SOIL FERTILITY MANAGEMENT IN LOW-RAINFALL FARMING SYSTEMS OF CENTRAL WESTERN NSW

SOIL PROFILE

Agricultural soils can generally be divided into three layers (Figure 2):

1. The *soil surface* refers to the top 10cm:

- The cultivation zone contains the most nutrients, and has stable aggregates, generally adequate infiltration influenced by large and small pores in the soil. Large pores can result from plant roots and worms.
- Problems can include crusting, hardsetting, aggregate instability, and a decline in organic carbon and plant nutrients.

2. The *sub-surface* refers to 10 - 30cm:

- In healthy soils this is characterised by stable aggregates, and an adequate infiltration rate helped by continuous macropores, allowing roots to grow freely.
- Problems can include poor drainage and aeration, ploughpans, acidity and salinity.

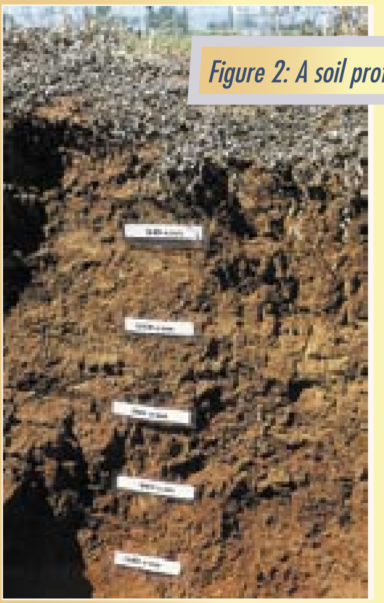

Figure 2: A soil profile

Catherine Evans

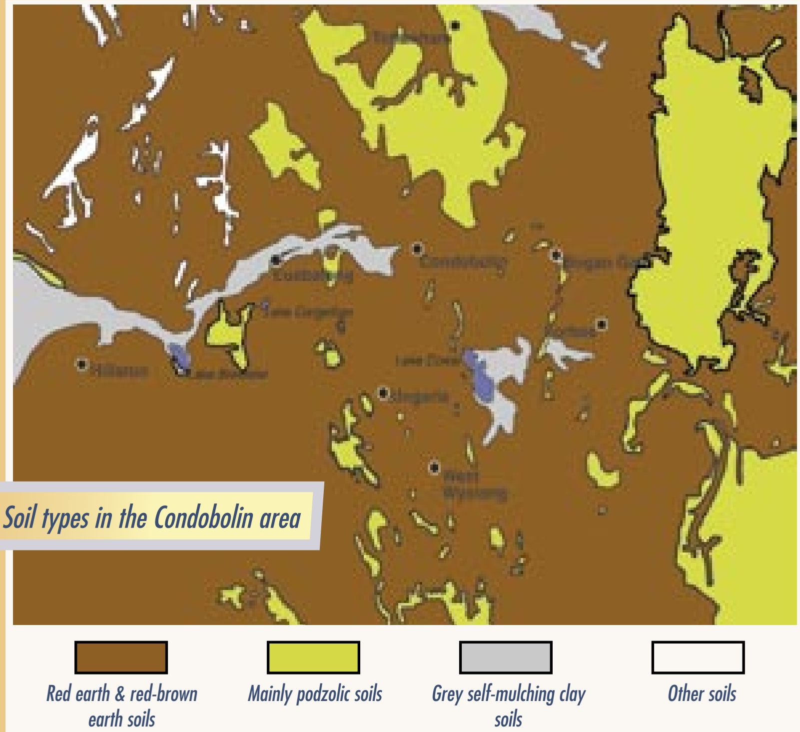

Figure 1: Soil types in the Condobolin area

3. The *sub-soil* is below 30cm and not directly influenced by farming practices.

Soil structure refers to the way in which the soil components (sand, silt and clay) are held together. Structure is important in determining the infiltration rate and drainage of water, sealing and crusting of the soil surface, together with aeration and structural stability.

