Subsoil constraints in the Northern and Yorke landscape region

Subsoil constraints occur in many of the 50-plus soil types in the Northern and Yorke region, limiting root growth and crop and pasture yields.

Introduction

Throughout the Northern and Yorke landscape region there are more than 50 different soil types each with different soil attributes and characteristics. Subsoil constraints occur in many of these soils limiting root growth and crop and pasture yields.

These constraints can be naturally occurring such as high calcium carbonate levels, poorly structured clays (sodic soils), naturally high levels of boron and / or salt or infertile subsoil layers while other subsoils issues can be induced by land management practices such as compaction (hard pans), subsurface acidity or pH stratification.

Treatment options are diverse and are at different stages of research, but include use of various amendments, soil modification techniques and breeding of more tolerant plants better adapted to these conditions.

This fact sheet will describe each subsoil constraint and where possible provide treatment options.

Soil groups in the region

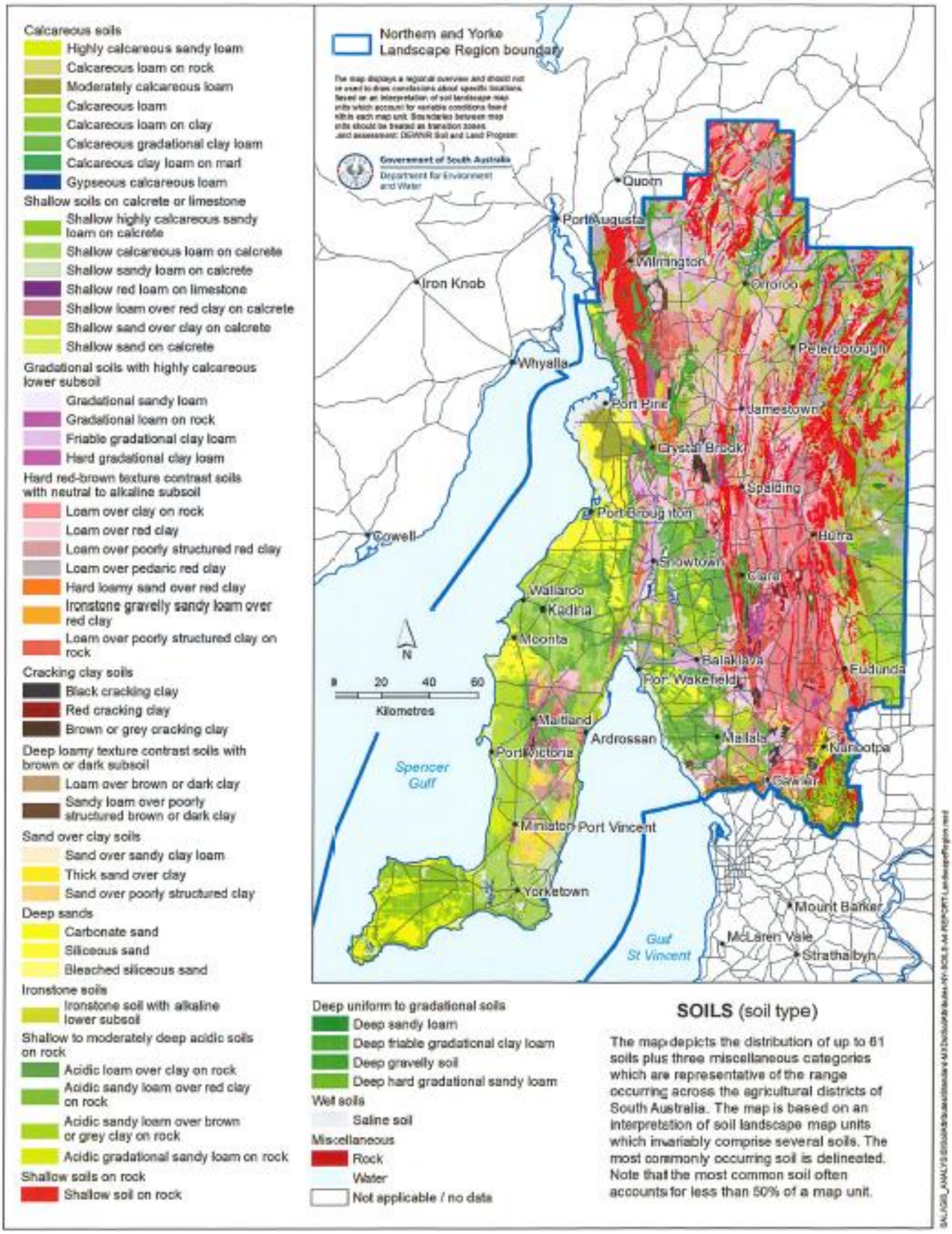

Figure 1: Soil groups in the Northern and Yorke Landscape region

Key soil types and issues

Soil type	Extent	Key subsurface and subsoil issues
Calcareous soils	These generally occur on the Yorke Peninsula, east of Burra, on the plains from Mallala to Snowtown and in the Upper North	The soils have variable amounts of fine carbonate throughout the soil profile. Surfaces are alkaline and alkalinity usually increases with depth. Soil pH in the subsoil can be greater than pH 9.0 ($CaCl_2$). Hard carbonate – mostly nodules, concretions and calcrete fragments are common within the profile that decreases the effective soil volume and water holding capacity. Deeper layers often contain high subsoil salts, high exchangeable sodium percentage (ESP), high pH and boron.
Shallow soils on calcrete or carbonate	Occur mostly on the Yorke Peninsula	Soil profiles are variable, but are all underlain by a hard carbonate layer of calcrete at a depth of 50 cm or less. The calcrete is often fractured and its thickness can vary from a few centimetres to many metres. The subsoils are generally neutral to alkaline. Subsoil salts, sodic clays and boron can be an issue.
