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The effects of cropping on the grey soils of the Western CMA region

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Farming on the grey soils in the Western Catchment Management Authority (CMA) region has substantially increased in the last 25 years, mainly in the Brewarrina and Walgett shires. Most of the land used for cropping is either flood plains requiring very little clearing or lake beds requiring no clearing. Cropping in this low rainfall zone is used as an alternate income to large grazing activities. Cropping on the grey soils in the Western CMA region covers an area of approximately 48 000 ha (Resource Assessment and Monitoring Systems).

It is important to characterise the effect of these cropping activities on the physical and chemical properties of the soil, both to determine changes to the natural resources base and provide information to assist landholder's decision making about the soil's future management. This publication draws from information gathered during an extensive soil

sampling and analysis program conducted in the Western CMA region by NSW DPI in early 2008 as well as from existing information from other low rainfall cropping areas.

This extensive sampling process involved collection of soil samples to the depth of 120 cm from 56 sites on the grey soils in the Western CMA region (Figure 1). These soils were analysed for their chemical and physical properties. At each site a 30 cm deep pit was used to characterise soil structure and samples of soil aggregates were collected for stability analysis. Forty-five sites were on cropping paddocks that had various cropping histories. These sites differed in the time since first cultivated, intensity of cropping and cultivation practices. The remaining 11 sites were from paddocks that had never been cropped.

The grey soils of this region are described as vertosols in Australian classification (*Isbell 1996*).

Vertosols have the following characteristics:

- (i) a clay field texture or 35% or more clay throughout the solum except for a thin surface crust with a thickness of no more than 3 cm; and
- (ii) when dry, open cracks occur at some time in most years. These are at least 5 mm wide and extend upward to the surface or to the base of any plough layer, self-mulching horizon, or thin, surface crust; and
- (iii) slickensides and/or lenticular peds occur at some depth in the solum.

Broadly, vertosols have high clay content throughout the soil profile and the clay content increases with depth. The key feature of vertosols is the ability to shrink/swell during wetting and drying which results in large open cracks occurring in the soil. This feature allows many soil processes to occur including some repair of soil structure, and in some cases these

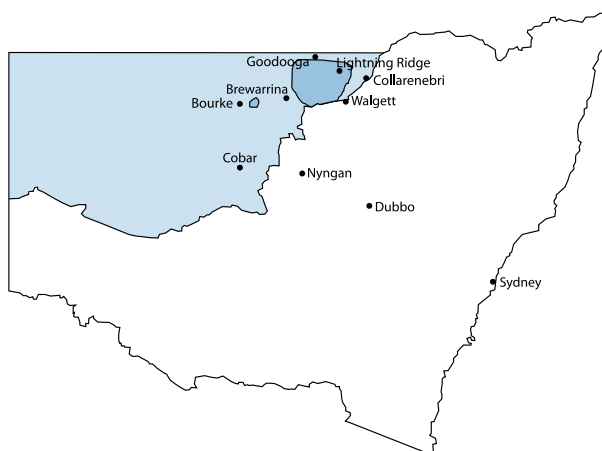


Figure 1. Western CMA grey soil sampling area (darker area).

soils develop a mulch of small soil aggregates on the surface layer. Extensive cracking also allows rapid water infiltration and aeration of the deeper soil layers.

The broad physical properties of the 56 sites are shown in Table 1.

Table 1. Typical physical properties of the grey soils in the Western CMA region.

Depth (cm)	Horizon	Texture	Soil structure
0–10	A1	Medium Clay	Fair
10–45	B1	Medium Clay	Good
45–80	B2,1	Medium Clay	Good
80–120	B2,2	Medium Clay	Good

The broad chemical properties of the 56 sites are shown in Table 2. These grey vertosols have naturally low fertility. On average, phosphorus and nitrogen levels are low for winter cereal production in the Western CMA region. The current level of phosphorus is below the desired level of 15–20 mg/kg (ppm), while nitrogen required to produce a 1.8 t/ha wheat crop is 40 kg/ha. This requirement equates to 34 mg/kg of soil nitrate in the top 10 cm of soil.

Fertiliser needs to be applied to increase the opportunity for maximum yield where moisture is not limiting. Landholders must consider their approach to risk, stored soil moisture and seasonal predictions before determining fertiliser rates.