Ultimately, soil structure is important because it can affect yield and income. If the soil structure is in poor condition, plants cannot take the greatest advantage of rain, so production is not maximised, leading to reductions in income. For example, farming practices such as spraying and sowing can be drastically delayed by poor soil structure due to poor infiltration of water, causing boggy paddocks (Table 1).

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WHAT IS SURFACE CRUSTING?

- Surface crusting is the formation on the surface of a compacted layer of soil between 2 and 5mm thick.
- Surface crusting can lead to delayed or poor plant emergence (Figure 3).

Figure 3: Surface crusting

Catherine Evans

What Causes Surface Crusting?

- Raindrop impact separates the soil into finer fragments of clay and sand at the soil surface, destroying its structure.
- Soils containing dispersive clays.
- Soils with poor soil structure and little ground cover leaving them exposed to raindrop impact.

Management of Surface Crusting

- Surface crusting can be prevented by maintaining a good cover of organic material on the surface, retaining stubble and including a green manure crop or pasture phase with good pasture growth.
- If the crusting is associated with dispersive clays, broadcasting gypsum may help in the short term.

A test for surface crusting

The dispersion test (Figure 4) indicates if the soil is sodic (when wetted these soils can develop surface crusting and poor infiltration):

- Air-dry three lumps of soil the size of a pea seed.
- Place lumps into a saucer of rainwater. Don't touch or move them once they are in the water.
- Check the soil after 10 minutes to see if the water around it has started to go cloudy. If it has, the soil has started to disperse and may be sodic. The soil should be checked again after 30 minutes, 2 hours and 24 hours.
- The cloudy water around the soil is caused by sodium attracting a layer of water around the clay particles preventing them from remaining joined. It is these separated particles which cause the water to look cloudy.

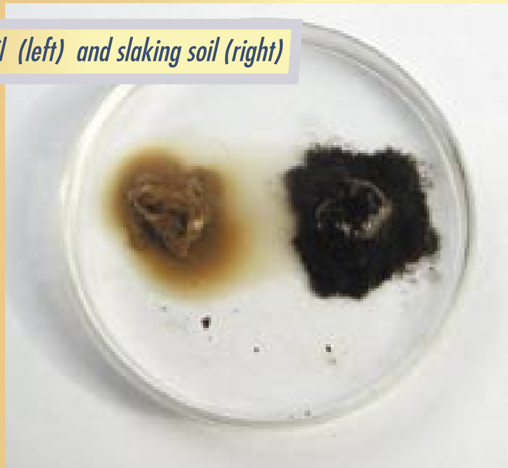


Figure 4: Dispersive soil (left) and slaking soil (right)

Megan Rogers

Figure 5: Compacted soil

Nathalie Brown

WHAT IS SURFACE COMPACTION?

- Surface compaction refers to the compression of the soil reducing the volume of pores in the soil.
- Roots are not strong enough to penetrate the compacted layer, and rainfall runs off the surface rather than infiltrating.
- Bulk density and penetrometer measurements will help determine the extent of compaction in the soil (Figure 5).

What Causes Surface Compaction?

- Surface compaction may be caused by heavy machinery being used, or livestock movement on the soil, when it is too wet.
- It is commonly characterised by deep wheel ruts or hoof prints.

Management of Surface Compaction

- Keep heavy machinery and livestock off wet soils.
- Control traffic farming also reduces compaction occurring on large areas of the soil.

Figure 6: Lupin plants showing root deflection due to a ploughpan

Brendan Scott

WHAT IS POOR STRUCTURAL STABILITY?

- The inability to maintain soil structure when wetted. Can be associated with slaking or dispersive soils.
- The soil surface is often cloddy when cultivated and needs several cultivations to achieve a good seedbed.

What Causes Poor Structural Stability?

- Generally, an organic carbon content less than 1%. When it rains the soil wets and then hardens quickly, forming big hard clods at the surface.

Management of Poor Structural Stability

- To overcome poor structural stability, increased organic carbon levels are important.
- If this is associated with dispersive (sodic) soil, limestone or gypsum may be applied to improve soil structure. Before applying soil ameliorants such as limestone or gypsum it is important to seek advice on the best options.

