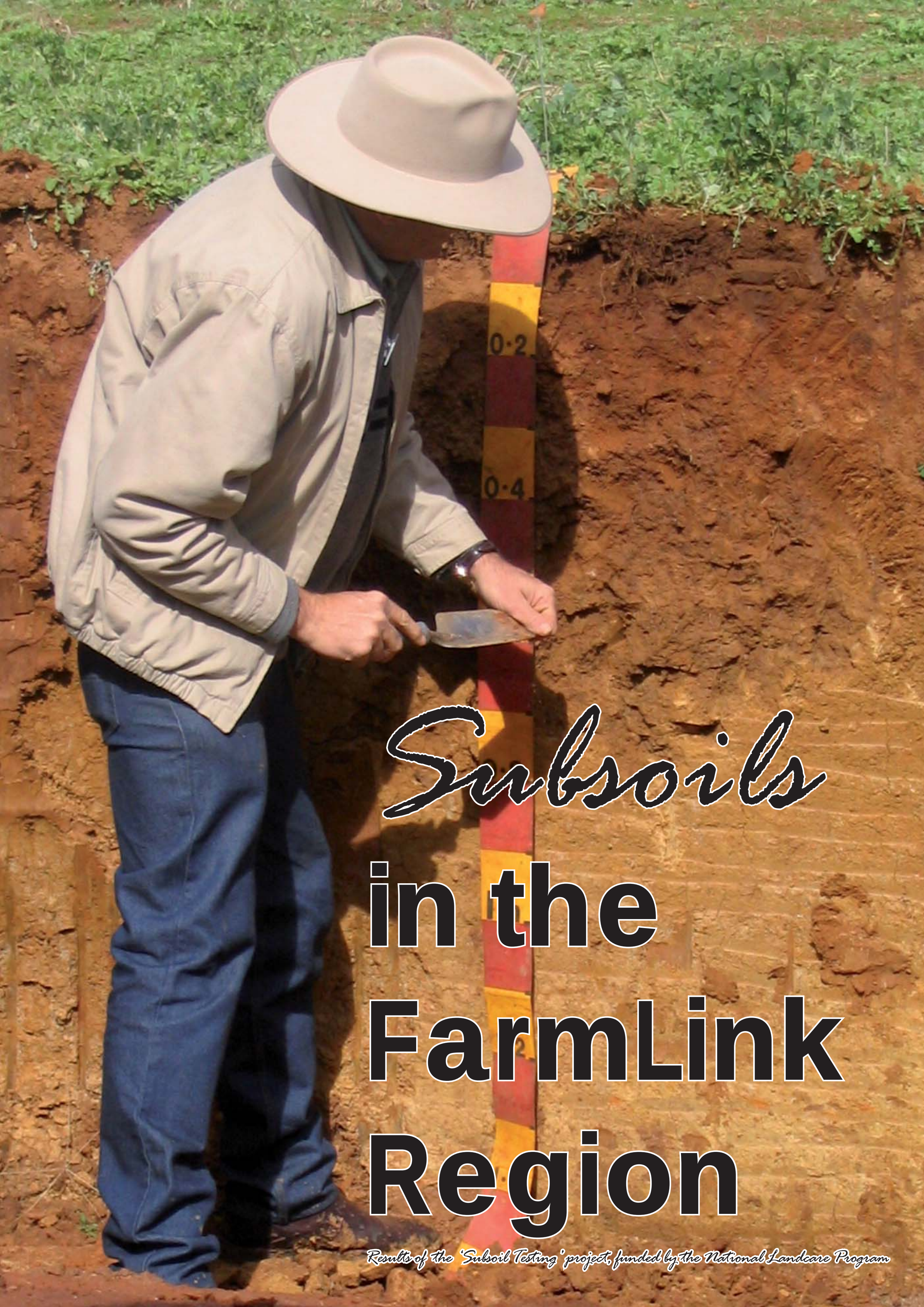


Subsoils in the FarmLink Region

Results of the 'Subsoil Testing' project, funded by the National Landcare Program

