clays that remain stable in water. (Refer to Dispersion on page 10 of this booklet and 2.7 Soil Dispersion/ Slaking Exercise).

Soil structure is important as it affects the movement of water and air through the soil, the growth of plant roots through the soil and the risk of degradation (such as erosion). Refer to 2.6 Friability Exercise and 3.5 Establishing Soil Structure.

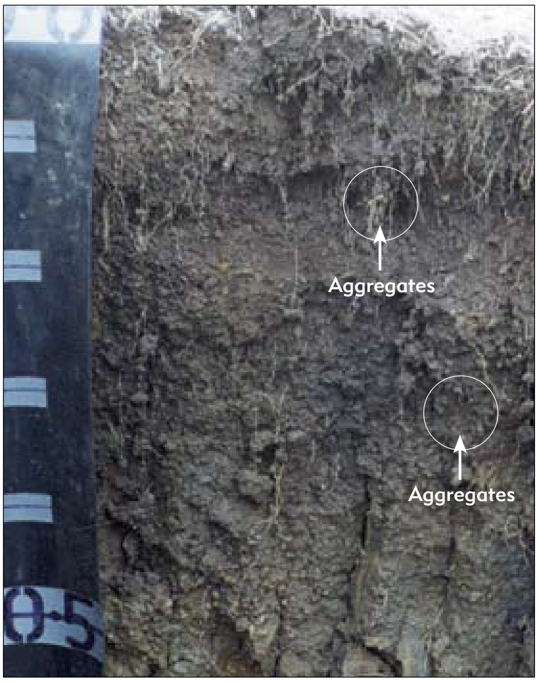


Figure 4 *Many small aggregates in the top 0.5 m of the soil means there are many macropores therefore roots are able to move freely within the soil.*

Porosity

Spaces or pores within and between aggregates can be either filled with air or water. The number, size and shape of the pores determines the amount and rate at which water and air can move into and through the soil, and also the amount of water held in the soil. Pores can be divided into two main classes based on the diameter.

Macropores - Macropores occur between the soil aggregates. They are responsible for the rapid movement of air and water into and through the soil but are not filled with water at low to moderate soil moisture contents. Because of their size, roots grow through macropores. These pores are normally greater than 0.1 mm in diameter.

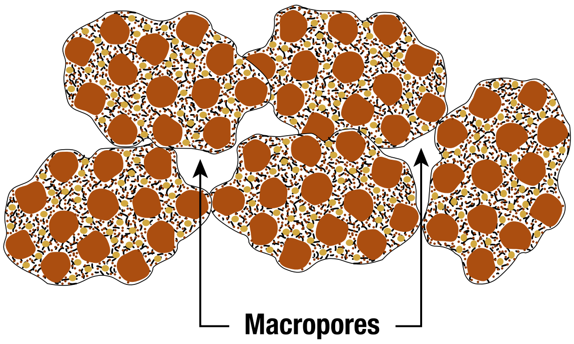


Figure 5 *Macropores between soil aggregates.*

Micropores - Micropores occur within the soil aggregates. They are the spaces formed between the sand, silt, clay and organic matter particles. Micropores are responsible for the water holding capacity of the soil and are the principal site for water extraction by roots. These pores are normally less than 0.1 mm in diameter.

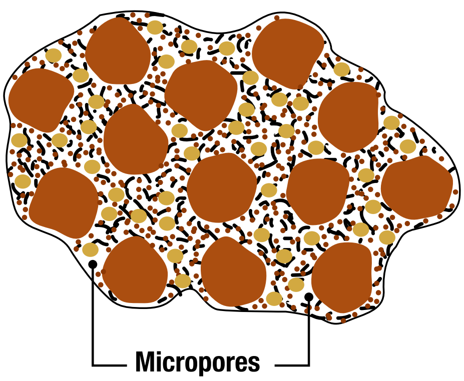


Figure 6 *Micropores within a soil aggregate.*

A well structured soil requires a combination of both macropores and micropores. Too many macropores will allow water to move easily into and through the soil, however very little water will be held for plant use. Sandy soils tend to have a greater percentage of macropores than silty soils or clays. This means sandy soils are well drained but unable to hold a great deal of water for plant use. Too many micropores will not allow enough water and air to move into or through the soil freely, resulting in runoff or drainage problems. Clayey soils generally have more micropores than macropores and are able to hold more water for plant use but are not as well drained as sandy soils.

Figure 7 *Very few aggregates means there are very few macropores, therefore roots will have difficulty growing in the soil.*

Soil structure is roughly determined by the texture of the soil although land management also has an important role to play. If a clay soil becomes waterlogged due to poor drainage, not enough air will exchange between the soil and the atmosphere. Plants may suffer as a consequence of the lack of oxygen to their roots. In comparison, plants growing in a sandy soil will generally show water stress faster than similar plants growing in a clayey soil. Refer to 2.6 Friability Exercise and 3.5 Establishing Soil Structure.

Refer to 2.7 Soil Slaking/Dispersion Exercise; also 3.5 Establishing Soil Structure and 3.6 Determining Soil Drainage.

Slaking

Figure 8 *Slaking*

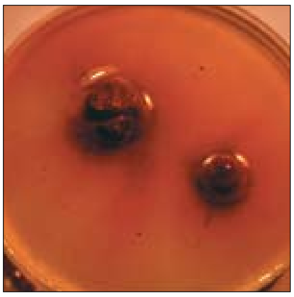


Figure 9 *Complete dispersion*

Unstable or disturbed soil aggregates will often slake or slump when wet. Slaking occurs when dry soil is wet rapidly. Water enters the soil aggregate through capillary action and traps air inside. The air pressure inside the aggregate increases. If the air pressure inside the aggregate is stronger than the strength of the aggregate, the aggregate will begin to disintegrate into micro-aggregates (slake). A strong aggregate will withstand the pressure and this is a sign of good soil structure. Soil deficient in organic matter will have weak aggregates. Slaked aggregates will block macropores, decrease the movement of water and air into and through the soil, and create crusts and hard-setting soils.

Dispersion

Dispersion is the structural breakdown of soil aggregates in water into the individual soil particles (sand, silt and clay). This is evident in a muddy puddle or dam where dispersed clay particles are suspended in water. Dispersed clays can block micropores and macropores and result in structural damage to the soil. Clods, surface seals or hardpans are often found in soil with dispersable clay.

The behaviour of the clays when wet depends on which positive ions (sodium, calcium or magnesium) dominate. Dispersion is a chemical process in which the negatively charged clay particles react with positively charged sodium ions in the soil. Clay particles dominated by sodium ions will often disperse in rainwater.

