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

Nutrient status (phosphorus)
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Cover photo: Harvesting the wheat crop at Mingenew.
2.8 Nutrient status (phosphorus)

**Key messages**

**Condition and trend**
- Nutrients, such as phosphorus (P), are essential for profitable agriculture in the south-west of WA; however, excess P – more than is required for optimal production – is stored in many agricultural soils.
- On average, pasture soils and arable soils contain 1.3 times and 1.6 times respectively, as much P as is required for optimal production.
- Production in P-enriched soils is more likely to be constrained by soil acidity (50–60% of pasture and arable soils), potassium (K) (50% of pasture soils and less than 10% of arable soils), and sulphur (S) (30% of pasture soils).

**Management implications**
- The direct cost of excess P application in the agricultural areas of the south-west of WA is estimated to be about $400 million per year.
- Reducing the amount of P to optimal levels could lead to economic benefits (reduced fertiliser costs or redirection of fertiliser costs to removing other constraints), and reducing the off-site impacts of agriculture (reduced leaching and run-off of P).
- Removing other nutrient and soil constraints (acid soils, K, S) is likely to increase productivity and profit of agriculture.
- Regular monitoring of soil nutrients at a paddock scale will provide the information to optimise fertiliser application and profitable yields, and minimise off-site impacts.
- Industry bodies, especially those providing fertiliser advice, need to be aware of this nutrient status assessment and should provide fit-for-purpose, element-specific fertiliser recommendations to derive optimal economic outcomes for producers and to minimise off-site impacts.
Figure 2.8.1 Resource condition summary by shire (left) and by Ag Soil Zones (right).
Table 2.8.1 Resource condition and summary trends for nutrient status (phosphorus)

<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>Soil P fertility well in excess of optimal range. Ceasing P application would see P levels very slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Mullewa to Morawa</td>
<td>Soil P fertility well in excess of optimal range. Ceasing P application would see P levels very slowly decrease to optimal levels.</td>
<td></td>
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<tr>
<td>3 West Midlands</td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Central Northern Wheatbelt</td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Swan to Scott Coastal Plains</td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Darling Range to South Coast</td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels very slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Zone of Rejuvenated Drainage</td>
<td>Soil P fertility is well in excess of optimal range. Ceasing P application would see P levels very slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 2.8.1 Resource condition and summary trends for nutrient status (phosphorus) (cont.)

<table>
<thead>
<tr>
<th>Ag Soil Zone</th>
<th>Summary</th>
<th>Condition and trend</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>8 Southern Wheatbelt</strong></td>
<td>Soil P fertility well in excess of optimal range. Ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>9 Stirlings to Ravensthorpe</strong></td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>10 South Coast – Albany to Esperance</strong></td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels slowly decrease to optimal levels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>11 Salmon Gums Mallee</strong></td>
<td>Soil P fertility in excess of optimal range. This could change to well in excess with continued P application; however, ceasing P application would see P levels very slowly decrease to optimal levels.</td>
<td></td>
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</tr>
</tbody>
</table>

**Condition grades**
- P fertility index = >0.75 (P very deficient)
- P fertility index = 0.75-0.9 (P deficient)
- P fertility index = 0.9-1.1 (P optimal)
- P fertility index = 1.1-1.5 (P excess)
- P fertility index = <1.5 (P well in excess)

**Recent trends**
- Improving
- Deteriorating
- Stable
- Unclear

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

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**Condition and trend**

**In condition**

**In trend**
Overview

This chapter assesses the phosphorus (P) status of agricultural soils and the implications for both production and the environment. In this assessment the focus is on soil P; however, this is put into context with other potential constraints to plant growth, such as soil acidity, potassium (K) and sulphur (S), to derive a summary of the nutrient status of soils in the south-west of WA.