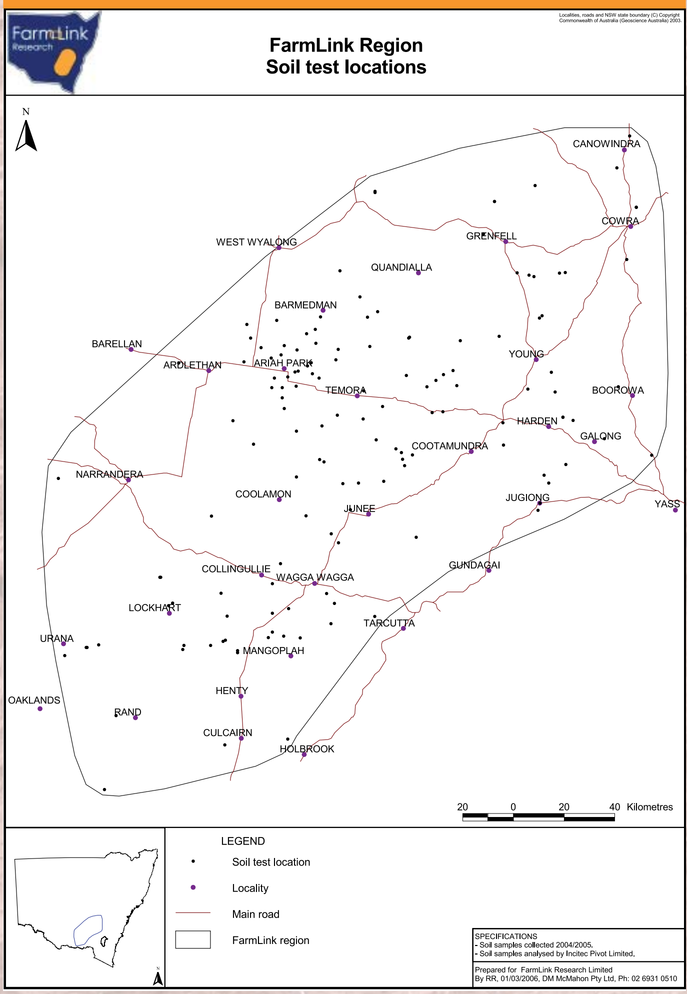
The project...

Topsoil testing is considered a routine management practice for most growers, with the importance of identifying and managing surface soil constraints for optimum production well recognised. However recent research has highlighted the potential impact subsoil constraints can have on our production systems, resulting in a renewed focus on identification of subsoil issues in the region.

In 2004, FarmLink successfully applied for the funding of a 1-year Subsoil Testing project through the National Landcare Program of the Department of Agriculture, Fisheries and Forestry. The project was established to raise awareness of subsoil issues and determine their extent and severity, commencing in 2005.

Almost 700 soil samples were collected from 139 paddocks across the FarmLink region (Fig. 1a), covering approximately 4 million hectares. The samples, which included intervals to 80cm depth, were collected primarily by local agribusiness and FarmLink staff. Samples down to 180cm depth were collected from 25 of the paddocks by CSIRO.

Figure 1a - Location of subsoil tests in the FarmLink region



Soil sampling at Grenfell, 2005

All soil samples were divided into intervals at sampling for analysis of individual layers:

- 0-10cm ('topsoil')
- 10-20cm ('subsurface')
- 20-40cm ('subsoil')
- 40-60cm ('subsoil')
- 60-80cm ('subsoil')