Gradational soils with highly calcareous lower subsoils.	Widespread across the region	High fine carbonate levels in the middle to lower subsoil may cause nutritional imbalances. Strong alkaline, high sodium, high boron and raised level of salts may occur in the middle to lower subsoil of some profiles.
Hard red-brown texture contrast soils with an alkaline subsoil	These occur from Gawler through the central area and up to Wilmington, Orroroo and Peterborough. Around Maitland and Minlaton on the Yorke Peninsula.	Subsoil issues can be poor drainage through clay layers (sodic or poorly structured), alkaline subsoils, subsoil salts and boron can be an issue. Soil acidity and pH stratification can be an issue on the surface and subsurface. In some soils shallow or saline water tables can be a problem.
Cracking clay soils	These occur in patches throughout the NY landscape region such as around Clare and Crystal Brook.	The red and brown subsoils can be dispersive. High alkalinity, high to very high boron and sodium levels and elevated levels of salts can occur at depth.
Deep loamy texture contrast soils with brown or dark subsoil	Patches occur around Clare and Wirrabara and Wilmington	Can be intermediate to poorly structured sub-soil. Strong alkalinity, high sodium levels, boron and raised levels of salts can occur.

Sand over clays	Stansbury and Sandilands on the Yorke Peninsula	Clay subsoils can be poorly structured and dispersive. Subsoils can be alkaline to strongly alkaline. Boron can be a problem. Saline areas can occur.
Deep sands	Carbonate sands occur at Warooka Siliceous sands occur south of Moonta, Bute, Port Broughton, Avon and other smaller areas	These soils are sandy throughout the profile and dominantly contain calcium carbonate. Subsoils are alkaline to strongly alkaline. Poor subsoil fertility. These soils are sandy throughout. Subsoils can be alkaline. They often develop hardpans and have poor subsoil fertility.
Shallow to moderately deep acidic soils on rock	These occur in the Clare Valley, Bundaleer Hills between Spalding and Jamestown, near Kapunda and from Gladstone to Wilmington.	Soil depth is determined by depth to parent rock from less than 50 to just over 100 cm. Subsurface layers are often bleached and generally contain coarse fragments. Soils are generally slightly to strongly acidic throughout.
Deep uniform to gradational soils	Patches throughout the Northern and Yorke Landscape Region	Patches throughout the Northern and Yorke Landscape Region.
Shallow soil on rock	Throughout most of the NY Landscape Region except for the Yorke Peninsula.	Soils are very shallow to shallow over rock.