A Test for Soil Structural Stability

The slaking test (Figure 4) indicates the stability of the soil, and how it will react when wetted:

- Air dry three lumps of soil the size of a pea seed.
- Place these into a saucer full of rainwater.
- If small bubbles appear in the water and the lump of soil collapses, then the soil has slaked. The organic carbon is too low to hold the soil particles together.
- The water causes the soil to slake by filling all the air spaces and forcing the air out. If the soil maintains its shape, then it has enough organic carbon to hold it together, creating a good structure.
- Most soils around the Condobolin district are naturally low in organic carbon.

WHAT IS A PLOUGHPAN OR SUBSOIL COMPACTED ZONE?

- A ploughpan or deep compacted zone is a smeared or compacted layer just beneath the depth of tillage.
- Plants roots may deflect sideways along the ploughpan until they can penetrate the compacted layer via a macropore (Figure 6).

What Causes Ploughpans or Subsoil Compacted Zones?

- Continued cultivation at the same depth. They often result from the soil being too wet when cultivated, and may also be associated with poor soil structure.

Management of Ploughpans or Subsoil Compacted Zones

- Deep tillage can overcome the problem, but the ploughpans will return if the practices that cause them continue to be used.

WHAT ARE POOR DRAINAGE AND AERATION?

- Poor drainage and aeration are characterised by subsoils which are light coloured (yellow) with coloured flecks (grey/red).
- Is more likely to be found in areas of the paddock which are lower, and where the water may pond.
- The plants may exhibit yellowing due to losses of nitrogen and reduced oxygen resulting from too much water in the root zone (waterlogging).

What Causes Poor Drainage and Aeration?

- Poor drainage and aeration are caused by many of the factors outlined above, including compaction, surface crusting, low aggregate stability and ploughpans

Management of Poor Drainage and Aeration

- To reduce the impact of poor aeration and drainage the soils should be maintained to increase organic carbon and so achieve better aggregate stability. Good pasture phases can help to increase organic carbon.

Table 1: Soil Problems, Causes and Management in Central Western NSW

Crusting

Identification

Layer of denser, cemented soil between 2 - 5mm thick.
Poor plant emergence.

Cause

Raindrop impact, poor structural stability, low organic carbon.

Management

Maintain good ground cover through a pasture phase and stubble retention to improve organic carbon levels.

Cause

Dispersive clays.

Management

Broadcast gypsum.

Compaction

Identification

Deep wheel ruts or hoof marks.
Poor plant emergence and growth.

Cause

Heavy machinery and livestock movement on wet soil.

Management

Controlled traffic farming. Keep livestock off excessively wet soils.

Poor structural stability

Identification

Slaking or dispersive soil. Increased su surface soil when cultivated. Requires m cultivation to achieve a good seedbed.

Cause

Low organic carbon.

Management

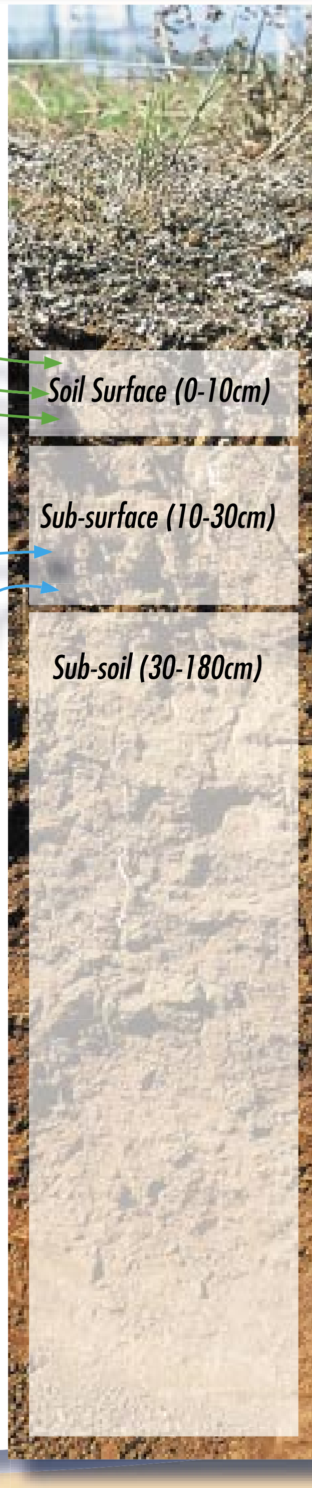
Increase organic matter levels throu phase, stubble retention and use of

Cause

Dispersive clays.