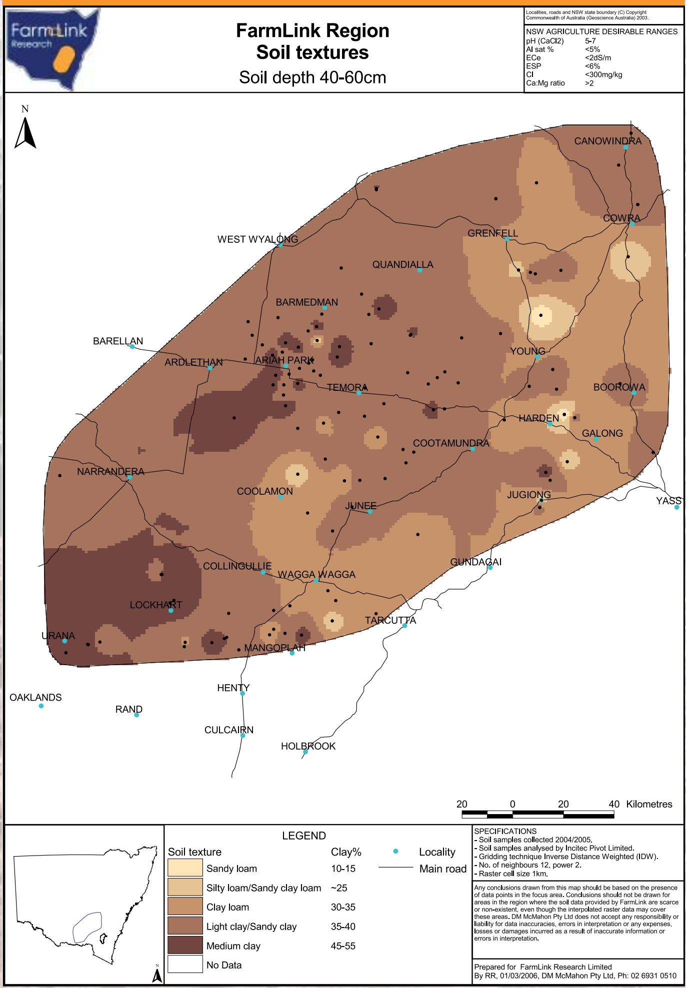
The samples were tested at the Incitec Pivot Laboratory in Werribee, Victoria, with analyses including:

- pH_{Ca}
- colour
- texture
- organic carbon
- chloride
- electrical conductivity
- exchangeable cations (including aluminium & sodium %)

Following collation of soil test results, FarmLink engaged local consultants, Rural Management Strategies Pty Ltd, to report on the major subsoil constraints in the region and potential management practices. DM McMahon Pty Ltd were engaged to produce zonal maps of each of the major constraints using critical limits.

Please note that some zones cover areas where few soil tests were taken (due to interpolated raster data). The maps should be used to make general observations only about the distribution and severity of subsoil constraints in the FarmLink region and to target further research.

Figure 1b - Soil texture at 40-60cm, showing lighter soils at depth to the east of the region and heavier clay soils in areas to the west and south.



General observations:

- Soil acidity, particularly **subsurface acidity**, was most prevalent on the lighter soils to the east of the region. This is to be expected where higher rainfall causes acidity in the topsoil to leach into the subsurface layer.
- The majority of subsoil problems were found on the heavier clay soils to the north of Temora and south of Lockhart. **Subsoil alkalinity, salinity and sodicity**, constraints which are typical of heavier textured soils, were most prevalent in these areas.

Future directions:

- Athough there has been a renewed focus on subsoils research in recent years, the inaccessibility of subsoils means mechanical amelioration practices in a broadacre situation has proven difficult. Biological amelioration, where the roots of tolerant plant species are able to modify the subsoil environment, may be the key.
- However, in some cases it may be more effective to simply adjust target yields and inputs to operate within the limitations of the subsoil constraint. To do this, future research needs to focus on potential yield losses resulting from different critical levels.

This document was written and compiled by Kirrily Condon, Communications Co-ordinator, FarmLink. FarmLink gratefully acknowledges the National Landcare Program for their funding, and to the following people and organisations for their support throughout the project:

- **Felicity Gummer, FarmLink (project co-ordinator)**
- **Ag'n'Vet, Wagga Wagga**
- **BFB, Temora**
- **Chandlers Landmark, Harden, Young & Monteagle**
- **Delta Agribusiness, Harden & Young**
- **Elders, Ariah Park**
- **Landmark, (formerly Junee)**
- **Lockhart Rural Services, Lockhart**
- **Ryders, Grenfell**
- **NSW Department of Primary Industries, Wagga Wagga**
- **CSIRO, Canberra**
- **Rural Management Strategies, Cootamundra & Wagga Wagga**
- **DM McMahon Pty Ltd, Wagga Wagga**