Soils with more than six percent sodium attached to the clay are known as sodic and may have soil structure problems as a result. To improve soils with dispersable clays, sodium can be replaced by calcium, to flocculate clay. Flocculation is when the clay particles join together to form relatively stable small aggregates. Calcium is the active ingredient in gypsum and will flocculate the clay particles to form stable aggregates. Over time, the calcium in gypsum is leached to lower soil layers or removed with the crop or pasture. The addition of further gypsum may be required. Gypsum is only effective in treating soil structure problems resulting from dispersed clays. The action of plant roots and micro-organisms will also flocculate clay particles to form aggregates. This is a slow process and disruption of the aggregate due to tillage or trafficking will allow the clay particles to disperse again.

Sodic soils should not be confused with saline soils. Sodicity refers to the exchangeable sodium cations held on the surface of clay particles. The higher the percentage of sodium compared to the other exchangeable cations, the more sodic the soil is. Salinity, on the other hand, refers to the total amount of salts dissolved in soil solution.

Many subsoils in Victoria are clays that exhibit clay bonding as the principal form of aggregate adhesion. Many of these subsoils have dispersive clays that can be difficult to manage. The addition of gypsum at the soil surface will slowly leach through to the subsoil over time. Plant root growth and the associated action of micro-organisms will assist dispersive clay subsoils over time and is likely to be more effective in improving soil structure than gypsum.

Refer to 2.7 Soil Slaking/Dispersion Exercise.

Soil colour

Soil colours are related to chemical properties, aeration or drainage, and organic matter. Soil colour is an important characteristic of the soil as it can provide an indication of the soil's drainage characteristics. Soil colour may also help you determine the different horizons of the soil.

Red colours suggest the presence of unhydrated iron oxides that are an indication of good drainage and aeration. Generally water can drain quite quickly through the profile of red soil and oxygen can therefore be stored in the macropores.

Brown soils usually have reasonable drainage. The brown colour is often (but not always) an indication of high amounts of organic matter.

Yellow soils have inadequate drainage. The yellow colour usually indicates that the soil remains saturated and is therefore starved of oxygen for periods of several weeks after rainfall. Yellow soils may also have a perched watertable.

Soils with grey subsoils are poorly drained, generally remain wet, and are starved of oxygen for many months, usually all winter. Subsoils of this colour often have a perched watertable and may have a green or bluish tinge often referred to as 'gleyed'.

Black soils can indicate high organic matter content or a high clay content. Black clay soils can have variable drainage characteristics ranging from moderately well drained to poorly drained.

Light coloured soils (particularly topsoils) are an indication that soil has been strongly leached of nutrients (iron oxides, aluminium and organic matter) which have been moved by water to a lower layer. The pale or white colour is commonly referred to as 'bleached' and usually only occurs as a layer of the soil, that is, there may be a brown layer, a pale layer and then a yellow layer. A pale layer is an indication that the soil is inadequately drained. A pale layer usually occurs when there is a problem below (usually a clayey subsoil) which stops water moving through the subsoil. The saturated soil causes anaerobic conditions (no oxygen) which change the chemistry of the soil. This change allows the chemicals in the soil (that gives the soil its colour), to become more soluble in water and therefore able to be leached from the soil. Refer to 1.3 Soil Profile.

Some soils may have splashes of bright colour (mottles) throughout the soil, particularly at depth. Mottles are usually bright patches of red, orange or yellow on a yellow, brown or grey background. Mottles indicate that the soil is inadequately drained. The colours are formed when the subsoil periodically becomes saturated and then dries out.

Refer to 2.3 Soil Colour and Depth Exercise; along with 3.6 Determining Soil Drainage.

Soil depth

The depth of a soil is a major factor in determining the quantity of water and nutrients that can be stored for plants and micro-organisms. Plant growth in shallow soils is limited by water storage and may not sustain agriculture (See Table 1 in this booklet).

Refer to 2.3 Soil Colour and Depth Exercise and 3.3 Assessing Total Soil Depth.

Stone content

Stone is a general term used to describe any hard material in the soil profile greater than 2 mm in diameter. Stone content will reduce the water and nutrient holding capacity of soil and limit its use for cropping because of cultivation difficulties. Specific names are sometimes given to the different sizes of stone as described in 2.4 Stone Size and Percentage Exercise.

Some stones occur in the soil as part of the weathering process. That is, they are remnants of the broken down bedrock. Other stones occur in the soil due to poor drainage and are commonly known as 'buckshot'. The presence of buckshot is an indication that there is (or was) a perched watertable. Buckshot is formed within the soil, (that is they are not transported). When the soil has been saturated, but the watertable has receded and the soil dries out, iron and manganese are left behind in the soil and form buckshot. You will often find buckshot in association with the pale horizon (A2 horizon), and the subsoil will often be yellow or grey with mottles throughout.

Refer to 2.4 Stone Size and Percentage Exercise; also 3.4 Assessing Stone Content and 3.6 Determining Soil Drainage.

1.2.2 CHEMICAL CHARACTERISTICS

Nutrients

Soil nutrients are mostly obtained from the weathering of parent materials and are therefore a limited reserve. Plant nutrients can also be added to the soil from the atmosphere. Some nutrients may be dissolved in rainfall and gaseous nitrogen is converted to solid mineral nitrogen by micro-organisms such as the rhizobia growing in the nodules on legume roots (e.g. peas, lupins, clover and lucerne). In the natural environment nutrients are cycled between the vegetation and the soil and few nutrients are lost from the system. These systems of nutrient inputs are normally sufficient to sustain vegetation. In productive agricultural systems however, these sources are not sufficient to supply all of the nutrients required by crops and pastures. Additional nutrient inputs through fertilisers are required.

Whenever grain, stock or wool is removed from a paddock, nutrients that were stored in the soil are exported. Nutrients removed need to be replaced, or the practice of farming will not be sustainable. Nutrients such as phosphorus, nitrogen, sulphur and zinc are some of the more common elements that are applied in the form of fertiliser. Without the addition of nutrients, the availability of nutrients for plant growth would be less than optimal and productivity would decline (Refer to Table 2).

The importance of plant nutrients can be based on the quantities required for adequate plant growth. The most important are macro-nutrients (required in larger quantities) which include nitrogen, phosphorus, potassium (potash), sulphur, magnesium and calcium. The other elements are classed as micro-nutrients (required in smaller quantities). One of the most common micro-nutrients in use is molybdenum. Any nutrient that is deficient has some effect on plant growth and may require only a small quantity to rectify the deficiency (for example a matchboxful per hectare for micro-nutrients).