Management

Gypsum may be applied.



Poor drainage/aeration

Identification

Lower areas in paddocks where water may lie for long periods. Light coloured soil (yellow), with flecks of grey/red. Plants may exhibit yellowing due to limited nitrogen and oxygen.

Cause

Compaction, surface crusting, poor structural stability and ploughpans. Duplex soils which drain poorly.

Management

Aeration can be improved by increasing organic carbon to achieve better structural stability. Good pasture phase and stubble retention can improve organic carbon.

Ploughpans

Identification

Poor plant growth. Plants display roots which deflect sideways along the compacted layer.

Cause

Heavy machinery and livestock movement on wet soil. Continual cultivation particularly when soil is wet. Poor structural stability.

Management

Keep livestock off excessively wet soils. Deep tillage, but ploughpans will re-form over time with continued cultivation.

Design: Michel Dignand

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more than one

gh good pasture
minimum tillage.

Catherine Evans

Salinity

Identification

Soil test EC1:5; 0.1dS/m - 0.15dS/m.
Poor and uneven plant growth in sensitive plants. White crystals appear on the soil surface. Clay soils appear loose and crumbly, spongy when cultivated.

Cause

Increase in soluble salts in soil. Water courses which are naturally saline. Rising water tables. Irrigation with saline water. Cyclic salt from the ocean deposited by rain or wind.

Management

Reduce use of saline water for irrigation. Plant salt tolerant species to maintain ground cover and increase water use.

Acidity

Identification

Soil test pH_{Ca}<5.0. Poor plant establishment and persistence in sensitive plants. Yellowing or necrotic tips on leaves. Short or stunted root growth. Increased levels of aluminium and manganese available to the plant.

Cause

Removal of agricultural products. Use of ammonium fertilisers. Soil type and parent material. Leaching of nitrates.

Management

Lime. Reduction in use of ammonium fertilisers. Tolerant cultivars.

Sodicity

Identification

Clay disperses when wetted. Loss of soil structure when wet, producing a soupy consistency. Sets like concrete as it dries.

Cause

High sodium levels.

Management

Gypsum, which displaces the sodium, allowing it to be leached (pH_{Ca}>6). Lime or lime/gypsum mix may be used when sodicity is combined with acidity (pH_{Ca}<4.8).

Cause

Rising sodium levels.

Management

Stop irrigating with water high in sodium.

WHAT IS SOIL EROSION?

In sheet erosion, the surface layer is removed by rain, and ends up further downhill. Wind erosion may move large amounts of soil off-farm (Figure 7).

Figure 7: Soil erosion

Catherine Evans

What Causes Soil Erosion?

- Poor soil structure leads to increased run-off and low resistance to erosion by wind and water.
- Bare soils with no organic material to bind the soil particles together are vulnerable to erosion.

Management of Soil Erosion

- It is important to maintain organic material on the soil surface throughout the year by retaining stubble and preventing over-grazing of pastures.

WHAT IS SOIL SALINITY?

Figure 8: Salinity near Condobolin

Peter Milthorpe

- Saline soils contain soluble salts which can be measured by electrical conductivity (EC).
- Soil salinity can be identified by:
  - The soil surface remains wet and greasy after being wetted.
  - Clay soils may appear loose and crumbly and when cultivated have a soft and spongy texture.
  - White crystals may appear on the soil surface (Figure 8).
  - Increased erosion from loss of ground cover.
  - Clearness of water in streams and dams because high levels of salt settle the sediment.
  - Poor and uneven plant germination and growth.
  - Crop leaves are smaller and darker in colour.
  - In pastures, grasses often dominate because they are more salt-tolerant than legumes.

What Causes Soil Salinity?

