Mapping subsoil constraints

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A flexible choice of data layers can be used to locate and identify subsoil constraints to root growth such as acidity and soil depth

Subsoil constraints have been estimated by GRDC to cost the Australian grains industry over one billion dollars annually, by limiting root-growth into the subsoil and crops ability to take-up water and nutrients. Loosing access to water in a water-limited environment is not smart because in addition to the financial cost associated with lost yields, there is an environmental cost due to increased deep drainage, nutrient leaching and secondary salinity.

Subsoil constraints do not occur uniformly across the paddock and identifying where they occur is the first step in improving the financial and environmental performance of the farm. There are many types of subsoil constraints including acidity, sodicity, compaction, boron toxicity, root-impeding gravel layer etc.

Dr Mike Wong and colleagues at CSIRO used a range of data sources from a 200 hectare paddock at Buntine, WA to test two hypotheses.

- Selected yield maps, soil type maps and geophysical sensing, such as apparent electrical conductivity (ECa) and gamma radiometric sensing, could be used by agronomists in collaboration with growers to locate areas affected by subsoil acidification.
- Selected yield and gamma radiometric maps could be interpreted to locate shallow soils over root-impeding cemented gravel layer.

The crop model APSIM (The Agricultural Production Systems Simulator) was used to show that in a water limited environment, subsoil constraints have the greatest yield depressing effect in medium to wet years. This is because there is sufficient rainfall to permeate the subsoil but the crop cannot access this water. Yield maps selected from these years are therefore expected to be the most informative for identifying where subsoil constraints are located across the paddock. Targeting soil tests in the low yielding areas recorded in wet years could help identify the specific subsoil constraints including acidity and shallow soils.

"In sandy soils, clay content controls plant available soil water holding capacity (PAWC) and consequently crop yield and base cation removal in harvested grain. Clay content further influences soil acidity by controlling pH buffering capacity and rate of acid production due to nitrate leaching. Therefore, the risk of soil acidification should vary with soil type" explained Mike Wong.

"But many farms do not have detailed soil type maps for every paddock, so, gamma-radiometric and ECa surveys can be used to estimate clay content across a paddock.

In non-saline shallow soils, an ECa survey can be used to estimate depth to the subsoil constraint and hence the PAWC, if there is sufficient contrast in electrical conductivity between the soil layer and the underlying subsoil material. For example, ECa surveys are used to estimate soil depth to clay pans in duplex soils. However, an ECa survey cannot be used to estimate depth of sandy soil over cemented gravels, commonly found in highly weathered Australian landscapes. This is because both materials have similarly low electrical conductivities, in the order of 0.1-1.0 mS/m.

These cemented gravels contain natural radioactive isotopes of potassium, uranium and thorium. Gravels are particularly enriched with thorium whereas sandy soils common in WA consist mostly of quartz and contain little thorium. For this reason the researchers hoped to use gamma-radiometric surveys to locate subsoils.

The paddock used to test these hypotheses was sown to wheat in 1996, 1999, 2001, 2003 and 2005. In the other years lupins or canola were sown and a pasture phase was included at about a five year interval.

A common method of paddock analysis used for the creation of zones is to combine yield maps from a range of seasons with other spatial data layers such as ECa and terrain. This research instead selected a single yield map from 1999, when above average growing season rainfall occurred and yields were expected to be most sensitive to subsoil constraints. This map was used to locate the low yielding areas of the paddock (Figure 1a).

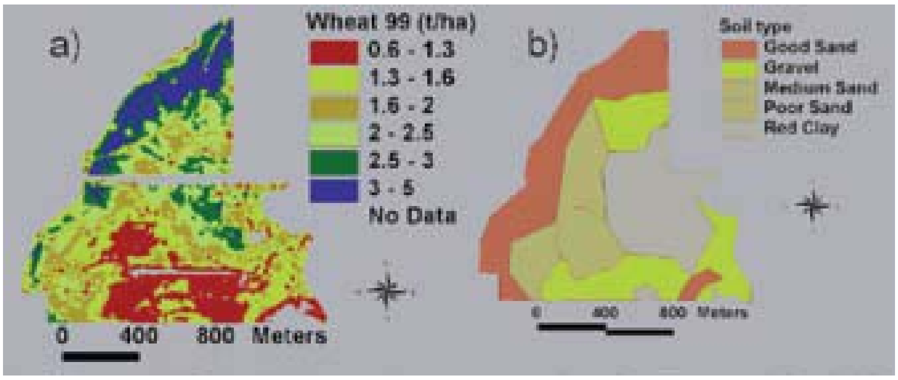

Figure 1. Wheat yields in 1999 (a) and grower-produced soil map of the field (b).

Based on paddock observations and experience the grower produced a soil type map, resulting in five soil types across the paddock, ranging from clayey loams (grower classified as red clay), deep white sands (poor sand) and gravels (Figure 1b)

A gamma radiometric survey was carried out in February 2004 when the soil was dry and an ECa survey was carried out in June 2004 when the soil was wet. Both were executed on 30m line spacing using a quad bike.

All spatial data sets were kriged to a 5m grid allowing the data sets to be overlaid.

Soil pH in calcium chloride and soil depth were measured at 65 locations across the paddock to represent the different soil profiles (from 0 to 200cm, wherever possible and at 10cm intervals) in areas with a range of yields, ECa and gamma-emission values. In addition, twenty five topsoils (0-10 cm) were sampled across the paddock and analysed for bicarbonate extractable phosphorus and potassium and total nitrogen contents.

The research established that the combination of the grower's knowledge and a flexible choice of spatial data could successfully locate subsoil constraints across a paddock. Subsoil acidity occurred as expected in the areas mapped by the grower as coarse textured poor sand. Areas of low yield mapped in a wet year combined with the soil analysis also located these areas. However, two additional small areas of subsoil acidity that were not seen on the yield map were identified by combining the ECa and gamma radiometric data (Figure 2). With pH of 4.3 to 4.6 these two areas are at imminent risk for yield loss due to subsoil acidification. The early identification of these areas permits pre-emptive site specific treatments to be applied before the acidity becomes more acute and difficult to treat.

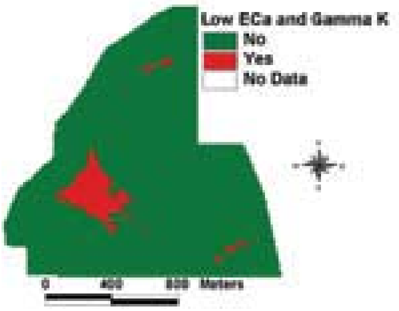

Figure 2. Areas where low apparent soil electrical conductivity <10 mS/m overlapped low gamma-ray emission from potassium <60 counts/100s, indicating very coarse textured soils with high risk of acidification.

In this paddock shallow soils occurred in the areas mapped as gravels. However, wheat yields in a wet year could only be used to locate one of the two areas of shallow soil. The other areas were located by sensing the strong gamma-ray emission from thorium. This suggests that in one area shallow soil was not limiting wheat exploitation of water and consequent yield. This result was assumed to be due to differences in the closeness of packing of the gravel layers as crops (lupin) with thicker roots were affected in this area. Therefore, in this situation separate analysis of yield and gamma radiometric data would be required to make decisions about fertilizer inputs to the paddock areas with shallow soils.

This work provides a flexible approach to locate and identify subsoil constraints to accommodate the individual grower's aptitude and preference, and access to spatial data. The desired outcome is better use of water in severely water-limited crops to improve the financial and environmental performance of the farm.

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