Diagnosing and ameliorating problem soils: decision tree on how to diagnose and ameliorate problem soils

Department of Agriculture and Food, Western Australia

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DIAGNOSING AND AMELIORATING PROBLEM SOILS
(Decision Tree on How to Diagnose and Ameliorate Problem Soils)

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INTRODUCTION:
Most cropping paddocks in Western Australia have lower yielding areas within paddocks that perform poorly in most years. If the agronomy and management are good, the poor yields are usually due to soil-related problems. Some of these problems can be corrected or reduced by adopting certain proven practices. However, it is important to identify and quantify the problem so that decisions can be made on whether amelioration is possible and economically feasible.

OBJECTIVE:
The objective is to provide a simple decision tool for farmers and advisers to use in identifying and quantifying soil problems in agricultural soils in Western Australia. It could be used outside Western Australia by including local soil problems.

PROCESS:
Work through the decision tree step by step to identify and quantify the soil problems in poor performing paddock zones and to decide the feasibility of amelioration. It is necessary to eliminate the reasons for poor yield due to agronomic and management problems before using this diagnostic key on soil problems.

Note: To evaluate the economic feasibility of amelioration, use the ICV economic analysis tool (Graeme McConnell, Planfarm, which is included in the web version of this booklet).
INDEX FOR THE DIAGNOSTIC KEY ON SOIL PROBLEMS

Is the texture of the soil sandy throughout the profile?
- Yes: Go to step 1
- No:
  - Is the topsoil non-wetting (a drop of water takes >10 seconds to be absorbed by the soil)?
    - Yes: Go to step 1
    - No:
      - Does the soil get waterlogged (water within 30 cm of surface and crop leaves yellowing)?
        - Yes: Go to step 2
        - No:
          - Is the pH_{Ca} of either the topsoil or subsurface soil within 50 cm, less than 4.5 or more than 7.5?
            - Yes: Go to step 3
            - No:
              - Is the soil crusting, hardsetting, surface sealing or cracking?
                - Yes: Go to step 4
                - No:
                  - Is the rooting depth restricted by rock, a dense clay layer, hardpan (red-brown, calcrete, siliceous etc.), cemented gravel or a traffic or plough pan?
                    - Yes: Go to step 5
                    - No: Then the low yields are due to nutritional problems or root diseases. Do soil & tissue tests next season.

Non-wetting sandy soils and pale deep sands

From any poorly performing area of a paddock, can you make a coherent soil ball, that can be held between thumb and forefinger [from any soil layer (horizon) up to 1 m depth] by mixing the soil with water and kneading? (Use TopCrop Soil Texture Card. In high and medium rainfall zones, if there is unglazed gravel in the profile it may still be productive.)

Yes

Is the topsoil non-wetting (a drop of water placed on the soil after scraping off the top 2-3 mm remains as a bead for more than 10 seconds)?

No

Go to step 2

Yes

Is the rainfall from April to October less than 175 mm?

Yes

Claying is beneficial only in wet years. Negative response in dry years. Furrow seeding with or without banded surfactant is an option.

No

Does test solution No. 2 from LMS water repellency test kit get absorbed into the soil within 10 seconds (2 molar ethanol or 12 mL of industrial grade methylated spirits made up to 100 mL with water can be used)?

Yes

Moderate yield increase and good weed control from claying. Furrow seeding with or without banded surfactant is an option.

No

Substantial benefit in yield and weed control from claying. Furrow seeding with or without banded surfactant is an option.

For information on texturing a soil see Appendix 1 for TopCrop Soil Texture Card.
Does the soil get waterlogged to affect crop yields (water within 30 cm of the surface and the crop leaves turning yellow)?

Yes

Is there a drainage outlet or opportunity to drain the land?

No

Drainage is not possible. Try to prevent water coming onto the land by intercepting the water upslope with earthworks and redirecting it into farm dams.

Yes

Is the land saline \([\text{EC}_{(1.5 \text{ water})}] > 0.6-0.8 \text{ dS/m (60-80 mS/m)}\) ?