- Salts can come from old naturally saline water courses or lakes, rising water tables, use of saline irrigation water, ocean salt deposited inland by rainfall, and weathering of salt-forming parent materials.
- Natural salinity can be increased by clearing native vegetation, causing the water table to rise.
- Transient salinity results from a combination of accumulated salt in the root zone, and perched water tables.

Management of Soil Salinity

- Correcting salinity is difficult. The best way of managing saline areas is to plant tolerant varieties (Table 3).

WHAT ARE SODIC SOILS?

- Sodic soils disperse when they come in contact with water. In the Condobolin area approximately 6% of surface red soils are sodic (sodium of greater than 5% of the ECEC) and many sub-soils are sodic (Figure 9).
- Sodic soils lose their structure when wet, and form a 'soupy mess', setting like concrete when they dry:
  - When the soil surface is wetted plants have problems emerging and there is little air in the soil for the plant roots and micro-organisms. If erosion occurs it tends to be dramatic, large layers of soil being removed.
  - When the soil dries the plant roots can't penetrate the soil to reach nutrients and water. Tillage becomes more difficult and costly.

What Causes Sodic Soils?

- Sodic soils occur naturally where sodium has remained in the soil as weathering has occurred. It can also be caused by management practices such as the use of high-sodium bore water.

Management of Sodic Soils

- Sodicity can be improved with the use of gypsum or limestone, which can be spread throughout the year and incorporated by machine or rainfall:
  - Gypsum quickly reduces the effect of sodic soils and gradually allows the sodium to be leached from the soil.
  - Gypsum is best used on soils with a sodicity problem and pH_{Ca} of more than 6.0.
  - Limestone may be used on soil with pH_{Ca} less than 6.0. Limestone contains the calcium portion of gypsum which displaces the sodium.
  - Limestone is preferable if the soil is has pH_{Ca} less than 4.8.
  - A combination of gypsum and limestone may be used if soil pH_{Ca} is between 4.8 - 6.0.
  - If soils are sodic at depth, then an application of gypsum may be beneficial.

Gypsum

- Gypsum is calcium sulphate ($CaSO_4 2H_2O$).
- Gypsum is a salt and dissolves easily. The increase in salt concentration quickly alleviates the adverse effects of sodic soils. The salt component helps to hold the soil particles together, reducing the amount of dispersion.
- The effect of Ca is to displace Na from the exchange sites in the soil and, in most situations, the Na will be leached from the soil. This process, however is not as rapid as the salt effect.
- When buying gypsum it is important to get a fine and pure product.

Figure 9: Sodic soil having dried after wetting

Catherine Evans

WHAT IS SOIL ACIDITY?

Acidification occurs naturally, but agricultural practices increase the development of acidity.

Soil acidity is dealt with in depth in the sister publication, 'Acid Soil Management in Low-Rainfall Farming Systems in Central Western NSW', available from offices of NSW Agriculture.

SOILS IN CENTRAL WESTERN NSW

What is nutrient deficiency?

Nutrient deficiency exists where the soil nutrient plus the nutrient applied in fertiliser is less than that required by the plant for maximum growth. With major nutrients such as N, P, K, S and Mg fertiliser rates are likely to be designed to maximise economic returns, and may be less than required for maximum plant growth.

Generally the surface soils around Condobolin have low phosphorus and sulphur levels and high levels of magnesium and potassium.

HOW TO INTERPRET YOUR SOIL TEST

- Soil tests are important aids in determining which nutrients are in your soil and what fertiliser to use. They can also explain some changes in production.
- It is important that soil samples are collected correctly so that the area you are interested in is represented and so that you get the information you require.

Collecting the soil

- Collect approximately 35 soil cores (0 - 10cm) from around the paddock in question.
- Avoid areas which are not representative of the paddock such as gateways, headlands and sheep or cattle camps.
- Mix the cores together and take a sub-sample from these weighing approximately 300 grams. Keep the sample cool: don't leave it on the dashboard or in the back of the vehicle where it may heat and sweat, as this may change the level of nutrients in the soil.
- Have the soil tested at an accredited Australian laboratory and check the results against the local estimates and industry standards; or see your local agronomist for an interpretation of the results (Table 2).