Farming systems

In 1997 farming systems were equally distributed between multiple tillage, reduced tillage and direct drill on the 24 cropped paddocks. Since then there has been a clear trend away from multiple tillage to reduced tillage or no-till over the last 10 years (Figure 2). In 1997 none of the paddocks surveyed were using no-till, but since then the use of no-till has increased and now applied across 31% of the cropped paddocks surveyed.

Multiple tillage practices are applied by some landholders to create a 'rough' surface to reduce the risk of wind and water erosion. Usually, this is done where there is insufficient stubble or residue remaining across a paddock.

The survey found that most farmers do not apply fertilisers. Herbicides are the main method of weed

Table 2. Typical chemical properties of the grey soils in the Western CMA region.

Depth cm	pH CaCl2	ECe dS/m	Nitrogen (nitrate – N03) mg/kg	Potassium (K) meg/100g	Chloride (Cl) ppm	Phosphorus (P) Colwell mg/kg	Organic C %	Sulfur (s) KCL mg/kg
0–10	7.63	0.16	10.09	1.88	16	19.99	0.48	3.18
10–30	7.94	0.27	9.68	1.22	84	5.93	0.33	4.33
30–60	8.10	0.54	10.92	1.22	311			
60–90	8.11	1.16	9.23	1.27	641			
90–120	8.09	1.73	5.55	1.26	894			

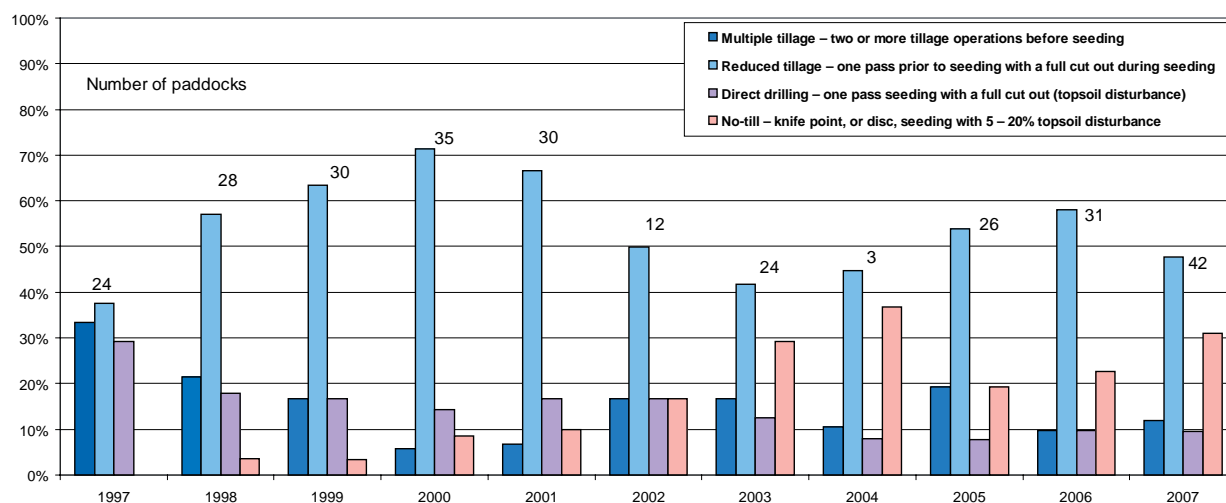


Figure 2. Cultivation practices of 45 selected cropping paddocks in the Western CMA region since 1997.

