Report card on sustainable natural resource use in agriculture
Status and trend in the agricultural areas of the south-west of Western Australia

Supporting your success
2.6 Water repellence

**Key messages**

**Condition and trend**

- Water repellence is a widespread problem on soils with low clay contents or high organic matter levels in the topsoil, in the medium to high rainfall zones.

- The extent and severity of water repellence appears to be increasing as cropping increases together with early sowing, minimum tillage and reduced break of season rainfall. More baseline data is needed to carry out a quantitative assessment.

**Management implications**

- The average annual opportunity cost of lost agricultural production in the south-west of WA from water repellence is estimated at $251 million.

- Water repellence also increases the risk of wind and water erosion, off-site nutrient transport and possibly soil acidification through increased nitrate leaching.

- Increased area of cropping on soils in medium to high rainfall zones has increased the economic impact of water repellence, as these soils would previously have been in permanent pastures.

- Early and dry sown crops are more affected by water repellence than later sown crops. Amelioration of water repellence is therefore more important for early sown crops.

- Farming systems that increase soil carbon levels in the topsoil, such as stubble retention and no-till farming, are contributing to the increase in water repellence.

**Figure 2.6.1** Resource condition summary for water repellence.
<table>
<thead>
<tr>
<th>Ag Soil Zone</th>
<th>Summary</th>
<th>Condition and trend</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mid West</td>
<td>The northern part of this zone has problems with water repellence on the pale and yellow sandplain soils.</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>2 Mullewa to Morawa</td>
<td>The soils of this low rainfall zone generally have no problems with water repellence. Inversion ploughing may be improving the situation.</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>3 West Midlands</td>
<td>This zone is very susceptible to water repellence due to a high proportion of leached sands and sands over clay or gravel.</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>4 Central Northern Wheatbelt</td>
<td>The majority of soils that have higher clay contents are not vulnerable, although some areas of sandplain are very susceptible to water repellence.</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>5 Swan to Scott Coastal Plains</td>
<td>Most of the aeolian (wind deposited) sandy areas are severely water repellent. No problems where alluvial soils occur.</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>6 Darling Range to South Coast</td>
<td>Forest soils now in crop (previously pastures) have severe water repellence problems.</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>7 Zone of Rejuvenated Drainage</td>
<td>The higher rainfall western portion of the zone has water repellence in sandy gravelly areas.</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>8 Southern Wheatbelt</td>
<td>Majority of low rainfall areas have no problems. There are some problems on grey sands in the south of the zone.</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>9 Stirlings to Ravensthorpe</td>
<td>Similar to South Coast, but the shallow nature of sandy topsoils allows water to stay in the root zone.</td>
<td>Fair</td>
<td>Poor</td>
</tr>
<tr>
<td>10 South Coast – Albany to Esperance</td>
<td>Large areas of grey sands (deep and duplex) present water repellence problems when cropped. Perennial pastures overcome these constraints.</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>11 Salmon Gums Mallee</td>
<td>The heavier and often calcareous soils have no problems, but sandy surfaced soils may have water repellence problems.</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Table 2.6.1 Resource status and trends summary for water repellence

<table>
<thead>
<tr>
<th>Condition grades</th>
<th>Very good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Very poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water repellence uncommon/absent</td>
<td>Water repellence of minor abundance</td>
<td>Water repellence of low abundance</td>
<td>Water repellence common</td>
<td>Water repellence widespread</td>
</tr>
</tbody>
</table>

Recent trends

- Improving
- Deteriorating
- Stable
- Unclear
- Variable
- Evidence and consensus too low to make an assessment

Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
Overview

Soil water repellence is the resistance of soils to wetting, sometimes to the extent that they remain dry even after significant rainfall events or irrigation.

Soil water repellence is caused by the presence of organic hydrophobic coatings on soil particles. These coatings are commonly waxes, alkanes (paraffins) and long chain fatty acids that are left behind following the microbial breakdown of plant material. Soil organic matter may also be highly water repellent.

The consequences of water repellence are:

- poor crop and pasture establishment
- increased risk of wind and water erosion
- poor water and nutrient use.

Water repellence generally only affects the organic-rich surface layer as the soil below the surface usually has less hydrophobic compounds and consequently wets up more readily.

Most water repellent soils have clay contents of less than 1%. Soils with higher clay content (even yellow sandplain soils with as little as 3–4% clay) are generally not water repellent. Most soils with greater than 5% clay do not express water repellence unless excessive organic matter is present e.g. dry peat and mallet hill soils. Clay particles, which are less than 2 µm in size, have a large wettable surface area, compared to sand particles. They can coat the sand and organic matter, enabling wetting to occur.

The increase in farming systems that improve soil carbon levels in the topsoil, such as stubble retention and no-till farming, may contribute to the increase in water repellence. Recent studies, however, show that...
these systems do not necessarily reduce yields, and undisturbed root channels from previous crops may still allow good water infiltration to the root zone (Roper et al. 2013).