Yes

There is no significant benefit from raised beds as the soil is too saline. Explore salinity management options.

No

Raised beds can be beneficial with improved drainage.

Is there a clay layer within 15 cm of the surface?

No

There is no significant benefit from raised beds unless 5 t/ha (or more) gypsum is incorporated.

Yes

Is the clay layer very dense, dispersive and/or is the \(\text{pH}_{w} > 8.5\)?

Yes

Raised beds with proper drainage can be beneficial.

No

Refer to dispersion test in step 4 (see Appendix 2 for details).
Soil pH (Acidic or Sodic Soils)

Step 3

Is the soil pHw >8.3 in any layer to 50 cm depth (more than about pHCa 7.5)?

No

Is the soil pHCa <4.5 in any layer to 30 cm. depth?

Yes

Is the soil pH between 4.3 and 4.5 in any layer to 30 cm?

Yes

Is the soil colour yellow, brownish yellow or reddish yellow?

No

Does the clay content increase with depth to a sandy loam or a loam within 30-40 cm?

No

Go to step 4. At high pH boron toxicity and Cu, Mn, and Zn deficiencies may occur. Soil and tissue test. If boron toxic, grow tolerant crops and varieties.

No urgent need to lime. If the pH is close to 4.5, liming to prevent further acidification is beneficial which will also improve nutrition and increase crop options. As lime takes time to move down the profile and the pH of the surface soil needs to be raised above pH 5.5 before it moves down, liming before the problem arises will prevent future yield decline.

Liming recommended. Good yield response in acid-sensitive crops such as barley.

Very good yield response to liming in most crops, except lupins. Better nutrition and more crop options. The lower the pH and/or higher the clay, the higher the lime rate.

Good yield response to surface application of lime is expected with time. The lower the pH and/or higher the clay content, the higher the lime rate required. Grow aluminium-tolerant crops and varieties.

Surface application of lime not effective in the short to medium term. Deep banding with ripping and some surface application may be helpful. High rates required. Grow aluminium-tolerant crops.

Note: Refer to Farmnotes on soil acidity and liming published by the Department of Agriculture, Western Australia.
**Step 4a**

**Hardsetting, crusting, surface sealing or cracking soils**

1. Is the soil texture within 30 cm of the surface heavier than a loamy to clayey sand (i.e. sandy loam or heavier)?
   - **No** → **Go to step 5**
   - **Yes**
     - When the soil is completely dry, are there surface cracks more than 10 mm wide?
       - **No** → **Go to step 4b**
       - **Yes**
         - **When the soil is completely dry, are there surface cracks more than 10 mm wide?**
           - **No** → **Go to step 4b**
           - **Yes**
             - Is the soil self-mulching (i.e. breaks into crumbs or small peds/structural units)?
               - **No** → **Go to step 4b**
               - **Yes**
                 - Test for dispersion (Appendix 2). If dispersive, apply gypsum. Work the soil only at correct moisture content. No-till with stubble retention and removing stock during wet periods is recommended.

This soil should be productive if managed properly. Periodic soil analysis for exchangeable sodium percentage (or cation ratios) is recommended and if sodium levels are increasing relative to calcium, topping up calcium levels with gypsum would maintain the soil in good condition. If there are gilgais (which some farmers call crabhole clay), raised beds may be an option, but maintenance may be on-going and costly. If poor yielding, check for nutrient deficiencies and toxicities.
Step 4b

**Hardsetting, crusting or surface sealing soils**

- Does the soil set hard or form a surface seal or a surface crust on drying?
  - Yes
  - No ripping required unless there is sub-surface compaction. If the structure is stable but still poor yielding, check for nutrient deficiencies or toxicities. See TopCrop Australia Nutrition Ute Guide (Primary Industries and Resources, South Australia).