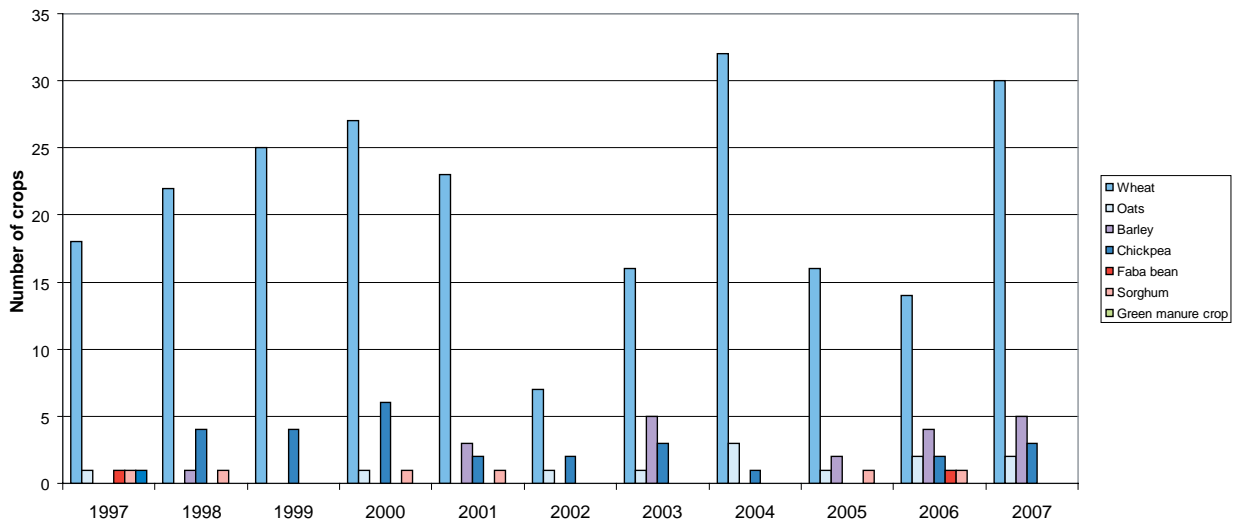


Figure 3. Number and type of crop on 45 paddocks in the Western CMA region since 1997 (fallow not included in the crop total).

control, especially to control summer weeds which can deplete soil moisture.

Wheat is the most commonly grown crop on the grey soils across the western NSW flood plains, and represents 50–85% of the annual crop each year since 1997 (Figure 3). This continued dominance of wheat increases disease risk, especially when stubble is retained and a minimum or no-till system is in place. Rotation crops are typically oats, barley and grain legumes. Grain legume crops include chickpeas and faba beans, but these represent a very small proportion of annual production. Using a broad leaf crop in the rotation provides an opportunity to reduce the winter grass weed burden and breaks the cereal disease cycle.

Following suitable spring and early summer rains, crops such as sorghum are often grown and anecdotally sunflowers have been grown.

Three possible cropping systems for use in the region are:

- wheat /fallow/wheat (low risk low return)
- wheat in rotation with grain legumes
- opportunity cropping (choosing a crop with the highest returns spreads risks but requires a higher level of management).

Chemical properties of grey cropping soils of the Western CMA region

Organic carbon

Soil organic carbon (SOC) describes the carbon associated with soil organic matter (SOM). SOC is the organic fraction of the soil that is made up of decomposed plant and animal materials as well as microbial organisms. It does not include fresh and un-

decomposed plant materials, such as straw and litter, lying on the soil surface.

SOC is important for all aspects of soil fertility. Decomposition of soil organic matter releases nitrogen, phosphorus and a range of other nutrients for plant growth. SOC promotes soil structure by holding soil particles together as stable aggregates. It influences other soil physical properties such as water holding capacity and infiltration. It provides food for soil fauna and flora and can influence soil biodiversity and microbial populations. This assists root growth and plant nutrient uptake by creating burrows and suppressing crop disease causing organisms.

Types of soil organic carbon

It is convenient to divide total SOC into different pools dependent on their rate of breakdown.

- Labile pool: includes freshly added plant and animal residues as well as micro-organisms
- Slow pool: includes well-decomposed organic materials, (e.g. humus)
- Inert pool: includes material that is old, resistant to further breakdown and represents the products of the last stage of decomposition, (e.g. charcoal)

Therefore soils differ not only in total SOC, but also in the distribution of carbon amongst the three pools. The pools of SOC affect different soil processes. The slow pool contributes the majority of soil nitrogen and the inert pool, if present in high enough quantity in soil with less than 50% clay, can contribute to the cation exchange capacity of the soil.

The grey soils of the Western CMA are naturally very low in SOC with an average of 0.48% in the 0–10 cm soil depth and 0.35% in the 10–30 cm soil depth (Figure 4). The cropped paddocks had a slightly lower SOC than the paddocks that had never been cropped.



Figure 4. Organic carbon (%) at 0–10 cm and 10–30 cm on cropped and un-cropped grey soil paddocks in the Western CMA region.

The following factors increase the rate of loss of organic matter:

- cultivation
- repeated wetting and drying of soil
- burning stubble
- high temperatures and adequate soil water.