Common subsoil constraints

Subsoil constraints can be either physical, chemical or biological and can have a significant impact on soil water storage and use, nutrient regimes and crop growth and yield. Some of the more common constraints are outlined below.

Soil type	**Extent**	**Key subsurface and subsoil issues**
PHYSICAL CONSTRAINTS		
Stones / gravel	Throughout profile	Stones or gravel can occur in bands throughout the soil profile can take up the volume of the soil that reduces the available water holding (AWHC) capacity of the soil and impede root growth.
Rubbly broken calcrete	30-60 cm	Rubbly broken calcrete takes up the volume of the soil and reduces AWHC and soil fertility. Root growth is moderate throughout the calcrete layers.

Laminar impermeable calcrete	30-100 cm	Difficult for plant roots to penetrate apart from the cracks and holes.
Hard pan / high soil strength	15 – 50 cm	Some soils can physically have a high bulk density (>1.5 g/cm3) that impedes root growth and decreases oxygen and water movement in the soil. Some of the sandy soils can have a weakly compacted A2 layer (hardpan) resulting in poor growth. Root growth is reduced when the penetration resistance is greater than 2.5 MPa. Test with a penetrometer.
CHEMICAL CONSTRAINTS		
High free lime (carbonates)	Throughout profile or in subsoil layers	Calcium carbonate can occur throughout the profile (calcareous) soils or in other soils can be concentrated in the subsoil layers. High carbonate levels (greater than 8%) can increase soil pH and reduce the availability of phosphorus, zinc, manganese and copper. Test by 1-2 drops of hydrochloric acid and observe the reaction. The strength of the effervescence will determine the amount of free lime present.
Sodic clay	10-60 cm	Dispersive or sodic clays (those soils with a high level of exchangeable sodium) are structurally unstable and readily breakdown. When these soils get wet, the clay particles breakdown, disperse and block pore spaces. When the soils dry out they set hard and restrict root growth and drainage. Sodic clays can occur in the surface, subsurface and subsoil. These soils often occur with columnar or massive structure. A field dispersion test can be carried out. Dispersion can also be indicated by a soil test. When the exchangeable sodium percentage is greater than 6% of the cation exchange capacity then these soils are considered sodic. 6-15% highly sodic.
Subsurface soil acidity	5-20 cm	If soil pH in the subsurface falls below pH 5.0 ($CaCl_2$) then the productivity of crops and pastures starts to fall, nutrients such as magnesium, calcium, phosphorus and molybdenum become less available, microbial activity starts to decline and toxic amounts of aluminium can be released into the soil. High amount of aluminium burns off plant roots and reduces the up-take of nutrients and moisture.

		The soil pH should be maintained greater than pH 5.0 ($CaCl_2$) and extractable aluminium less than 1-2 ppm.
Toxic layers – salt, boron, high pH	40-100 cm	Salt, boron and high pH often occur where fine lime accumulates in the sub-soil. These become limiting to plant growth when ECe (salt) is greater than 5 dS/m; boron >15 mg/kg or pH (water) is greater than 9.2.
Saline soils	50 cm+	When the water table is close to the surface then water can be drawn to the surface by evapotranspiration. When the water evaporates it can leave the salts through the profile and at the surface. A high concentration of dissolved salts in the soil or water can cause ion toxicity and affects plant's ability to absorb water. Salinity is a limiting issue when the ECe (salt) is greater than 5 dS/m.
Transient salinity	5 – 40 cm	Transient salinity is natural salts in the upper profile (not associated with a water table). Salts are often leached down the profile and then brought to the surface by evapotranspiration. Salinity is a limiting issue when the ECe (salt) is greater than 5 dS/m.
High aluminium in alkaline layers	40 – 100 cm	High aluminium can occur in high alkaline layers affecting plant growth. When aluminate $Al(OH)_4^-$ is greater than 0.8 mg/L and pH (water) is greater than 9.0 (Rengasamy and Rathjen 2003).
BIOLOGICAL CONSTRAINTS		
Reduction in good soil organisms	0-20 cm	Biological subsoil constraints can occur when there is a reduction in the activities of good soil organisms such as earthworms, *Rhizobia*, and arbuscular mycorrhizae.
Increase in pathogens or nematodes	0-20 cm	Subsoil constraints can occur when there is an increase in pathogens or plant-parasitic nematodes.