- Does the soil disperse, slake or slake and disperse (see note at bottom of page on test for dispersion and/or slaking)?
  - Yes
    - Disperses
    - Will respond to gypsum. Ripping may cause trafficability problems unless gypsum can be slotted into rip lines. The effect of ripping may not last if gypsum is only applied to surface. May need to apply Cu, Zn & Mn and more P than in other areas. If applying gypsum, add more N than normal. Boron toxicity may be a problem in some alkaline soils. If boron-toxic, grow tolerant crops and varieties.
  - No
    - Slakes
    - Slakes and disperses
    - May or may not respond to gypsum. Do test strips. Increasing organic matter by no-till crop establishment and stubble retention is recommended.

Note: Refer to Appendix 2 for details of test for dispersion and slaking, as well as, management options for slaking and/or dispersing soils.
Step 5

Traffic pans, hardpans and other restrictions to root growth

Is the soil texture sandy (sand, loamy sand or clayey sand) to a depth of 35-40 cm?

Yes

When the soil is wet, try pushing a steel rod about 8-10 mm in diameter into the soil. If there is a traffic pan, some resistance to penetration will be felt as it passes through the traffic pan, after which it will go through easily again. Is there a traffic pan within 40 cm?

Yes

Deep ripping recommended. The effect of ripping would last longer with tramline farming.

Caution: Rip sodic clay layer only if gypsum can be applied into rip line.

No

No, sandy loam or heavier.

Is there a detectable compacted layer on a pit face (test with a magnifying glass or probing with a knife blade or hand shovel) within 30 cm, as opposed to a texture contrast layer as in a duplex soil? Compaction may go deeper than 30 cm depending on the nature of traffic.

Is there a traffic pan within 40 cm?

Yes

Is there a siliceous pan, clay pan, cemented gravel or a dense clay layer within deep ripping depth?

Yes

Ripping may be helpful. Do a structural stability test as in step 4 for gypsum responsiveness. The effect of ripping would last longer if traffic is on tramlines.

No

No

Beyond ripping depth is there a dense poorly structured subsoil, calcrite pan, siliceous pan, red-brown hardpan, clay pan, cemented gravel or bedrock within 80 cm?

Yes

Nothing much can be done. Tailor inputs according to yield potential.

No

No

Problem may be due to nutrient deficiencies or toxicities or root diseases. Do soil and tissue tests.

Note: If the soil texture is heavier than a sandy loam and has good structure, 50-60 cm depth is enough to give good yields.
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GLOSSARY

**ICV economic analysis tool**: Invest (in amelioration) Cull (from cropping) or Vary (inputs) economic analysis tool developed by Graeme McConnell, Planfarm Pty Ltd, 4 Clive Street, West Perth, WA 6005.

**LMS**: Land Management Society, Western Australia.

**pH<sub>w</sub>**: soil pH measured in water at a soil to solution ratio of 1:5 w/v.

**pH<sub>Ca</sub>**: soil pH measured in 0.01M calcium chloride at a soil to solution ratio of 1:5.

**EC<sub>(1:5)</sub>**: electrical conductivity measured in water at a soil to solution ratio of 1:5 w/v, which is a measure of salinity.

**dS/m**: deciSiemens per metre – standard unit of measuring electrical conductivity.

**mS/m**: milliSiemens per metre – unit of measuring EC (used commonly in WA). 1 dS/m = 100 mS/m.

**ESP**: Exchangeable Sodium Percentage-exchangeable sodium fraction expressed as a percentage of cation exchange capacity.

**Gilgais**: depressions and mounds formed on soil surface due to shrink swell (cracking) clays.

**Tramline farming**: also called controlled traffic farming, a crop production system where machinery wheel tracks are confined to defined tramlines to reduce soil compaction in other areas by matching equipment widths.
SOIL FIELD CARD

PROCEDURE FOR FIELD TEXTURING SOILS

The texture of a soil reflects the size distribution of mineral particles finer than 2 mm. If it is gravely, remove the gravel.

1. Take a sample of soil that will sit comfortably in the palm of your hand from the layer of soil to be textured.

2. Form a bolus of soil by moistening the sample with water and kneading it. Knead the soil for 1-2 minutes while adding more water or soil until it just fails to stick to the fingers. The soil is now ready for shearing (ribboning). Note how the bolus feels when kneading it.