To maintain and increase organic matter:

- retain stubble and plant residues,
- adopt no tillage practices,
- avoid long bare fallows.

Phosphorus

Phosphorus (P) is essential for healthy plant growth and cell division. Good P nutrition in plants results in:

- improved seedling vigour
- better root development which allows for better uptake of soil moisture and nutrients leading to more robust plants
- more grains per head resulting in higher grain yields.

The measured phosphorus levels in the paddocks sampled showed a decline in P level as the number of crops grown in the last eleven years increased (Figure 5), indicating that cropping has depleted

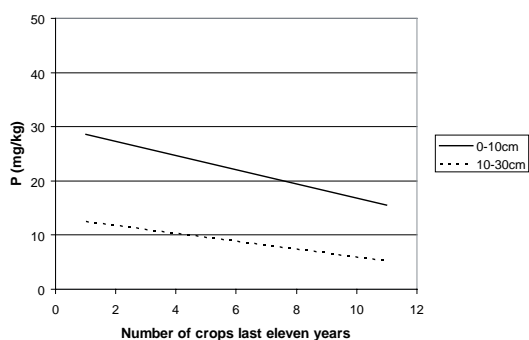


Figure 5. Available soil P (Colwell) in the cropped grey soils of the Western CMA region.

soil phosphorus levels. To maintain or increase yield, phosphorus should be applied. It should be noted that for soils containing significant amounts of carbonate as can occur in these semi arid soils, the use of Colwell or Olsen P test is recommended (Holford 1997).

The phosphorus levels in these paddocks were below the 30 mg/kg considered a minimum for crop production. Farmers in the region should pay careful attention to the level of available P in paddocks before planting.

In a soil with low P availability, apply a P fertiliser. Place the fertiliser close to the seed when sowing. A guide to P fertiliser requirements based on soil test results is given in Table 3.

Table 3. Relating the Colwell P test to winter cereal cropping (Source: Agfact P1.4.5 Phosphorus nutrition for winter crops).

Soil phosphorus level	P (mg/kg) ¹	Phosphorus rate (kg/ha)
Very Low	1–10	15
Low	10–20	10–14
Medium	21–35	5–9
High	>35	0–4

¹ samples to 10 cm depth

Nitrogen

Nitrogen (N) is a key element for plant growth. It is found in all plant cells, in plant proteins and hormones and in chlorophyll. Nitrogen is most often the limiting factor for grain protein content.

Nitrogen deficiency results in reduced production of the green pigment chlorophyll, resulting in yellow leaf pigments in older leaves where nitrogen is translocated within the plant from old to young leaves.

In the Western CMA region the grey soils are inherently low in N (Figure 6). There is often less than 4 mg/kg of soil N at any given depth. There was a small measured increase in soil N on the cropped soils. The survey noted that grain growers in this area

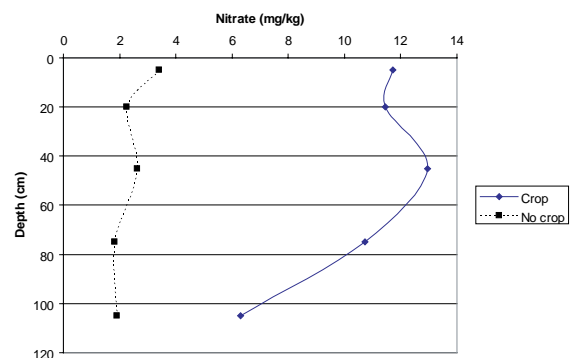


Figure 6. Nitrate of the grey soils of the Western CMA region.

had not applied any nitrogenous fertiliser therefore this increase in soil N may be due to increased N fixation during fallow periods and/or by the use of grain legumes in the cropping rotation.

As a guide a 1 t/ha crop uses 22 kg/ha of nitrogen.

To improve soil nitrogen status, monitor the grain protein level. If protein is falling then soil nitrogen levels could be declining. A protein level above 12.5% is desirable. Monitor the crops for yellowing of the older leaves as an indicator of N deficiency.

To increase soil N apply a fertiliser that contains N or use pulse crops.