Nutrients are required for productive agriculture. Too little of any nutrient can lead to poor biological growth and agricultural production and a poor economic outcome. Equally, too much of a nutrient can be an economic disadvantage if it is still being applied, and can lead to losses that result in off-site impacts. For example, algal blooms can occur if nitrogen and P are lost from agriculture through run-off and leaching to waterways.

Western Australia’s soils have long been renowned for their infertility. At the end of the 19th century, large increases in plant growth were obtained with the application of guano from the Abrolhos Islands, and later, imported superphosphate, the first inorganic fertiliser used in WA. Since then many farmers have adopted a traditional approach to P fertiliser management of ‘a bag of super to the acre each year’.

Given the traditional approach to P fertiliser management (Weaver and Wong 2011) nutrient applications, especially of P, need to be carefully managed to maximise farm profitability and reduce off-site impacts. Fertiliser represents the single largest farm input cost (Western Australian Farm Inputs Taskforce 2009) and fertile agricultural landscapes have a major impact on water quality (Dougherty et al. 2011).

Assessment method

Available records (140 000 samples from 1982–2012) were assessed to determine nutrient status for P, K, S, and soil acidity for arable and pasture soils in the south-west of WA. The proportion of samples above or below critical soil test values was used to determine the extent of a nutrient excess or deficit. A soil P fertility index (P_{90}) was derived from the ratio of measured soil test P to critical soil test P values. This index is an indicator of the severity of soil P excess or deficit to achieve 90% of maximum production of pastures or crops. Based on this index, values of 1 are optimum, and those greater than or less than 1 are in excess or deficient respectively.

Some adjustments can be made for potential bias in P fertility assessments due to the way various agricultural sectors use soil testing and apply the results of soil tests. For example, the Australian Bureau of Statistics (2010) reports that only 25% of farms undertake soil
testing, and recent assessments of Australian Soil and Plant Analysis Council (ASPAC) laboratories suggests that 85–90% of all soil sampling is undertaken for cereal cropping. Additionally, soil test P values for paddocks that are routinely soil tested were found to be marginally elevated in comparison to those that are not. Details of the methods used to determine the soil fertility status of P, K and S, and soil acidity can be found in Weaver and Wong (2011).

Current status and trends

The median $P_{90}$ fertility index of pasture and arable soils was 1.29 and 1.57 respectively. This is within the range (1.00–1.74) of other soil testing programs conducted from 1982 to 2012. Soils deemed to be P deficient ($P_{90} < 1$) were on average within 20% of the critical soil test P values to achieve optimal production, while those deemed to have excess P ($P_{90} > 1$) had on average 60–70% more available soil P than required. Overall, 63% of pasture soils and 87% of arable soils had excess P ($P_{90} > 1$).

Adjustments for potential bias reduced the median $P_{90}$ fertility indices of pasture and arable soils to 1.13 and 1.50 respectively. The number of pasture and arable soils that exceeded the $P_{90}$ critical soil test values was adjusted down to 56% and 80% respectively (Table 2.8.2). This assessment of soil P status for cropping soils shows similar results to that of Neuhaus et al. (2012).

Multiple nutritional issues have potential to impact on plant productivity. More than 70% of soils had pH less than 5.5, and 49% and 8% of pasture and arable soils respectively, were K deficient. More than 60% of pasture soils were assessed as S deficient. More than 50% of soils had excess P and were also assessed as acid (pH < 5.5), potentially reducing the uptake of available P and other nutrients. Twenty-nine per cent of pasture soils and 7% of arable soils had excess P and were also assessed as K deficient. For pasture soils, 19% had excess P as well as being assessed as acid, and K and S deficient.