Managing subsoil constraints

Poor crop or pasture growth, despite a good season may be an indicator of subsoil constraints. Yield maps, EM maps and / or NDVI maps can also highlight areas of low or poor growth.

Multiple subsoil constraints may be present and can vary with soil types across paddocks. It is important to diagnose soil constraints correctly before developing a management plan.

Methods of detection may be by digging a number of soil pits in different soil types to determine the depth of the roots and observe if there are any restrictions to root growth. This can be backed up with physical and chemical soil testing to understand paddock variability.

A number of constraints such as stone or gravel or high carbonate levels will not be overcome but other constraints may be managed and treated.

Deep ripping and soil amendments

Consistent responses to deep ripping have been seen on the hard pans and thick sand over clays, however results have been variable on sandy loams over reddish clay and various calcareous soils.

High soil strength can be overcome by using deep rippers, inclusion plates, spaders and delvers. The application of amendments such as composts and manures in poorly structured subsoil clays have shown promise at Stockport but have had limited responses in drier areas.

A trial at Bute on a sand over clay in 2019, deep ripping, plus inclusion plates and spading gave a lentil yield increase of up to 0.75 t/ha in 2020.

Gypsum for sodic soils

The use of gypsum to improve sodic surface soils is a common practice but the use of gypsum to treat subsurface and subsoil sodicity is much more difficult and expensive. If the dispersive or sodic clay is in the subsurface then gypsum could be incorporated into this layer with either deep ripping, spading or delving.

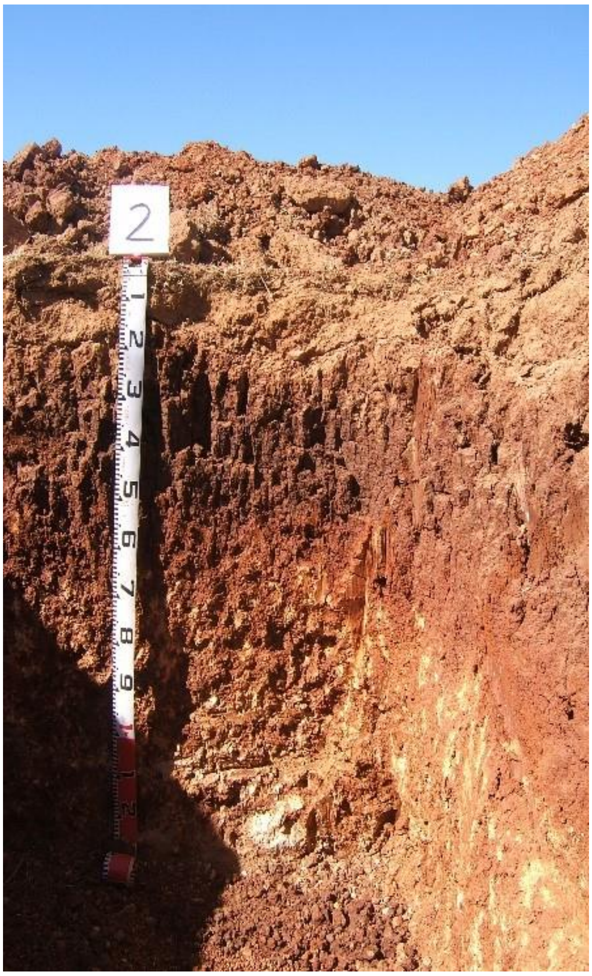

Figure 2: Red-brown earth near Mt Bryan: *Roots to 70cm due to high carbonate and high sodium. Acidic in the surface and subsurface.*

If the dispersive or sodic soil is in the subsoil then deep ripping with a large amount of gypsum will be expensive and unlikely to be economical.