Soil pH

Soil alkalinity or acidity (measured as pH) plays an important role in the solubility of nutrients and hence their availability and/or toxicity. When the soil is strongly acid (e.g. pH in CaCl_2 less than 5.5) the availability of many important nutrients such as phosphorus and molybdenum is reduced while some elements (e.g. aluminium and manganese) become available at toxic levels. Conversely if a soil is strongly alkaline (e.g. pH in CaCl_2 above 8.0) the plant may have difficulty taking up minerals such as zinc. A neutral pH (6–7.5) provides the best mineral nutrition for crop growth and is best for the release of N from soil organic matter by micro-organisms.

In the Western CMA region the grey soils have neutral topsoils and alkaline subsoils (Figure 7). Cropping has raised the soil pH in these soils by 0.1 to 0.8 pH units. This result is similar to an earlier study conducted in the Walgett, Coonamble and Trangie area where it was shown that cropping had increased topsoil pH at all sites as compared with the uncropped soils. It was thought that the acidifying influence of organic matter had been lost as a result of conversion to cropping and the more alkaline soil below the surface had been brought to the surface by cultivation (*Dryland Cropping Guidelines for the Western Farming Systems Zone 2005*).

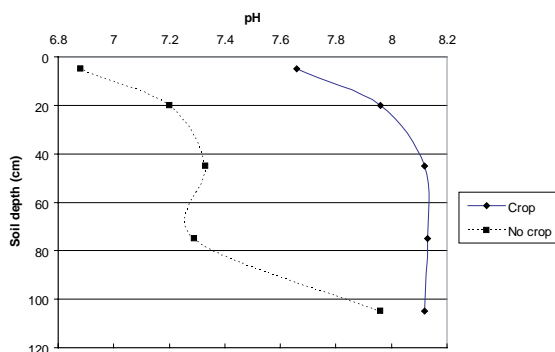


Figure 7. Soil pH (CaCl_2) of grey soils of the Western CMA region.

In alkaline soils, carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) may be present at high concentrations. Excess bicarbonate inhibits root growth in plants, but this effect is highly variable. Alkalinity also results in the toxicities or deficiencies of several nutrients, for example:

- decreased solubility of iron and manganese with increasing pH
- low availability of zinc at high pH resulting from the adsorption of zinc to calcium carbonate (CaCO_3). Bicarbonate may also impair the uptake and transport of zinc to the plant shoots.

Availability of phosphorus is generally low in alkaline soils due to adsorption to clay particles. At times of low soil moisture when root growth is restricted, phosphorus deficiency can occur.

The optimum pH ranges for different crops are given in Table 4.

Table 4. Optimum pH (H_2O) ranges for selected crops.

Crop	Optimum pH range
Barley	6.0–8.0
Wheat	5.5–8.0
Oat	5.5–8.0
Chickpea	5.5–7.0
Field pea	6.5–8.5
Sorghum	5.5–8.0

(Source: *Dryland Cropping Guidelines for the Western Farming Systems Zone 2005*)

Most studies on nutrient availability in response to pH have focused on topsoils. Given that nutrient concentrations in subsoils are already low, the significance of subsoil acidity or alkalinity on nutrient availability is unclear. However, it is usually uneconomic to ameliorate subsoils with additional nutrients or adjuncts to change the pH. In some areas subsoil constraints are managed by reducing the inputs on heavily constrained sites and/or through the use of appropriate crop varieties (see *Constraints to cropping soils in the northern grains region: a decision tree*).

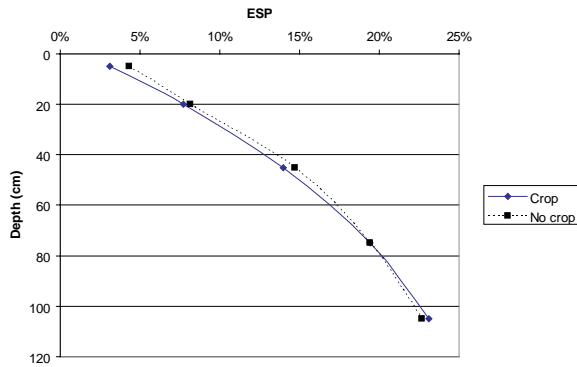
Sodicity

Sodicity is a measure of the exchangeable sodium in a soil. Exchangeable sodium, like other exchangeable cations, is held loosely on negatively-charged clay particles. A soil is defined as sodic when sodium makes up more than 6% of the total exchangeable cations, and the electrical conductivity is low. A soil chemical test reports sodicity as exchangeable sodium percentage (ESP); an ESP of more than 6 indicates a sodic soil.