Table 2.8.2 Assessment of nutrient status

<table>
<thead>
<tr>
<th>Summary of other sampling programs</th>
<th>South-west agricultural zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>pastures</td>
<td>wheat</td>
</tr>
<tr>
<td>Year</td>
<td>2009–10</td>
</tr>
<tr>
<td>Number of samples</td>
<td>109,000</td>
</tr>
<tr>
<td>Sampling density (hectares per sample)</td>
<td>230</td>
</tr>
<tr>
<td>Median P fertility index</td>
<td>1.29 (1.13)</td>
</tr>
<tr>
<td>Median P fertility index (for P deficient soils)</td>
<td>0.84</td>
</tr>
<tr>
<td>Median P fertility index (for soils with excess P)</td>
<td>1.60</td>
</tr>
<tr>
<td>% with excess P</td>
<td>63 (56)</td>
</tr>
<tr>
<td>% with pH constraint</td>
<td>77</td>
</tr>
<tr>
<td>% with K deficiency</td>
<td>49</td>
</tr>
<tr>
<td>% with S deficiency</td>
<td>61</td>
</tr>
<tr>
<td>% with excess P and a pH constraint</td>
<td>50</td>
</tr>
<tr>
<td>% with excess P and a K deficiency</td>
<td>29</td>
</tr>
<tr>
<td>% with excess P and a S deficiency</td>
<td>28</td>
</tr>
<tr>
<td>% with excess P and a pH constraint, and K and S deficiency</td>
<td>19</td>
</tr>
</tbody>
</table>

Note: Values in parentheses have been adjusted for potential bias.
Discussion and implications

Fertiliser represents the single largest input cost to farming in WA. Optimising fertiliser use presents economic and environmental opportunities for agriculture. Soil testing to inform fertiliser decision-making can reduce unnecessary economic and water quality risks.

Soils with excess P

For soils with excess P ($P_{90} > 1$), applying additional P fertiliser rarely contributes to positive economic outcomes. In contrast, not applying P represents an economic opportunity as P reserves in the soil are used. Running down soil P reserves (the super bank) can continue until the critical soil test P value is reached, at which time P should be applied to maintain optimal soil P fertility.

Overcoming constraints to crop and pasture production by applying required nutrients, such as K and S, or by applying lime to reduce soil acidity, provides conditions more likely to optimise production than applying more P. Such conditions exist when critical soil test values are reached and not exceeded. At this point, crops and pastures use nutrients optimally, and the risk of nutrients, such as P, being lost from agricultural soils reduces (Figure 2.8.2).

Soils with excess P represent an increased off-site water quality risk compared to soils with optimal P fertility. Adding more P unnecessarily increases off-site risks above that already posed by high P fertility soils.

Soils with optimal P

Soils containing optimal P levels ($P_{90} = 1$) require maintenance P applications to retain their status. Pastures and crops grown on these soils may not achieve production potential if there are other constraints caused by soil acidity or deficiency of K or S. In the presence of these constraints, pastures will not be able to optimally use soil P, and water quality risks will be greater. It is therefore important to achieve balanced soil nutrition to optimise economic outcomes and minimise off-site water quality impacts (Figure 2.8.2).

Figure 2.8.2 The relationship between soil nutrient levels for P, K and S, crop or pasture growth, and the risk of P loss.
Soils with P deficiency
For soils with P deficiency ($P_{90}<1$), applying additional P often contributes to positive economic outcomes. Failure to apply P in these situations may contribute to water quality risks because of poor plant growth, low nutrient uptake, and erosion (Figure 2.8.2). Increasing soil P reserves (the super bank) should continue until the critical soil test P value is reached, at which time maintenance P applications should be applied to retain soil P fertility at an optimal level.

P fertiliser decisions
The extensive datasets assessed here suggest that P should be recommended in less than 40% of pasture soils and less than 20% of arable soils. However, these general findings of high P fertility should be applied cautiously to fertiliser strategies at the individual farm and paddock level. Farm-scale fertiliser strategies should be determined through the use of routine soil testing, and in light of varied production constraints. Soil testing should be encouraged, particularly in the beef and sheep grazing sector, where there appears to be a low uptake of this practice to inform fertiliser strategies. The P status on a representative property in the Vasse–Geographe Catchment demonstrates both the variable, but generally excessive, levels of P across the property (Figure 2.8.3).