Table 2 *Nutrients (kg) removed from the soil per tonne of production (Source: Pivot Fertilisers).*

Crop or Pasture (per tonne)	**Nitrogen** (kg)	**Potassium** (kg)	**Phosphorous** (kg)	**Sulphur** (kg)	**Calcium** (kg)
Wheat	21	5	3	1.5	0.4
Lupins	51	9	4.5	3	2.5
Canola	40	9	7	10	4
Pasture	30	15	3	2	9
Wool	1	0.1	0.02	0.2	-

Nutrients can also be lost from the soil through leaching below the rooting zone, and the burning of stubbles. Leaching removes water-soluble nutrients such as nitrate, while burning can remove nutrients via smoke. Burning can mineralise organic phosphorus bound in organic matter that would normally take many months to become available for plant use via decomposition by micro-organisms. This gain does not, however, outweigh the loss of nitrogen and other nutrients to the atmosphere through burning.

Soil pH

Soil pH is a measure of acidity or alkalinity. A pH of 7 is neutral, above 7 alkaline and below 7 acid. Natural water should have a pH of 7. Because pH is measured on a logarithmic scale, a pH of 6 is 10 times more acid than a pH of 7 and a pH of 8 is 10 times more alkaline than a pH of 7 etc.

Soil pH can be measured either in water or in calcium chloride and the pH will vary depending on the method used. As a general rule, pH measured in calcium chloride is 0.7 of a pH unit lower than pH measured in water. Soil pH can change from season to season and the water method reflects these changes more so than the calcium chloride method. When a laboratory measures your soil's pH it is important that they specify which method (water or calcium chloride) was used.

The pH of soil is important for normal plant development. The soil must contain all of the essential elements in an available form and each element must be present in particular concentrations to achieve a balance. Changes in the soil pH level can affect this balance and the availability of plant nutrients. For example, low pH levels can make aluminium more available to such an extent that it becomes toxic to some plants. The ideal pH for growing plants is between 6.5 and 7 (water). The extremes for pH (water) are 4 for acid soils and 10 for alkaline soils (Refer to Table 3).

Soil pH can affect the type and productivity of the plants grown. Lucerne, for example, grows poorly on soils with a low pH (acid) due to the increased availability of aluminium and manganese. The impact of pH will depend on the quantity of the toxic nutrients in the soil. Soil tests are useful to indicate possible toxicities. Table 4 gives a generalised pH range for some common agricultural plants.

Acid soils can have their pH increased (made less acid) through the addition of lime. Lime is an alkaline substance and can neutralise the acidity. There is no economic treatment for decreasing pH on alkaline soils. The rate at which the pH of an acid soil will alter with lime application depends upon the soil texture and the amount of organic matter. The amount of lime required to change the pH of soil is dependent on the soil texture and is referred to as the buffering capacity. Acid sandy soils require less lime to increase the pH than do acid clay soils. Clay soils generally have a high buffering capacity, that is more lime is required to alter the pH by one unit compared with sandy soil. However, the effect of lime will be short-lived on sands compared with clays due to leaching of lime through the sand. Agricultural practices have an acidifying effect on soils, and clay soils tend to take longer for agriculture to decrease the soil pH than sandy soils because of clay's higher buffering capacity.

Refer to 2.8 Soil pH Exercise and 3.7 Interpreting pH.

Available and unavailable nutrients

The availability of nutrients for plant growth depends upon the form in which the nutrients exist in the soil (mineral form or organic form). Nutrients in mineral form exist as elements, whereas nutrients in the organic form are associated with organic compounds produced by plants, animals or micro-organisms. Plants can only take up nutrients in mineral form and rely on the action of micro-organisms to change organic nutrient forms into mineral nutrient forms. This process is known as mineralisation and relies on an active microbial population. The majority of nutrient mineralisation occurs in the top 10 cm of the soil due to the high concentrations of organic matter and oxygen in that layer. Mineralisation occurs mostly during late autumn and spring when the soils are wet and warm.

Table 3 *The general effect of soil pH (water) on some plant nutrients where ⇩ indicates decreasing nutrient availability, ⇦⇨ indicates equal nutrient availability and ⇧ indicates increasing nutrient availability.*

	Soil pH						
Plant Nutrient	**Strongly Acid** 4.0-5.0	**Medium Acid** 5.0-6.0	**Slightly Acid** 6.0-6.5	**Neutral** 6.5-7.5	**Slightly Alkaline** 7.5-8.0	**Medium Alkaline** 8.0-8.5	**Strongly Alkaline** 8.5-10.0
Nitrogen	⇩	⇩	⇦⇨	⇦⇨	⇦⇨	⇩	⇩
Phosphorous	⇩	⇩	⇦⇨	⇦⇨	⇩	⇩	⇧
Aluminium	⇧	⇧	⇧	⇦⇨	⇦⇨	⇩	⇩
Molybdenum	⇩	⇩	⇩	⇦⇨	⇦⇨	⇦⇨	⇦⇨
Sulphur	⇩	⇩	⇦⇨	⇦⇨	⇦⇨	⇦⇨	⇦⇨

An opposite process to mineralisation can occur, known as immobilisation. Immobilisation is the process where plant available mineral nutrients are made unavailable, normally by micro-organisms. That is, the mineral nutrients are returned to an organic form. Micro-organisms in the soil require mineral nutrients similar to those required by plants. Micro-organisms and plants sometimes compete for mineral nutrients. This is particularly noticeable following the incorporation of stubbles or pasture residues into the soil. The micro-organisms are provided with a food source (carbon in the organic matter) but require other nutrients such as nitrogen and phosphorus to decompose the organic matter. These nutrients are temporarily tied up in the microbial population and are unavailable for use by plants. As the organic matter decomposes, nutrients become available for plant use. Nutrients in the microbial population are not lost, they are just temporarily unavailable.

Table 4 *Preferred soil pH (water) range for a number of common crop and pasture species.*

Crop or Pasture	pH Range
Wheat	5.5 - 9.0
Barley	6.0 - 9.0
Oats	4.5 - 8.5
Triticale	4.5 - 8.5
Lupins	5.0 - 6.5
Peas	6.0 - 8.0
Canola	6.0 - 7.5
Ryegrass	5.5 - 7.0
Phalaris	6.0 - 8.0
Cocksfoot	5.0 - 7.5
Lucerne	6.0 - 8.0

Nutrients in mineral form can be lost from the system due to leaching or being tightly bound to clay and other soil components. As discussed above, soil pH will affect the quantity of mineral nutrients fixed to soil particles. Nitrate, the available form of nitrogen, can be easily leached from the soil if excess water moves through the soil profile. Leached nutrients are normally lost unless deep rooted plants are grown. Much of the phosphorus when added to the soil as superphosphate becomes bound to clays in the soil, fixed in an unavailable form, and becomes available slowly over a period of time (often months to years).