Australian Government
Department of Agriculture, Fisheries and Forestry

Subsoil... acidity

- ► Acidity defined as pH_{Ca} less than 5.0
- ► Associated with aluminium toxicity (>5%).
- ► Subsoil acidity found mostly at 10-20cm (45% of sites) towards the east of the region, improving with depth.
- ► Subsurface acidity can be slowly ameliorated by maintaining topsoil pH_{Ca} at 5.5 through liming; use of aluminium tolerant species may be more efficient. Other options are being investigated.

Distribution

Although acidity in the topsoil (0-10cm) across the FarmLink region is still widespread (affecting 50% of sites tested, *Fig. 2a*), this can be readily managed through the application of fine limestone.

Of greater concern is the extent to which acidity has leached into the subsurface (10-20cm, *Fig. 2e enlarged*). Subsurface acidity was found at 45% of all sites tested, particularly to the north and east of the region which corresponds with higher rainfall zones. Literature suggests that most soils with pH_{Ca} of 4.8 in the topsoil and 500mm average annual rainfall will have developed subsurface acidity.

Leaching of acidity into the subsurface occurs when the topsoil pH_{Ca} falls below 5.0. The further the acidity moves down the profile, the greater the effect on plant growth and the harder it is to correct. Figures 2b to 2d show the limited presence of acidity in deeper subsoil layers from the samples taken. A small number of sites (14%) were acidic at 20-40cm, while only 1 site at Tarcutta was acid throughout the profile to 80cm.

Effect

Increasing soil acidity results in increased availability of aluminium (*Fig. 2f*) and manganese, as well as reduced availability of molybdenum, phosphorus, magnesium and calcium. Aluminium toxicity causes most of the problems associated with acid soils due to stunted root development of sensitive crops and pastures, limiting access to moisture and nutrients. Most plants can tolerate levels below 5%, although this varies according to the soil's electrical conductivity (*Table 1*). Aluminium usually doesn't occur where pH_{Ca} is above 5.2.