Water repellence is a significant land management issue in the south-west of WA, affecting more than three million hectares of sandy soils in the high and medium rainfall zones.

**Assessment method**

Assessment was conducted in three ways:

**Hazard from soil-landscape mapping**
Spatial extent of water repellence was derived from the soils and their properties described in DAFWA’s soil-landscape mapping of the south-west of WA.

Assessing water repellence hazard using the soil-landscape mapping is described in van Gool et al. (2005). The resultant hazard map is a prediction of the likelihood of water repellence occurring and is not based on actual measurements.

**Soil testing**
A very limited data set of laboratory soils testing has been used to validate the accuracy of the hazard map.

**Condition and trend determined from farmer surveys**
In addition, farmer surveys provide land managers perspectives on current condition and trend from observations on their own properties.

**Current condition and trend**
Nearly 3.3 million hectares of agricultural soils across the south-west of WA are at high risk of water repellence and a further 6.8 million hectares are at moderate risk (Figure 2.6.2). The cost of water repellence resulting in reduced production is estimated at $251 million per year (Herbert 2009).

While limited data are available for assessing current condition and tracking trends in water repellence, there are a several sources of evidence to determine if the extent of the hazard shown by the hazard map is realised in practice.

![Figure 2.6.2 Water repellence hazard. The classes represent the proportions of the soil-landscape map units with high water repellence hazard.](image)
Soil testing

The degree of repellence is assessed by the molarity of ethanol droplet (MED) test, which determines the concentration of an ethanol solution required to penetrate the soil surface in 10 seconds. Ethanol solution decreases the surface tension of water droplets as the concentration increases, which allows water easier entry into soils of increasing water repellence. This analysis is done under controlled temperature conditions (20–25 °C) in a laboratory. An abbreviated form of this method is carried out in the field.

There are a limited number of actual measurements of soil water repellence across the south-west of WA. Available data are presented below.

Analysis of data from field tests

The surface of 8800 sites from the DAFWA regional soils survey program were field tested for water repellence using the criteria in Table 2.6.2. The results indicate that water repellence is widespread throughout the south-west of WA (Figure 2.6.3). An analysis of these data with soil type (WA Soil Groups) demonstrates a strong correlation between water repellence and sand content in the topsoil (Table 2.6.3).

Table 2.6.2 Field test rating criteria for water repellence

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Non-water repellent</td>
<td>Water is absorbed into soil in 10 seconds or less</td>
</tr>
<tr>
<td>R</td>
<td>Water repellent</td>
<td>Water takes more than 10 seconds to absorb into soil and the 2-molar ethanol solution is absorbed in 10 seconds</td>
</tr>
<tr>
<td>S</td>
<td>Strongly repellent</td>
<td>2-molar ethanol takes more than 10 seconds to absorb into soil</td>
</tr>
</tbody>
</table>

Figure 2.6.3 Water repellence of sites measured in the field with the abbreviated MED test.

Table 2.6.3 Relationship between WA Soil Groups and water repellence

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Proportion of soils that are water repellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA Soil groups with a sandy surface</td>
<td>67%</td>
</tr>
<tr>
<td>WA Soil groups with a non-sandy surface</td>
<td>36%</td>
</tr>
</tbody>
</table>

Table 2.6.3 shows the proportion of soils that are water repellent based on WA Soil Groups.
Analysis of data from laboratory tests

The degree of water repellence is determined using the laboratory MED test (King 1981; Carter 2002). MED categories are shown in Table 2.6.4. Limited unpublished data from 1863 topsoil samples from the soil quality and DAFF soil carbon program (Daniel Murphy, UWA and Frances Hoyle, DAFWA) and DAFWA (Derk Bakker, David Hall and Paul Blackwell) are displayed the Figure 2.6.4.

The laboratory results, although less conclusive, indicate that water repellence is widespread except in the eastern and northern areas of the wheatbelt and the Salmon Gums Mallee zone, and most severe on coastal sandy soils (Figure 2.6.4). Summers (1987) estimated that 1–1.3 million hectares of the South Coast – Albany to Esperance zone were moderately to severely affected by soil water repellence. This was determined from soil samples collected at one kilometre intervals in transects from the coast to about 50 km inland, perpendicular to the coast.

Table 2.6.4 Categories of water repellence using the MED test

<table>
<thead>
<tr>
<th>Category</th>
<th>Molarity of ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very severe</td>
<td>&gt;3.5</td>
</tr>
<tr>
<td>Severe</td>
<td>2.3–3.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.1–2.3</td>
</tr>
<tr>
<td>Low</td>
<td>0.1–1.1</td>
</tr>
<tr>
<td>Nil</td>
<td>0</td>
</tr>
</tbody>
</table>

An analysis of all the data, where the clay percentage of the sample is known, demonstrates that the less clay in the sample the higher the repellence (Table 2.6.5)

Table 2.6.5 Relationship between topsoil clay percentage and water repellence

<table>
<thead>
<tr>
<th>Topsoil clay %</th>
<th>Proportion of samples in moderate, severe or very severe MED categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay &lt;9%</td>
<td>42%</td>
</tr>
<tr>
<td>Clay ≥9%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Figure 2.6.4 Water repellence for topsoil samples measured in the laboratory with the MED test. Source: Soil quality and DAFF soil carbon program (Daniel Murphy, UWA and Frances Hoyle, DAFWA), Derk Bakker (DAFWA), David Hall (DAFWA) and Paul Blackwell (DAFWA).
Farmer surveys

Farmer surveys in several areas of the south-west of WA indicate that water repellence is widespread, increasing, and significantly affects agricultural production (Davies et al. 2013).