Most nutrients applied as fertilisers for agriculture are in mineral form and are readily available to plants. Depending on the soil pH and soil type, some nutrients applied through fertilisers will become fixed to the soil particles, others may be easily leached, particularly on soils low in clay and organic matter. Nutrients can also be applied in the organic form although this is more common in the home garden situation. Compounds such as blood and bone, manures, compost and fish meal are all organic fertilisers and are known as slow release fertilisers due to the mineralisation required by micro-organisms to convert the organic form of nutrients into the plant available mineral form.

1.2.3 BIOLOGICAL CHARACTERISTICS

Soil micro-organisms and roots make up the biological component of soil and affect both the chemical and physical characteristics of a soil. Micro-organisms are responsible for the breakdown of plant residues and can control the nutrients released during decomposition. Under high residue loads, micro-organisms can tie up plant available nutrients to increase their own population. Nutrients are tied up in the microbial population until such a time that residue levels are decreased and the nutrients then become available for plants. Using this system, micro-organisms can hold nutrients such as nitrate in an organic form and prevent leaching below the root zone.

Roots and soil organisms (which include earthworms and fungi) are able to stabilise soil aggregates with compounds excreted from their cells. These compounds are able to stick micro-aggregates together to form water stable macro-aggregates. Roots and earthworms form stable channels through the soil which are known as biopores. These have the same characteristics as macropores. In addition to forming channels, earthworms are able to cycle nutrients and organic matter through different parts of the soil profile.

Earthworms feed on soil organisms and root exudates. Earthworm activity is concentrated in the root zone when soils are moist. As soils dry over summer, earthworms burrow down through the profile. Following the autumn break, they burrow back to the surface. Not all soils host earthworms and there is still debate as to acceptable earthworm numbers.

1.3 SOIL PROFILE

1.3.1 WHAT IS A SOIL PROFILE?

A soil profile is a three-dimensional section of the soil and consists of various horizontal layers (horizons). The physical, chemical and biological characteristics of soil can vary significantly down the soil profile. Different horizons arise from different soil forming factors, drainage regimes and management and result in a great variance in the appearance of soils. Describing the characteristics of a soil profile will assist you to differentiate one soil type from another.

Soil horizons

A horizon is defined as an individual layer within the soil profile. Every soil profile consists of at least one horizon. Horizons can be divided into broad groups known as the topsoil, subsoil and rock. The topsoil consists of the 'A' horizon(s), the subsoil consists of the 'B' horizon(s) and the rock consists of the 'C' horizon and/or an 'R' horizon. Sub horizons can exist within these broad groups.

Topsoil	
A0 horizon	Decomposing crop and pasture stubble.
A1 horizon	Most organic horizon. Usually darker in colour than the lower part of the profile. Zone of maximum biological activity.
A2 horizon	Similar texture to the A1, lighter in colour (often referred to as 'bleached'), less organic matter and less biological activity. This horizon does not always occur.
Subsoil	
B1 horizon	This horizon is a transition between the A horizon and the B2 horizon. It has more characteristics similar to the B2 horizon than the A horizon. This horizon does not always occur.
B2 horizon	This horizon is usually the area of most clay accumulation and strongest colour. It may have mottles (splashes of bright colour).
Rock	
C horizon	Weathered parent material (rock or unconsolidated material) little soil development and sometimes too deep to observe.
R	Solid rock that varies in depth. May be close to the surface or may be too deep to observe.

Figure 10 *Generalised soil horizons*

Various combinations of the above characteristics may exist in different profiles, for example:

A1 horizon

B1 horizon

B2 horizon

C horizon

Figure 11 *Soil profile showing A1, B1, B2, and C horizons.*

A1 horizon

A2 horizon

B2 horizon

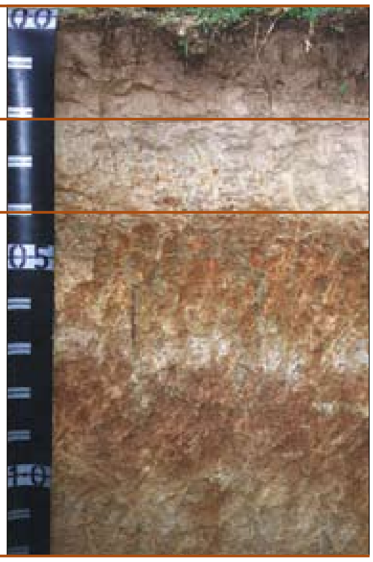


Figure 12 *Soil profile showing A1, A2 and B2 horizons.*

Soil colour

Distinct changes in colour throughout the profile can assist in differentiating the different horizons. The surface (A0 and A1) horizons are usually darker in colour than the horizons directly below, due mainly to higher levels of organic matter.

A 'bleached' A2 horizon may occur below the A1 horizon that is characterised by a pale or white colour. This horizon commonly occurs above a clayey subsoil that restricts water movement. Water accumulates in the topsoil until it can percolate through the subsoil. This causes leaching of the organic matter and other soil colouring compounds out of the topsoil, giving it a pale appearance.

The subsoil is often stronger in colour than the topsoil and may exhibit 'mottles' which are splashes of bright colour. Mottles occur when the subsoil remains wet for quite some time, leading to the soil being starved of oxygen. Mottles usually occur in conjunction with an A2 horizon and they rarely occur in the topsoil.

Soil texture

The texture of the soil can differ from the topsoil to the subsoil. In some cases there is a strong texture difference between the topsoil (e.g. sandy loam) and the subsoil (e.g. heavy clay). Assessing the changes in texture throughout the profile can assist you in understanding how the soil functions.

Types of soil profiles

Soil profiles can be divided into three classes according to the level of texture change vertically down through the soil profile. The nature of the soil profile is another feature used in soil classification that divides soils into three groups: Uniform, Gradational and texture contrast (Duplex).

Uniform - Profiles feature minimal texture difference. No clearly defined texture boundaries can be found. Clay loam, for example, may continue from the topsoil (A horizon) down to the subsoil (B horizon). The grey soils of the Wimmera are uniform and show clay texture in the topsoil and subsoil.

Figure 13 *Uniform soil profile*

Gradational - Profiles show a gradual increase in clay down the profile such that each successive horizon passes gradually from one to another. These soils are usually good cropping soils. Some of the red soils around Ballarat and Warragul fall into this category.

Figure 14 *Gradational soil profile*

Texture contrast - Profiles with a significant texture difference between the topsoil and the subsoil. Commonly, the texture becomes abruptly more clayey in the transition from the topsoil to the subsoil. The red soils of northern Victoria and some Mallee soils are predominantly texture contrast soils with a sand, silt or clay loam topsoil over a medium to heavy clay subsoil. The significant change in texture between the topsoil and the subsoil can often lead to structural problems with the subsoil impeding water and air movement and root growth.