Most grey soils are naturally sodic (ESP greater than 6) either in the subsoil or throughout, but the

conversion to cropping appears to have had little effect on the ESP on these soils (Figure 8). Similar results have been recorded in other grey soils around Walgett, Coonamble and Warren (*Dryland Cropping Guidelines for the Western Farming Systems Zone 2005*).

Figure 8. Exchangeable sodium percentage (ESP) of the grey soils in the Western CMA region.



Electrical conductivity

Electrical conductivity (EC) of the soil is a measure of the concentration of salts in the 'soil water solution'. The soil water solution is made up of positive and negative ions dissolved in soil water (for example calcium, magnesium, carbonate, chloride). A low level of $EC_{1.5}$ (e.g. 0.1–0.5 $\mu\text{S}/\text{cm}$) is desirable; but a soil with no salt in solution ($<0.05 \mu\text{S}/\text{cm}$) contains very few plant-available (soluble) nutrients, and has a limited ability to suppress dispersion in soils with ESP values as low as 2 or less. The impact of EC on dispersive potential is shown in Figure 9. Note $EC_{1.5}$ values above 0.7 $\mu\text{S}/\text{cm}$ can be toxic to some sensitive plant species resulting in yield decline.

The electrical conductivity of the grey soils in the Western CMA region is similar to soils in the Walgett, Coonamble and Warren area (Figure 10). Different crops differ in response to soil electrical conductivity levels. Yields of wheat and barley will experience yield declines when the soil $EC_{1.5}$ reaches 1.0 and

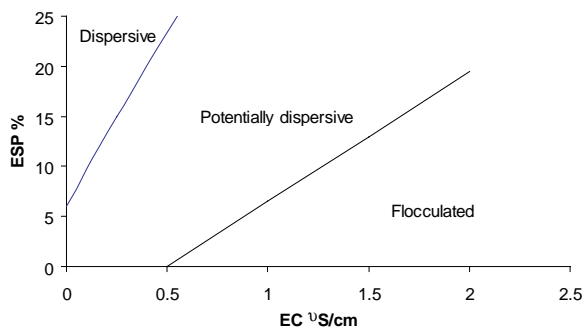


Figure 9. Clay dispersion depends on the interaction between sodicity (ESP) and salinity ($EC_{1.5}$) (Source: *Dryland cropping guidelines for the Western Farming Systems Zone*).

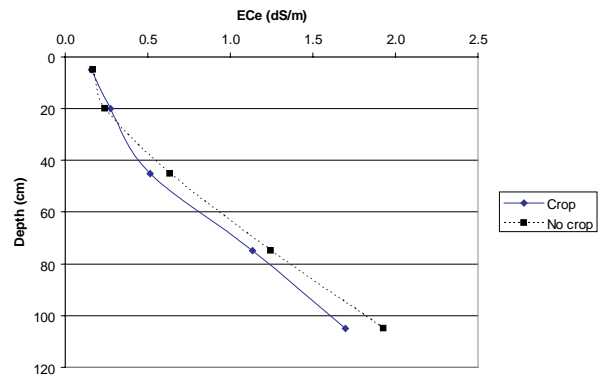


Figure 10. Average electrical conductivity of the soil water extract (EC_e) of grey clay soils in the Western CMA region.

1.3 $\mu\text{S}/\text{cm}$ respectively. Grain legumes have lower tolerances to soil EC.

There is a significant difference between the measured $EC_{1.5}$ values on the flood plains and lake beds possibly due to leaching when the lakes contain water (Figure 11).

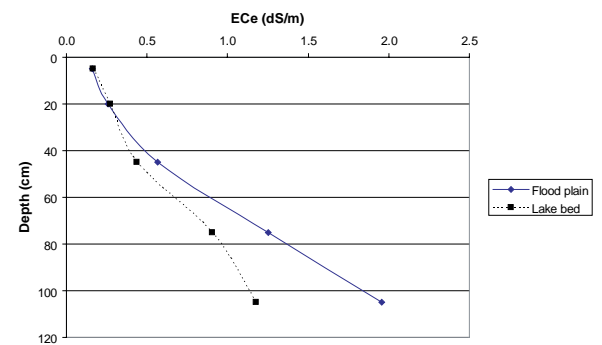


Figure 11. Average electrical conductivity of the soil water extract ($EC_{1.5}$) of the grey flood plain and lake bed soils cropping paddocks in the Western CMA region.