3. Press out the soil between the thumb and forefinger to form a ribbon. The ribbon should only be 2–3 mm thick.

The behaviour of the bolus and of the ribbon determines the field texture. Do not determine the texture grade solely on the length of the ribbon.

<table>
<thead>
<tr>
<th>Texture Grade</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY</td>
<td>Plastic bolus like putty, smooth to touch, becomes stiffer as clay content increases, forms ribbon of 50–75 mm or more.</td>
</tr>
<tr>
<td>CLAY LOAM</td>
<td>Coherent plastic bolus, smooth to manipulate, forms ribbon of 40–50 mm.</td>
</tr>
<tr>
<td>SANDY CLAY LOAM</td>
<td>Strongly coherent ball. Feels sandy, forms ribbon of 25–40 mm.</td>
</tr>
<tr>
<td>LOAM</td>
<td>Feels smooth &amp; spongy, forms ribbon of about 25 mm.</td>
</tr>
<tr>
<td>CLAYEY SAND</td>
<td>Clay stains fingers, very slightly coherent ball, minimal ribbon 5–15 mm.</td>
</tr>
<tr>
<td>LOAMY SAND</td>
<td>Very slightly coherent ball, minimal ribbon about 5 mm.</td>
</tr>
<tr>
<td>SAND</td>
<td>Cannot form a ball. Non-coherent.</td>
</tr>
</tbody>
</table>
Soil Structure Test

Structural stability in soils with clay contents greater than a loamy sand or a clayey sand can be evaluated by the following tests for dispersion and slaking.

**Slaking:**
- Slaking is the disintegration of dry soil aggregates into tiny pieces when wet rapidly.
- Slaking causes the soil to slump and then it sets hard into a compact mass on drying in most soils.

**Dispersion:**
- Dispersion is the breakdown of soil aggregates into individual mineral particles – sand, silt, and clay.
- Dispersion causes the soil to appear muddy when wet rapidly.

**Slaking Test:**
1. Take a small piece of a dry soil clod about 1 cm in size, and drop it into a small glass of distilled or rain water (rain water from concrete tanks not suitable).
2. The clod will disintegrate into tiny pieces with air bubbles escaping. If it slakes, it will happen within a few minutes.

**Dispersion Test:**
1. Leave the sample from slaking test undisturbed for 24 hours to see whether the soil disperses without remoulding (highly dispersive). For soils that need an input of energy for dispersion, such as the impact of rain drops or cultivation or stock trampling; take a handful of pulverised soil (after removing gravel), moisten it with distilled or rain water and mix it and knead it thoroughly for 4–5 minutes with the fingers.
2. Make a small ball about 8–10 mm in size, drop it gently into a glass of distilled or rain water and leave it for 24 hours.
3. If the soil is dispersive, it will disperse with the water making it cloudy or muddy. If not, it will be clear or settled.

<table>
<thead>
<tr>
<th>Gypsum Responsiveness</th>
<th>Soil Properties</th>
<th>Management Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>Highly dispersive (disperses without remoulding)</td>
<td>Apply 2.5–5 t/ha gypsum (generally higher the pH or sodicity). Adopt no-till with stubble retention. Remove stock during wet periods.</td>
</tr>
<tr>
<td>+ ++</td>
<td>Dispersive (disperses after remoulding)</td>
<td>Apply 2.5–5 t/ha gypsum. Adopt no-till with stubble retention. Remove stock during wet periods.</td>
</tr>
<tr>
<td>+ + +</td>
<td>Slaking and dispersing</td>
<td>Do test strips. May or may not respond to Gypsum. Increase organic matter by no-till and stubble retention. Remove stock during wet periods.</td>
</tr>
</tbody>
</table>

**Test for Dispersion:** Leave the sample from slaking test undisturbed for 24 hours to see whether the soil disperses without remoulding. If it disperses, it is highly dispersive. If not, it is either dispersing or slaking.

**Soil Structure Test**
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An electronic version of this booklet can be found at: www.agric.wa.gov.au

The web version of this booklet has quick links to the ICV economic analysis tool, tramline farming, relevant Farmnotes and photos of some problem soils.