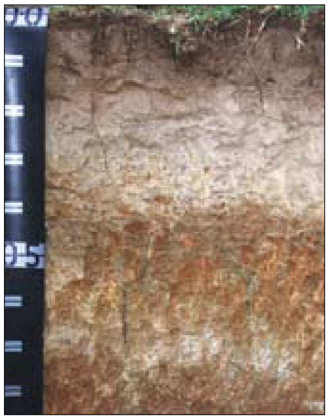


Figure 15 *Texture contrast soil profile*

Leaching

Leaching is the movement of water soluble soil material down the profile. Nutrients can be lost through leaching and may end up in waterways, increasing the risk of algal blooms. Over very long periods, clay particles may move down the profile leaving silt and sand particles behind. This is evident in gradational soils and highlighted in duplex soils that have a high concentration of clay particles in the subsoil. Organic matter in the form of humus can also be leached. This mostly occurs in the topsoil due to the smaller quantities produced. Silica, iron and aluminium oxides are also susceptible to leaching. The leaching of clays, organic matter, silica, iron and aluminium is a very slow process occurring over hundreds to thousands of years.

Soluble ions (plant nutrients) can be easily leached out of the profile, particularly in sandy soils. This is the reason why strongly leached sandy soils are infertile. The rate at which compounds are leached from the soil depends on the soil type, permeability, rainfall and evaporation.

Calcium deposits in the form of carbonate, lime or gypsum occur when leaching is relatively weak. If rainfall does not often drain from the soil profile, deposits are built up at the depth to which water normally accumulates. Many soils in northern and north-western Victoria have lime deposits at depth as a result of leaching.

Soil pH is also affected by leaching processes. Soils formed in areas of high rainfall generally have an acid pH due to the leaching of alkaline materials from the soil over thousands of years.

Plant growth

The topsoil is the principal soil zone for water and nutrient uptake by plants, though plant growth will be limited if this is the only zone exploited by plant roots. Roots can be restricted from entering the subsoil due to the formation of a hard pan (compact soil layer) at the junction of the topsoil and subsoil. The presence of an A2 horizon and mottles indicate that roots may not grow deep into the subsoil. Plant roots that do grow into the subsoil have better access to water and are likely to be more productive and better able to withstand dry seasons.

Plants such as perennial grasses survive the summer because their roots grow down into the subsoil. Soil management practices that enable plant roots to explore the whole of the soil profile for water and nutrients will lead to increased productivity and sustainability. Understanding some of the processes that form different soil horizons will assist you to manage your soils for optimal performance.

1.4 SOIL FORMATION

The major factors involved in soil formation are: parent material (geology), climate, topography, biological activity and time.

The diverse array of soils occurring in Victoria are attributed to the variability in geology and topography, the variable climate (rainfall and temperature), biological activity (linked to plant, animal and human activity) and the length of time soil has had to develop.

1.4.1 SOIL FORMATION FACTORS

Geology

The mineral composition and grain size of the parent material strongly influences the type of soil formed. Basalt rocks, which underlie much of the Western District, have large quantities of materials available for clay formation and tend to form clay soils. Sandstones have more siliceous minerals and are low in clay forming materials and therefore tend to form sandy soils. Granites have both sand and clay forming material and may form sandy and clayey soils.

The transition from bedrock to soil relies heavily on the type of parent material and the surrounding climate. Some primary minerals such as quartz resist weathering and remain in the soil, often as sand or gravel. Soil formed on granites has quartz occurring as coarse sand or gravel, predominantly in the unweathered state whilst the rest of the granite has weathered.

Soils can form from the bedrock material lying directly below or from material transported from elsewhere. Soils occurring along river and creek valleys are derived from material transported by water. The soils on the northern Riverine Plain have developed on materials transported by water. Some soils in the Mallee and Wimmera and coastal dunes have developed from wind blown material.

Climate

Rainfall and temperature influence the amount of water available for the weathering of parent material rock to form soil.

High rainfall and high temperatures increase the rate of weathering, therefore soils formed in this environment tend to be deep. Low temperatures and rainfall reduce rock weathering, resulting in shallow soils with increased rates of organic matter accumulation. Dry climate periods can result in soils being blown by winds and deposited in other locations.

Biological activity

Plants add organic matter and support life within the soil. Plants and soil organisms play an important role in soil structure and nutrient cycling. Human and animal activity has a big impact on soil formation through activities such as burning and clearing land and changing native ecosystems.

Time

The length of time a soil has had to form is important. The older the soil the more nutrients and clay materials may have been leached to deeper soil depths or leached away completely. Refer to 1.3 Soil Profile.

Topography

Topography influences the rate of water runoff and hence the amount of water infiltrating the soil. It also affects drainage and the likelihood of soil being transported (eroded) from steeper areas to flatter areas. Well drained soils typically occur upslope, and there is generally an accumulation of water and transported material on lower slopes and in depressions due to erosion over thousands of years.

The landscape sequence illustrated in Figure 16 shows the relationship between slope and soil type. This sequence is not always obvious.

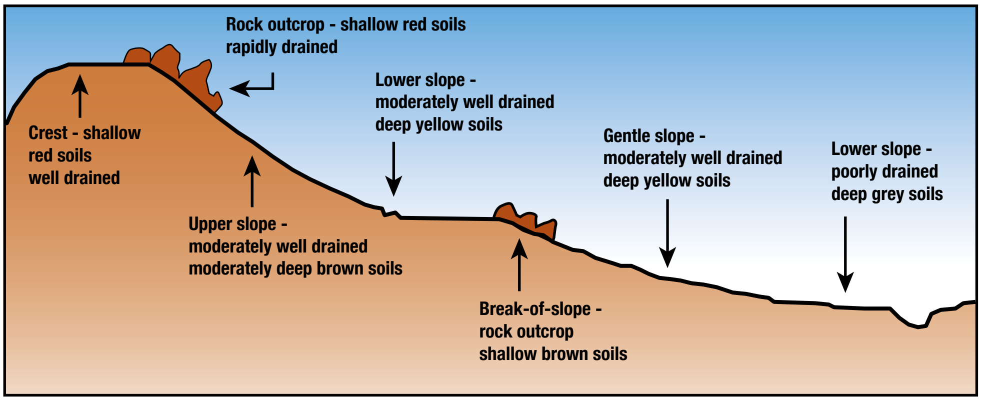


Figure 16 *Common landscape sequence in northern Victoria.*

The position in the landscape will influence the depth of the soil and the drainage capacity. Soils located close to the top of rises are generally shallower and drain better than the deeper soils located near the bottom of slopes. Erosion events over thousands of years are responsible for the transportation of soils from upper slopes to depressions. Soils lower in the landscape are therefore likely to be more fertile.