Gypsum (calcium carbonate), can improve the structure of sodic clays (clays with more than 5% exchangeable sodium and low $EC_{1.5}$) as it raises the $EC_{1.5}$ by providing soluble calcium to the soil solution. Calcium then displaces some exchangeable sodium.

Use test strips of gypsum at various rates (e.g. 2.5 t/ha and 5 t/ha). If a whole paddock is treated leave strips untreated to measure the benefits.

Physical properties of the grey cropping soils of the Western CMA region

Soil structure

Soil structure are the arrangements of soil particles and the pore spaces between them. Soil structure influences plant growth by controlling the movement of water and air, and influences root development.

There are three aspects to soil structure:

- structural form (the shape and size of aggregates, the nature of their faces, their porosity and their friability)
- structural stability (the ability of a soil to maintain its structural form); soils that resist slaking and dispersion, and aggregates that resist remoulding have high structural stability
- structural resiliency (the ability of a soil to recover its structural form after disturbance).

The cracking grey clays in the Western CMA region have a low structural stability. Quick wetting leads to rapid slaking and often crusting, traffic can compact them, and tillage when wet can result in remoulding or smearing. This results in reduced water infiltration, increased soil strength and affects plant root growth. Soil compaction by machinery or stock causes decreased yields. Compaction by livestock may also mean extra tillage to establish a crop. Cracking clays tend to have a high structural resiliency: drying can crack the surface crust and some soils form a self-mulching surface. Cycles of wetting and drying can reduce or remove the impact of compaction or smears.

Factors that promote good soil structure

- Organic matter helps to bind and stabilise the soil. The bonds formed provide resistance to wind and water erosion, and help to maintain an open pore structure.
- Tap-rooted and fibrous-rooted plants affect soil structure in different ways. Tap roots make large channels which, when the roots decay, provide ready access for water, air and other plant roots to the subsoil. Cultivation will destroy these channels.

Fibrous roots are useful for binding the soil. Numerous small roots make intimate contact with soil particles. When the roots die, their remains become incorporated organic matter, important to the stability of soil structure.

- Calcium, in the form of gypsum can help to improve a soil's structure in dispersive soils.

Monitor the crop's performance. If there are signs of water stress when not expected it may indicate a compacted layer. Digging a small hole 30 cm deep and examining the soil profile is a reliable method for finding a compacted layer. Root behaviour can be a useful guide because tap roots often turn at right angles when they hit a compacted layer. Canola and the grain legumes are particularly sensitive to these hard layers.

Slaking and dispersion

Slaking and dispersion are indicators of the stability of soil aggregates in water.

Slaking occurs when large soil aggregates collapse to form micro-aggregates (e.g. size <2 mm). Slaking may cause the soil to form a surface crust or an undesirable massive structure in the upper 10 cm of the soil profile. This will often impede water and air movement, root penetration and function and adversely impact on seedling establishment. The slaking of topsoil aggregates at 0–2 cm and 2–10 cm is influenced by tillage. This occurs because tillage breaks down soil components that bind the soil mineral fraction (e.g. SOC).

The cropped grey soils of the Western CMA region slake more readily than the soils from the un-cropped paddocks (Figure 12).

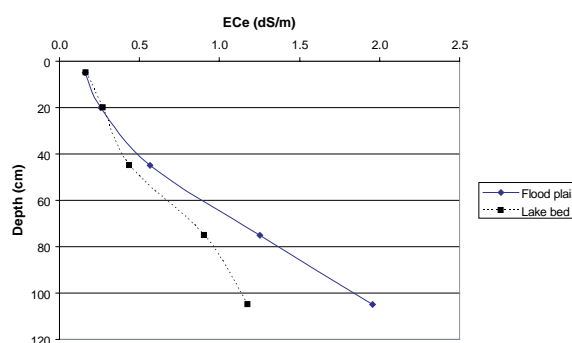


Figure 12. Slaking score at 0–2 cm, 2–10 cm and 10–30 cm on cropped and un-cropped grey soil paddocks in the Western CMA region.