Lime for soil acidity

Soil acidity is a major issue throughout the Northern and Yorke Landscape Region. This often occurs in patches in paddocks and firstly affects the yield and growth of most sensitive crops such as lentils, beans and chickpeas.

Soil pH mapping using either a grid mapping or using a Veris® on-the-go machine can be used to detect low soil pH in paddocks. Where the soil pH is less than pH 5.0 ($CaCl_2$) soil acidity has the potential to spread into the subsurface and lower layers. It is important to maintain the soil surface pH above pH 5.5 ($CaCl_2$) to prevent soil acidity from moving into these layers. Once a soil pH map has been prepared and if there are low zones of soil pH then it is recommended to go into these zones and sample and test the lower layers for soil pH.

If the subsurface layer and lower layers are acidic or become acidic then these are difficult and expensive to treat. If the soil pH falls below pH 5.0 ($CaCl_2$) then nutrients become less available and if the soil pH fall below pH 4.8 ($CaCl_2$) then toxic amounts of aluminium can be released into the soil. Treating subsurface soil acidity is difficult. It is suggested to use a high rate of good quality lime and then incorporate this into the top layer of the soil with either deep ripping, spading or delving.

Placing lime deeper into the profile is difficult and expensive. Gypsum has been used at times to ameliorate subsurface and subsoil acidity due to its higher solubility than lime. Gypsum does not influence the soil pH but can neutralise some of the toxic aluminium as aluminium sulphate.

Salt, boron, high pH, sodicity and high aluminium

Calcareous loams and other soils often have several subsoil toxicities including boron, salinity, high pH, sodicity and high aluminium with high pH.

Wheat varieties have been examined to assess their genetic variability in the tolerance of subsoil salinity, boron, high pH and Al (high pH soils). In recent work more than 200 breeding lines have been tested. Potential improvements of yield of around 10% have been observed where tolerance to multiple constraints were selected (Schilling 2020).

Figure 3: Calcareous soil east of Maitland: *Cereal roots should grow to 1 metre deep. In this case roots are limited to 60cm due to high carbonate, high soil pH, high sodium and high boron.*

Saline soils

Where soils are saline the salinity can cause ion toxicity and affects plant's ability to absorb water.

Improving soil cover and reducing bare soil will reduce the movement of water towards the soil surface due to evapotranspiration.

Where water tables are present and close to the surface then surface or deep drains and /or the planting of deep-rooted perennials on the recharge areas may be an option to lower the water table.

Biological

Rooting patterns vary between crop species and some species may help in modifying the subsoil environment. Biopores created by roots are more effective than mechanical tillage in opening up the soil, especially the subsoils (Dang et al. 2006). The roots of tap-rooted plants such as lucerne and canola, can drill through the soil and create channels after their roots die and decay for the roots of subsequent crops (Elkins 1985). This helps to improve the permeability of the subsoil.

Growing deep-rooted crops can also help in increasing microbial activities in the subsoil as well.

Improving the soil pH will improve the survival and activity of microorganisms such as Rhizobia. Crop diseases and nematodes should be managed.

Summary

In summary there are a range of soils throughout the Northern and Yorke landscape region with a wide range of subsoil constraints limiting root growth and crop yields.

Some of these constraints can be managed and treated effectively while for other constraints there no farming practices or technologies, at this stage that could provide an economic solution.

The most promising management option is the identification of crops that can tolerate these constraints. The investigation of genetic variability of crop species could provide a long-term solution to the problem of subsoil constraints that could ultimately lead to an increase in production and profitability.

More information

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