1.5 SOIL MANAGEMENT AND LAND DEGRADATION

Chemical, physical and biological characteristics of soil are dynamic as they can change over time. Under pre-settlement conditions these characteristics changed very slowly but, following clearing, the change in land management has detrimentally altered some soil properties leading to soil degradation. In Victoria, the major forms of soil degradation have been soil structure decline, wind and water erosion, nutrient decline, acidity, salinity and mass movement of soil.

1.5.1 SOIL STRUCTURE DECLINE

Soil structure decline is the breakdown of natural stable soil aggregates into smaller, unstable aggregates. Small aggregates will block macropores and are likely to slake and disperse (refer to 1.2.1 Slaking and Dispersion), causing further blockage. Soil structure decline is essentially a blockage of the plumbing system causing a decrease in the movement of water and air into and through the soil profile. Root growth is impaired and drainage is reduced leading to waterlogging, increased runoff and soil erosion. The emergence of plants can also be reduced due to soil structure decline.

Water is one of the main factors that can influence crop and pasture productivity. Seasonal rain is critical, but poorly structured soils may be unable to store this water for plant use. An unprotected soil surface can form a crust that may be impenetrable to germinating seeds, reducing emergence and productivity. There are five processes that can lead to the breakdown of soil structure: slaking, dispersion (see 1.2.1 Slaking and Dispersion), raindrop impact, tillage and compaction.

Raindrop impact

When a falling raindrop hits a soil aggregate, energy is exchanged from the raindrop to the soil aggregate. This transfer of energy can break down a soil aggregate with similar consequences to slaking. Raindrop impact can also initiate dispersion. Surface crusts commonly result from raindrop impact.

Tillage

During and immediately after a tillage operation, soil structure is seen to be improved through an increase in macropores. The detrimental consequences of tillage, however, can be seen following rain as the soil begins to settle and the soil structure collapses causing a decrease in the number of macropores.

The action of tillage disrupts and breaks soil aggregates that were originally cemented together by organic compounds or clay bonding. Tillage creates smaller aggregates that block macropores. Organic matter is exposed and oxidised by micro-organisms which makes the aggregates more prone to slaking and dispersion when the soil becomes wet. As with all forms of soil structure decline, the effects of tillage eventually lead to a decrease in the number of macropores.

Compaction

Soil compaction increases the density of the soil by applying a load (machinery or animal traffic) in excess of what the soil can support without deformation. Deformation of the soil occurs through a reduction in the number of macropores and there is a subsequent reduction in the movement of air and water into and through the soil. Water can often be seen to pond along tractor wheel tracks as evidence of this. The soil is least resistant to soil compaction when wet and most resistant when dry, and clay soils are more prone to compaction than loamy soils. Pugging of soil by animals during wet periods is also a form of soil compaction.

1.5.2 CAUSES OF SOIL STRUCTURE DECLINE

Soil structure decline results from:

- Excessive tillage - Tillage can lead to the formation of plough pans that obstruct water, air and root movement (refer to 1.5.1 Tillage). Plough pans develop as a result of tillage operations occurring at the same depth year after year, resulting in localised zones of very poor structure. Excessive tillage can also result in the whole of the tilled layer suffering from poor soil structure.

- Exposure of the soil surface - During fallows or overgrazing, exposure of the soil surface leaves soil aggregates vulnerable to raindrop impact. Raindrops, particularly during heavy storms, cause slaking and dispersion of aggregates, blocking macropores and forming a surface crust (refer to 1.5.1 Raindrop Impact). Exposed soil surfaces are also vulnerable to wind erosion.

- Machinery and animals compacting the soil - Compaction destroys macropores in the soil (refer to 1.5.1 Compaction). Compaction will occur most readily when soils are moist to wet and the depth to which soils are compacted can reach to 30 cm. Wet soils will pug or puddle resulting in extensive soil structure damage. Stock can damage the structure of dry soil through the trampling and crushing of soil aggregates. The aggregate remains are prone to wind erosion and will block macropores when the soil is wet. Compacting increases the risk of water erosion and waterlogging.

1.5.3 MAINTAINING AND IMPROVING SOIL STRUCTURE

Methods for maintaining and improving soil structure include:

- Minimal or direct tillage practices - A reduction in the number of cultivations to sow a crop or pasture will decrease the number of soil aggregates disrupted. The formation of plough pans will slow or halt and the majority of earthworm and root channels will remain intact.

- Stubble retention and maintenance of pasture cover - This protects the soil surface from raindrop impact and slows or halts the formation of crusts. Groundcover insulates the soil from temperature extremes and provides a food source for micro-organisms. Stubble or pasture residue cover of at least 30-50 percent reduces wind velocities at the soil surface, which in turn reduces the energy available to erode soil particles.

- Gypsum application to dispersive clay soils - Gypsum decreases the dispersion of clay particles and helps to stabilise and improve soil structure.

- Improved crop rotations - Deep rooted plants such as safflower, canola and lupins develop stable root channels in the subsoil. These channels can be utilised by shallow rooted crops. Deep rooted legumes will add nitrogen to the soil and provide a disease break. The traditional practice of fallowing is not useful in improving soil structure.

- Deep rooted ley pastures in rotation - Deep rooted pastures species such as lucerne or phalaris are able to exploit moisture and nutrient reserves in the subsoil. Annual grasses will assist with the improvement of topsoil structure more so than lucerne. A combination of both species will assist with both topsoil and subsoil structure.

1.5.4 WATER EROSION

Soil erosion by water is a large problem in Victoria. Water erosion occurs in various forms: sheet and rill erosion (erosion of surface soil layers), gully and tunnel erosion (erosion of the subsoils) and stream bank erosion. A combination of factors contribute to the water erosion process: vegetation cover, slope, soil type and climate. Raindrops hitting unprotected soil can detach soil particles. Runoff can transfer the detached soil away from a site. Dispersive soils are also a main contributor to water erosion, particularly with gully, tunnel and rill erosion. When dispersive soils are left unprotected, the clay particles are carried away from the site by runoff (refer to 1.5.1 Soil Structure Decline). As well as water erosion having a disastrous impact on the land itself, it also causes major problems downstream. When soil is moved away from a site it usually ends up in waterways contributing to siltation of streams and rivers and transporting nutrients for algal blooms. Ensuring that land has adequate groundcover, particularly during vulnerable times of the year (e.g. after the autumn break), will help protect land from water erosion.