Table 2: Soil interpretation chart

Organic Carbon: Soils at Condobolin are commonly about 1%, but range from 0.5 - 2%. Don't aim for a specific number but try to keep the level rising over the years.

pH Calcium Chloride ($CaCl_2$): Often abbreviated to pH_{Ca}. A measure of soil acidity/alkalinity. Acid soils become a problem below pH_{Ca} of 5.0. In the central west pH_{Ca} can range from 4.5 - 9.

Available Nitrogen (N): At 0 - 10cm a nitrogen level of less than 25mg/kg may indicate a deficiency. At depth (60cm) pre-sowing, a nitrogen level of less than 100kg/ha is low, and between 100kg/ha and 200kg/ha is considered adequate.

Available Phosphorus (P): Colwell < 20mg/kg is low, >35mg/kg is ideal. Bray <10mg/kg is low, >20mg/kg is high. Be careful as there are several types of phosphorus tests. Always check which test was used.

Available Potassium (K): Potassium is often extracted at the same time as phosphorus. Generally a Colwell extractable K (Kce) of 110 -135mg/kg is adequate for the Condobolin region.

Available Sulphur (S): Generally, 0 - 5mg/kg is low, between 5 - 10mg/kg is medium and above 10mg/kg is high. In the Condobolin region surface sulphur is generally low, but it increases with depth.

It is important to remember that the availability of N, P, K and S may change throughout the year depending on conditions and the time of sampling.

Electrical Conductivity ($EC_{1:5}$): This provides a measure of salts in the soil - salinity. In a sandy soil with an EC greater than 0.1 dS/m, salt sensitive plants will be affected and above 1 dS/m most crops will not grow. In clay soils with an EC greater than 0.15 dS/m, salt sensitive plants will be affected and above 2 dS/m most crops will not grow.

Exchangeable cations

Effective Cation Exchange Capacity (ECEC): A measure of soil fertility which increases with organic carbon and clay content. ECEC is the summation of all the cations (aluminium, calcium, magnesium, potassium, manganese and sodium). The values for the central west soils range from 5 to 11 cmol (+)/kg or meq/100g. The higher values will occur in soils with more clay content and a higher pH.

Percent saturation of ECEC: Indicates the percentage of cation exchange sites occupied by a particular cation. For example 5% aluminium saturation of ECEC indicates that aluminium occupies 5% of the ECEC- this can be toxic to sensitive plants.

Calcium (Ca): In the Condobolin region the calcium levels can range from 45 - 70% of ECEC.

Magnesium (Mg): In the Condobolin region the magnesium levels range from 15 - 40% of ECEC. Magnesium levels of <0.3 cmol (+)/kg may indicate a deficiency.

Potassium (K): Potassium level of 0.25 - 0.30 cmol (+)/kg or <5% of the ECEC is considered critically low. Around Condobolin, levels range from 5 - 20% of the ECEC.

Sodium (Na): Soils with sodium levels of 5% and above are considered to be sodic. The desirable range is below 5%.

Aluminium (Al): Aluminium becomes more readily available as the soil becomes more acidic. Below pH_{Ca} 4.6 and exchangeable aluminium of >5% plant growth will be affected.

Calcium to Magnesium Ratio (Ca:Mg): This ratio is important because too much exchangeable magnesium and not enough calcium may affect soil structure. The ratio should be at least 2:1.

Table 3: Salt-tolerant plants - maximum $EC_{1:5}$(dS/m)

Sensitive plants (< 0.15)	Moderately tolerant (0.15-0.34)	Tolerant (0.34-0.93)
White clover	Lucerne	Oats
Strawberry clover	Rice	Sorghum
Maize	Medic	Canola
Sub clover	Phalaris	Wheat
		Cotton
		Barley

Further Information

Soil acidity and liming Agfact AC. 19
Lachlan Soil Management Guide
SOILpak for dryland farmers on the red soil of Central West NSW
Acid Soil Action leaflets
District Agronomists

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NSW Agriculture

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