A survey of 28 farmers in the West Midlands in 2010 indicated water repellence as their top constraint to production (46%) ahead of soil water holding capacity and soil acidity. About 85% of these farmers indicated that the water repellent soils on their property were increasing in both area and severity. These results are not surprising given that sandy surfaced soils of low clay content dominate this area and the move to minimum tillage leaves more organic residues in the soil.

A survey of 26 farmers of the Northern Agricultural area in 2011 indicated water repellence as their top constraint to production (28%) ahead of acidity, soil water holding capacity and compaction. About 77% of these farmers reported that the area of water repellent soils was fairly stable. The majority (65%) also indicated that the severity of water repellence was stable, but a significant number (30%) said that severity was increasing.

A survey of 30 farmers in the Darkan area in 2011 indicated water repellence as their top constraint to production (27%) ahead of acidity, soil water holding capacity and numerous other constraints (Davies et al. 2013). The majority also indicated that the area and severity was increasing (52% and 50% respectively).

A survey of 23 farmers in the Calingiri area in 2011 indicated water repellence as their top constraint to production (21%) ahead of acidity, soil water holding capacity and compaction.

Growers’ perceptions of trend in area and severity of water repellence in three areas are graphically represented in Figure 2.6.5.
Discussion and implications

Although water repellence is a widespread issue affecting agricultural production, the exact severity, extent and overall cost to production is unknown. Yield increases of 100% have been recorded in some trials where the water repellence has been ameliorated, with improvements in soil organic matter and greater nutrient uptake efficiencies (Carter et al. 1998).

Water repellence is mostly an issue facing the grains industries, where annual germination and crop establishment are affected by the non-wetting soils. Glencross (1984) commented on 100–150% increases in annual pasture production where water repellence had been ameliorated by soil wetting agents, indicating there are also benefits for the livestock industries from managing water repellence. Permanent pastures, perennial pastures and irrigated crops are less affected.

Potato tubers inside mounds of non-wetting soils on the Scott River plain were difficult to wet.

A range of management options for cropping are available to overcome this issue, as a result of new techniques developed over recent years. The options can be divided into two categories:

- mitigation or short-term strategies that assist crop establishment but need to be repeated each year
- amelioration or more expensive long-term options which are done once but have a more sustained impact.

Mitigation options include improved furrow sowing (Blackwell et al. 1994), the use of banded wetting agents, incorporating a blanket wetting agent or water absorber, and full stubble retention with low disturbance seeding (Roper et al. 2013). Precision sowing into the previous year’s seeding slot is being tested as it has been shown that rainfall appears to prefer these old channels.

Amelioration encompasses rotary spading, soil inversion through the use of a mouldboard plough and clay spreading or delving.

Lenses of topsoil buried to about 40 cm using a mouldboard plough on a Yellow deep sand at Badgingarra.
Any decision on choice of an individual or combination of strategies should be underpinned by growers’ knowledge of their soil types, the area of repellent soils and their ability to finance management changes.

The more productive soils should be progressively ameliorated first – these are soils with good yield potential once water repellence has been overcome, while mitigation strategies may be employed for the balance of the program.

The best approach may be to use improved furrow sowing and/or banded wetting agents as mitigation tools. These work across a range of soil types over the whole seeding program at low cost. Some management actions to manage water repellence may have unwanted consequences, for example, spading and mouldboard ploughing results in significant disturbance of the soil surface which may lead to wind erosion in dry conditions.

The higher cost of amelioration strategies can then be applied to smaller areas of strong water repellence or where there should be big productivity gains.

Growers may even consider alternative land uses not affected by the need for annual germinations, like perennial pastures. Planting trees in areas affected by severe water repellence can avoid the high amelioration costs, particularly where repellence returns quickly. Claying of these areas is still being practised however.

**Recommendations**

- More baseline data is collected to enable a quantitative assessment of the spatial extent, severity, trends and costs of water repellence, particularly the effect of management on the change in water repellence status.
- Research, development and extension to develop and communicate effective and economical methods to manage and ameliorate water repellence is continued.

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**Acknowledgements**

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**Sources of information**


Herbert, A (2009). Opportunity costs of land degradation hazards in the South-West Agricultural Region. Resource management technical report 349, Department of Agriculture and Food, Western Australia.


Summers, RN (1987). MSc thesis. ‘The incidence and severity of non-wetting soils of the south coast of Western Australia’ University of Western Australia, Institute of Agriculture.