1.5.5 WIND EROSION

Wind erosion is the movement of soil material by wind. It is a major issue in areas with light textured topsoils. The coastal dunes and the sand plains and rises of the Mallee, Wimmera and East Gippsland are particularly prone to wind erosion. Again, ensuring adequate vegetative cover will help protect the land from wind erosion.

1.5.6 MASS MOVEMENT

Mass movement or landslips are a problem on steep agricultural land, mainly in West Gippsland and the Otway Ranges. Excess water in the soil decreases the soil's strength and increases pressures in the soil, resulting in a landslip. Soil on a slope that is not bound together by large tree roots can surrender to gravitational forces and slip. Landslips are an inherent characteristic of steep landscapes and have become more common following the removal of deep rooted, high water-using vegetation. Trees and other deep rooted vegetation reduce the occurrence of landslips by binding the soil together and decreasing water pressures within the soil.

The number of landslips can be minimised by planting deep-rooted pastures and trees above landslip areas. Excess water should be diverted away and cultivation should be minimised to maintain soil structure and drainage.

1.5.7 NUTRIENT DECLINE

Nutrients are exported when crops and pastures are removed from paddocks. Macro-nutrients, particularly nitrogen and phosphorus, need to be replaced in order to maintain viable productive agriculture. Micro-nutrients are normally available and plentiful in the soil and will not require replacement in the short term.

Nitrogen can be replaced biologically by growing legumes. Clover, lucerne and medics can be grown in pasture phases and lupins, faba beans, peas, and vetch in crop phases. The roots of legumes work together with bacteria to fix atmospheric nitrogen into a mineral form available for plants. Nitrogen is the only nutrient that can be biologically fixed. Nitrogen levels in the soil build up slowly under grain legume crops because of the large amounts removed when the crop is harvested. Soil nitrogen levels under pastures build up more rapidly, but the quantity of nitrogen depends upon the density of clover or medic plants.

Nutrient removal needs to be monitored to avoid nutrient decline. Nutrient budgets are useful to monitor removal of nutrients from the paddock and the approximate quantities needed to be applied as fertiliser. Soil chemical tests are useful to provide a benchmark prior to starting nutrient budgeting.

1.5.8 ACIDIFICATION

Acidification of the soil results from three main factors:

- The growth of plants acidifies the soil through the removal of calcium and similar alkaline chemicals. These alkaline chemicals have a strong influence on the buffering capacity of the soil. Fertilisers, apart from nitrogen, have an indirect effect on acidity by promoting increased plant growth which then has the acidifying effect.

- Organic matter releases dilute acids as decomposition takes place. This is a slow process but it does decrease the soil pH.

- Nitrogen fertilisers and nitrate produced by legumes can be leached from the topsoil leaving behind acidic ions which decrease pH. In productive clover or clover/grass pasture situations, nitrogen production can exceed plant demand. The excess nitrogen leaches below the root zone, acidifying the soil layers it is leached from. This can lead to subsoil acidification. Lime is useful in addressing topsoil acidity but will take too long to penetrate deep enough into the soil to be effective in treating subsoil acidity. Deep rooted grasses can provide a method of utilising subsoil nitrogen.

1.5.9 SOIL SALINITY

Soil salinity is the build up of salt in the soil to levels at which plant growth is directly affected, or causes structural problems on clay soils. Sodium chloride (or common table salt) is the most usual salt that causes salinity.

Soil salinity has resulted from:
- natural processes prior to land clearing;
- rising saline groundwater table discharging to the surface; and
- irrigation with saline water over long periods of time.

Rising saline groundwater is generally a whole of catchment issue and requires a co-ordinated approach from all in the community. Tree planting has been a major management strategy to reduce the recharge of water to groundwaters. The recharge of water to the groundwater can occur up to hundreds of kilometres from where the groundwater discharges to the soil surface and therefore makes management difficult.

The management of saline soils includes reducing the amount of salt entering the soil and enabling the salt present in the soil to leach from the profile. Applications of gypsum may then be required to improve the structure of clay soils.

In saline groundwater discharge areas, the removal of salt is often not possible due to the catchment nature of the problem. In these cases living with the salt is the option. The planting of salt tolerant high water-using species and the fencing of saline areas to exclude stock (minimise the risk of soil erosion) provide the main options.

1.6 GLOSSARY

A horizon:	The A horizon consists of one or more surface mineral horizons and is commonly known as topsoil. See also A1 horizon, A2 horizon and Topsoil.
A1 horizon: (part of the A horizon)	This is the mineral horizon at or near the surface, usually with some accumulation of organic matter making the colour darker than the underlying horizon. This horizon is usually high in biological activity. See also A horizon and Topsoil.
A2 horizon:	Part of the topsoil (A horizon). Lighter coloured horizon (known as bleached) usually below a more organic rich horizon (A1). The A2 horizon is usually poorer in structure and less fertile than the A1 horizon. Commonly an indication of impeded internal drainage. See also A horizon, A1 horizon and Topsoil.
Acidic:	Soils that have a pH less than 6.5.
Aerobic:	Soils in which free oxygen is abundant and chemically oxidising processes prevail. This usually occurs in well drained soils with good structure.
Aggregates:	The natural unit of soil structure formed by the soil's tendency to fracture along planes of weakness. Aggregates are also referred to as 'peds'.
Alkaline:	Soils that have a pH greater than 7.5.
Anaerobic:	These soils are deficient of free oxygen and reducing processes are predominant. This generally occurs in poorly drained or waterlogged soils, where water has replaced the air in the soil resulting in a bluey-grey coloured soil.
B horizon:	Commonly known as subsoil. Generally the horizon in the soil with the greatest concentration of clay and/or strongest colour.
B1 horizon:	The transitional horizon between the A and B horizons where the underlying B2 horizon properties dominate. See also B horizon, B2 horizon and Subsoil.
B2 horizon:	Sub horizon of the B horizon. Has more clay and/or stronger colour as compared to B1 horizon.
Biological characteristics:	Consists of the soil organisms: e.g. earthworms, fungi.
Bleached horizon:	Horizons that are paler than adjacent horizons and are best seen when the soil is dry. A bleach is generally associated with the A2 horizon, although it is not restricted to it. It generally occurs over a much less permeable subsoil, pan or hardrock. This horizon is the most leached part of a soil. Organic matter, clay, iron, aluminium and nutrient elements have been removed leaving an accumulation of silica, which gives the horizon its light colour. Field observations have established that bleached horizons are often saturated with water, and their occurrence is usually an indication of periodic waterlogging. This can indicate sodic subsoils when there is a strong texture contrast between A and B horizons.
Buckshot:	Rounded nodules formed in the soil when the soil has gone through seasonal saturation and drying phases over long periods of time. In the drying phase, iron and manganese are left behind to form these hard nodules.
Buffering capacity:	The ability of the soil to resist change in pH. Soils with a high clay and organic matter content have a higher buffering capacity and can tolerate the addition of acidifying fertilisers over an extended period, or at a higher rate of addition without becoming too acid. But, once it is acid, the soil will require large amounts of lime to reverse the effect. The amount of lime requires varies from soil to soil depending on the pH.
C horizon:	The layer below the A and B horizons that consists of consolidated or unconsolidated parent material that is not significantly affected by soil forming process. It is easily recognised by its lack of soil characteristic development and its visible geologic structure.