Industry bodies, especially those providing fertiliser advice, need to be aware of these findings and should provide fit-for-purpose, element-specific recommendations to derive optimal economic and environmental outcomes.

Compromises between agricultural and water quality objectives
Reducing the fertility status of soils to the agronomic optimum of P will not necessarily remove water quality risks altogether. However, it will reduce the high risks of unacceptable environmental consequences associated with current excessive soil P levels in the absence of other more effective measures to reduce nutrient loss to waterways.

Reducing the use of high water soluble forms of P will reduce P loss from sandy soils but will have little impact on P loss from non-leaching soils. Removing fertilisers with high water soluble P from the market may have a negative economic impact on agriculture, while not providing a universal benefit to water quality.

Implications for water quality risks
Risks to water quality increase as soil P fertility increases (Dougherty et al. 2011). Location, landscape characteristics and excess soil P levels can influence nutrient delivery to coastal waterways. While excess soil
P, and therefore greatest water quality risk, appears to be present in wheatbelt soils (Figure 2.8.1), this risk is offset by the location of this excess soil P in relation to waterways that are at risk. Lower rainfall in the wheatbelt reduces leaching and run-off, and any nutrient run-off entering streams has to travel long distances to reach coastal waterways. During the long path to the coast, much of these nutrients are assimilated and only move slowly downstream.

In contrast, soils in coastal and higher rainfall areas (more than 600 mm annually) still contain excess soil P. The higher rate of leaching and run-off, and proximity to sensitive waterways, increases the water quality risk from these areas, because there are fewer opportunities for nutrient assimilation within the stream network. Nutrient loads can reduce by up to 100 times through assimilation within a stream network, whereas the degree of P excess varies only up to 2 times.

Livestock industries, particularly those based on the coastal plain, and where the annual rainfall is greater than 600 mm, present the greatest scope for improved economic and environmental outcomes by adhering to fertiliser recommendations derived from soil testing. This scope occurs because of the proximity of these industries to sensitive waterways, and the reduced opportunity for nutrient assimilation within the stream network.

Assessment biases

This assessment methodology has potential biases that may both overestimate and underestimate soil P fertility. Soil test datasets may represent data from producers who are motivated to undertake soil testing, and soil fertility may be higher for those who are motivated to test compared to those who are not. This may overestimate soil P fertility.

In contrast, most early research on the response of pasture to P was based on clover pasture. Consequently the critical soil test values used in pasture soils, and this assessment, are based on the P requirements of clovers. However, different pasture species respond to P fertiliser to different extents. Clover is not very efficient at using P and requires more P in the soil to grow to its maximum potential. Grasses are much more effective than clover at taking up P; they require less P in the soil to reach maximum production. Many present-day pastures are dominated by grass and the use of critical soil test values for clovers will result in more P in the soil than grass requires. This may underestimate soil P fertility.

Recommendations

- Grazing and cropping businesses soil test paddocks routinely, at least every three years, to reduce both economic and water quality risks. This routine will enable the design of evidence-based fertiliser programs, ensuring that agricultural systems operate with optimal soil fertility and the risk of nutrient loss by leaching or run-off is minimised.
- Undertake analysis of commercial soil test data at a state level at approximately five-year intervals to identify temporal changes to soil fertility and water quality risk, given that under typical fertiliser management strategies, including cessation of P application, soil P levels are likely to change slowly.
- Undertake more research on how grass-based pasture systems respond to P and other nutrients. This is important given the cost of fertiliser and the need to minimise the off-site impacts of fertiliser use.
- Industry bodies, especially those providing fertiliser advice, are made aware of this nutrient status assessment and encouraged to provide fit-for-purpose, element-specific fertiliser recommendations to derive optimal economic outcomes for producers and to minimise off-site impacts.
Acknowledgements
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Sources of information