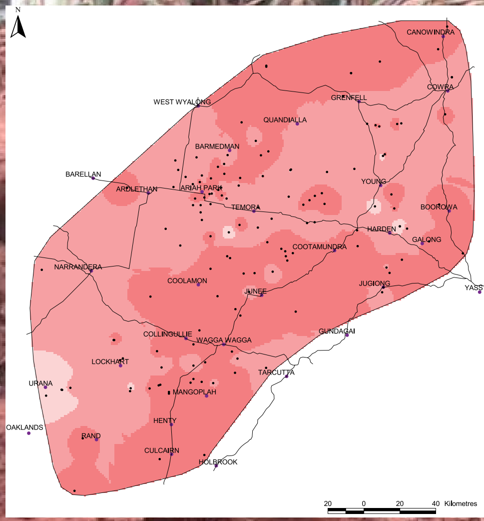


Fig. 2a*: 0-10cm

10-20cm

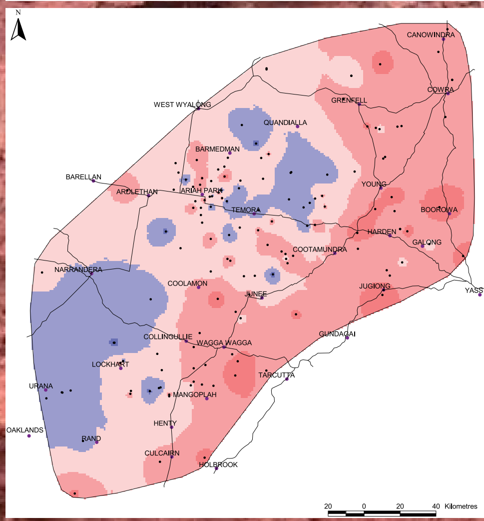


Fig. 2b*: 20-40cm

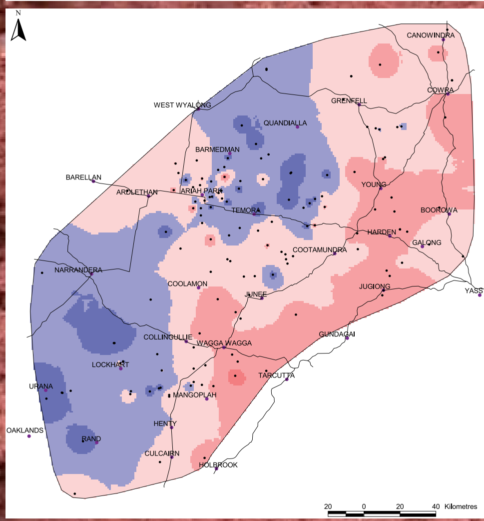


Fig. 2c*: 40-60cm

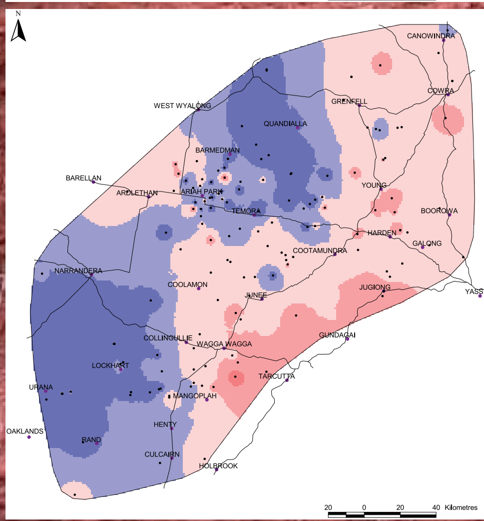


Fig. 2d*: 60-80cm

*see Legend Figure 2e

Fig. 2e: Soil pH_{Ca} at 10-20cm showing subsurface acidity

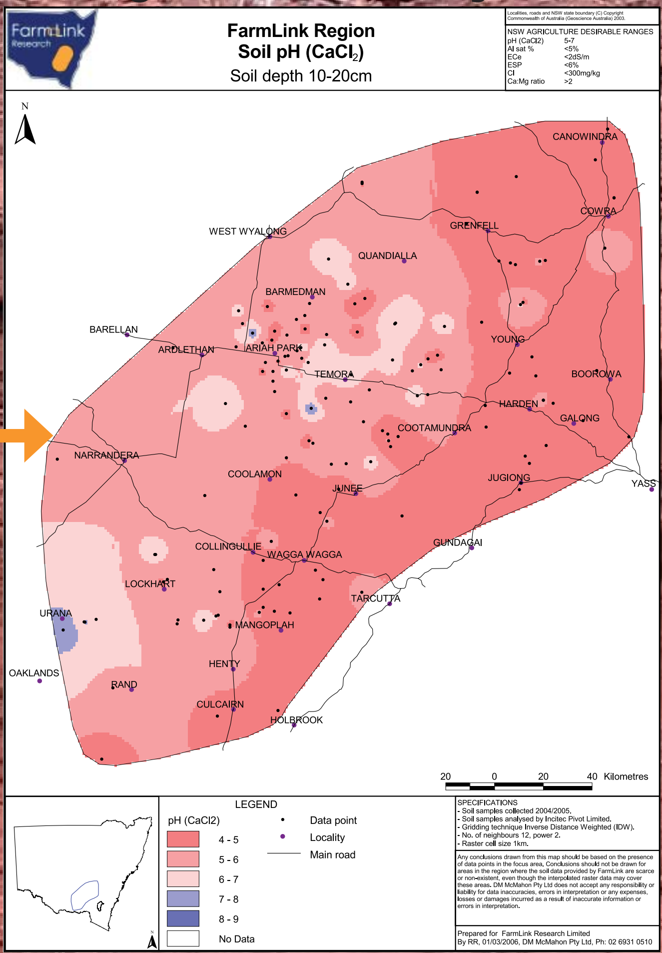
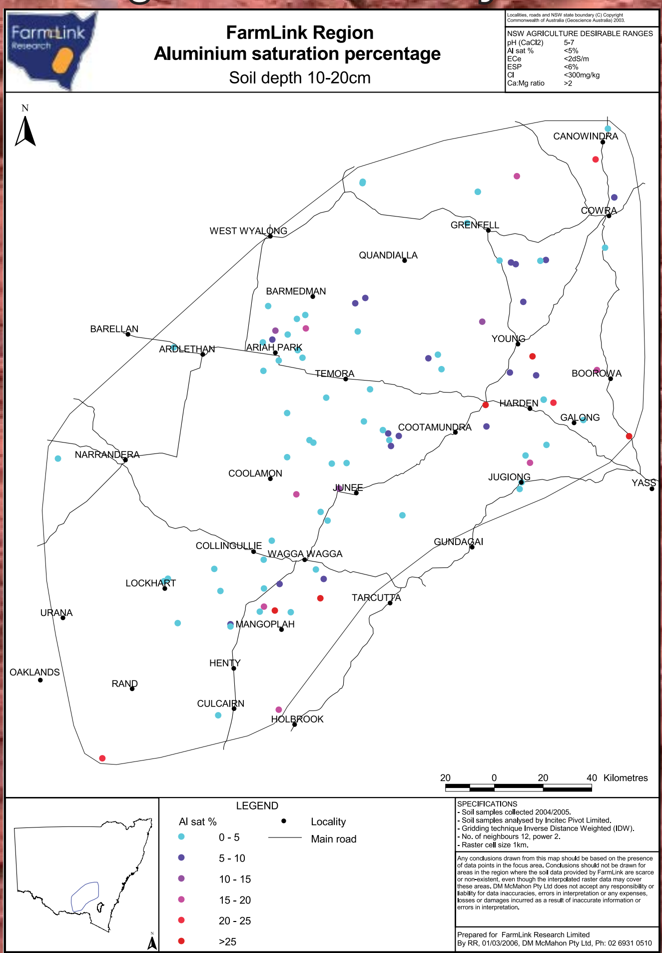