Dispersion:	Dispersion is the result of chemical instability of clay particles when wet. The clay particles repel each other causing the structural breakdown of soil aggregates in water into the individual soil particles (sand, silt and clay). This is evident in a muddy puddle or dam where dispersed clay particles are suspended in water. Dispersed clays can block micropores and macropores and result in structural damage to the soil. Clods, surface seals or hardpans are often found in soil with dispersable clay.
Duplex profile:	Profiles with a significant texture difference between the topsoil (A horizons) and the subsoil (B horizons).
Ferruginised ironstone nodules:	Iron enriched nodules commonly referred to as 'buckshot'.
Field capacity:	The amount of water remaining in a soil after it has drained (normally after two days) following saturation.
Flocculation:	The process whereby clay particles are attracted to each other to form relatively stable small aggregates. The opposite of dispersion.
Friable:	Soil aggregates between 0.5 and 2 mm in diameter that are well structured.
Gradational profile:	Profiles showing a gradual increase in finer texture (more clay) down the profile such that each successive horizon passes gradually from one to another.
Gypsum:	A naturally occurring form of calcium sulphate. Gypsum contains approximately 23% calcium and 18% sulphur. Gypsum provides calcium to improve soil structure and reduce crusting in hard setting clayey soils.
Hard pans:	A hardened, compacted and/or cemented horizon, or part thereof, in the soil profile. Hard pans often restrict root penetration within the profile and can restrict drainage. Deep ripping or chisel ploughing is used to overcome such problems.
Hardsetting:	Horizons or layers within the soil of very poor structure. Root growth and water and air movement is often impeded in hardsetting soils. Hardsetting soils are often found in A horizons.
Horizon:	A layer within the soil having characteristics and properties (e.g. colour, texture and structure) differing from the layer above and/or below it.
Humus:	The fraction of the soil organic matter that remains after plant and animal residues have decomposed.
Leaching:	The removal in solution of soluble minerals and salts as water moves through the profile.
Lime:	A naturally occurring calcareous material used to raise the pH of soil and/or supply calcium for plant growth. It is effective for treating acid soils.
Macropore:	Spaces in between the soil aggregates. These pores are normally greater than 0.1 mm in size.
Micropore:	Spaces in between the different particles (sand, silt, clay and organic matter) that make up an aggregate. These pores are normally less than 0.1 mm in size.
Mottles:	The presence of more than one soil colour in a horizon. The soil may differ in colour either within aggregates or between them. Mottling occurs as blotches or streaks of subdominant colour throughout the main colour. Mottling is often an indication of poor profile drainage but may be caused by the weathering of parent material.
Neutral:	Soils with a pH between 6.5 and 7.5.
Non-solid fraction:	Refers to the non-solid fraction that makes up soil; i.e. water and air.

Nutrient holding capacity: The capacity of the soil to hold nutrients. This is equivalent to Cation Exchange Capacity (CEC) as used by Soil Laboratories.

Organic matter: Organic materials in the soil from decomposing or fully decomposed plant, animal and microbial residues.

Oxidised: Combined with oxygen.

Parent material: The rock from which a soil profile develops.

Physical characteristics: The aspects of the soil that you can see or that physically impact on water or air movement and root growth. Physical characteristics include: soil, texture, soil colour, soil depth, soil structure, porosity, soil strength and stone content.

Plant available water: (PAW) The amount of water in the soil that can be extracted by the plant. It is defined as the difference in soil moisture content between the field capacity and the wilting point. It is expressed as millimetres of plant-available water within the root zone.

R: Rock.

Slaking: The breakdown of soil aggregates when wet into smaller sized micro-aggregates. These aggregates may subsequently disperse (see dispersion).

Sodic soils: Sodic soils are soils that have a high percentage of exchangeable sodium in relation to the Cation Exchange Capacity. A sodic soil contains suffficient exchangeable sodium to interfere with the growth of plants. To qualify as a sodic soil the exchangeable sodium percentage (ESP) must be greater than 6%. Sodic soils generally have very poor structure and often disperse.

Soil pH: A measure of soil acidity and soil alkalinity on a scale of 0 (extremely acidic) to 14 (extremely alkaline), with a pH of 7 being neutral. It gives an indication of the availability of plant nutrients and relates to the growth requirements of particular crops.

Soil profile: The vertical section of the soil from the soil surface down through the horizons including the parent material.

Soil strength: Refers to the bonding of the soil particles to form aggregates and the bonding between the aggregates. The strength of the soil can affect the ease with which roots can growth through the soil.

Solid fraction: Refers to the solid fraction that makes up soil; i.e. nutrient fraction and organic matter.

Structure: Describes the way the soil particles are arranged to form soil aggregates (peds) and the way the aggregates are arranged. Aggregates are units of soil structure that are separated from each other by natural plains of weakness. There are three grades of soil structure:

- Well structured - The soils are friable where most of the soil is formed as aggregates (peds). A well structured soil is preferable as this means there are many pathways (macropores) in the soil for the roots to go deep within the profile.
- Moderately structured - The soils are partly friable where at least two-thirds of the soil is made up of aggregates.
- Poorly structured - The soils are hardsetting or poorly friable where the aggregates are either very hardsetting or there are very few aggregates formed.

Subsoil: The B horizon and its subdivisions. Usually the clayiest part of the soil profile.

Texture: Texture provides an estimate of the relative amounts of coarse sand, fine sand, silt and clay size particles. Soil texture influences physical properties such as water holding capacity and water movement. Numerous soil properties affect the determination of texture such as type of clay minerals, organic matter and carbonates.

Topography: The landform or surface configuration of an area. The lay of the land.

Topsoil:	The A horizons and their subdivisions. Usually the most organic rich part of the soil profile.
Water holding capacity:	The amount of water held in a soil after any excess has drained away following saturation (field capacity).
Weathering:	The physical and chemical disintegration, alteration and decomposition of rocks and minerals at or near the Earth's surface by atmospheric and biological agents. The weathered materials become the mineral fraction of the soil.
Wilting point:	Defines the amount of water remaining in the soil when a plant permanently wilts and does not respond to added water.

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