Dispersion is a more severe form of structural collapse, but is often associated with aggregate slaking. Dispersion causes soil micro-aggregates to collapse into individual soil particles (sand, silt and clay) (Figure 13). Dispersion results from excessive exchangeable sodium and a very low $EC_{1:5}$. It is aggravated by cultivation and low soil organic matter.

In soils, increased sodium promotes excessive swelling. If $EC_{1:5}$ is very low, clay particles in soils with elevated sodium disperse, but as $EC_{1:5}$ increases clay particles are forced together.

Soils that swell excessively due to sodium have reduced soil pore space, slower rates of water and air



Figure 13. Dispersive soil in water.

infiltration, and drain less readily. These soils become readily waterlogged and dry slowly. These conditions adversely affect plant growth.

Best management practices for grey cropping soils of the Western CMA region

Broad recommendations

From the analysis of the soil testing on 56 grey soils in the Western CMA region it can be seen that cropping has had a direct effect on the physical and chemical properties of these soils. Past cropping activities have decreased the structural integrity and increased the risk of the surface layers of these soils to slaking. It can be seen that increased cropping measured by product removal increases the soil dispersion score in the ASWAT test, suggesting that cropping activities also increase the risk of these soils dispersing after rainfall. Cropping has marginally decreased the amount of organic carbon in the top 30 cm of these soils which in turn increases the risk of structural instability.

Cropping has changed the chemical properties of these soils, increasing the soil pH, and slightly increasing soil nitrogen, while there is a trend of decreasing soil phosphorus with an increasing number of crops.

Over the five years to 2008, there has been increased adoption of conservation farming practices such as reduced tillage or no-till, stubble retention and crop rotation. In other areas the adoption of these practices has halted the occurrence and rate of soil degradation. This leads to the recommendation that cropping be considered an economic and sustainable farming option within the farming systems of the Western CMA region with the following provisos.

- Cropping activities need to be timely and the cropping management should be a response to a longer term paddock/farm plan and climatic conditions.
- If cropping use conservation farming techniques.
- Soil testing should be undertaken to best determine the amount of fertiliser required.

Glossary

ASWAT test. A measure of soil dispersion in water (Aggregate Stability in WATER) that takes between 2 and 4 hours to complete. It is a modification of the Loveday & Pyle test. An ASWAT score 7–16 is serious dispersion, score 2–6 is moderate and a score 0–1 is negligible.

Chloride (Cl). Chloride is the most commonly occurring soluble anion in Australian soils. It is used as a measurement of soil salinity. It can accumulate in the lower portion of the soil profile. A concentration below 600 ppm is considered low and a concentration above 700 ppm can cause a 10% yield decline in wheat.

EC. A measure of the conduction of electricity through a saturated water paste; an indicator of the concentration of dissolved salts, and hence salinity. EC is commonly measured as the EC of a 1:5 soil water extract (EC_{1:5}) or a saturated paste extract (ECe). Units are deciSiemens/metre (dS/m).

Nitrate. The majority of plant N supplied from the soil is organic which is released through microbial processes into mineral forms, predominantly ammonium (NH₄⁺) and nitrate (NO₃⁻). Nitrate content of soil varies, both over time and with soil depth.

P (Colwell). A method used to measure soil phosphorus which uses sodium bicarbonate with a 1:100 soil to extractant ratio.

pH (CaCl₂). pH in calcium chloride (CaCl₂) is the standard method for measuring soil pH in all states other than Queensland. It is more accurate than the pH in water test.

Soil structure. This is the architecture of the soil and is given by the arrangements of solid particles and pore space. A well structured soil is characterised by a distinct 'crumb' structure, where individual mineral particles are clustered into stable aggregates or 'crumbs'. Poorly structured soils become very hard when dry. Poor structure impedes root growth, and results in poor internal drainage and inadequate aeration.

Sulfur (KCl). A method to measure soil sulfur. Extraction by 3:20soil/0.25M KCl solution heated 40°C for 3 hours. Sulfur deficiency is not a problem in soils with high organic matter, but it leaches easily. A soil result above 6 mg/kg is considered satisfactory.

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Dryland cropping guidelines for the Western Farming Systems Zone

Northern Wheat-Belt SOILpak

Further information

www.western.cma.nsw.gov.au or www.dpi.nsw.gov.au

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