Fig. 2f: Aluminium % at 10-20cm showing subsurface toxicity



Management

Research has shown that pH in the subsurface layer can be slowly increased by liming to maintain the topsoil at pH_{Ca} above 5.5. However this is a long process, and may be more cost effectively managed through the use of acid tolerant species (*Table 1*). Recent research has also renewed the focus on direct placement of lime into the subsoil using air injection, though more focus needs to be placed on its practical use in broadacre agriculture. A recently commenced project (NSW DPI & La Trobe University) is focusing on the potential for using nitrate based fertilisers which can make the soil more alkaline. Acidifying (ammonia based) fertilisers are currently used in broadacre agriculture and are a contributor to soil acidification rates, particularly where nitrates are allowed to leach through the profile.

Table 1 - % Aluminium$_{ex}$ tolerances of selected plants at different electrical conductivities (1:5 dS/m)

Aluminium tolerance	low EC (< 0.07)	med. EC (0.07-0.23)	high EC (> 0.23)
highly sensitive *eg. durum wheat, most barleys, faba beans, chickpeas, lucerne, berseem & Persian clovers*	9-16%	2-8%	0.5-2%
sensitive *eg. canola, albus lupins, phalaris, balansa clover*	17-20%	9-12%	3-6%
tolerant *eg. Whistler, Sunstate & Diamondbird wheats, tall fescue, subclovers, chicory*	21-32%	13-21%	7-10%
highly tolerant *eg. narrowleaf lupins, oats, triticale, cocksfoot*	33-43%	22-30%	11-16%

Reference:

Soil acidity and liming: Agfact AC.19, 3rd edition 2005. (B. Upjohn, G. Fenton, M Conyers, NSW Dept Primary Industries).

Subsoil...

alkalinity

- ► Alkalinity defined as pH_{Ca} greater than 8.0
- ► Can result in deficiencies of phosphorus and zinc.
- ► Subsoil alkalinity found mostly at 60-80cm (27% of sites), generally on heavy black or grey clay soils towards the west of the region.
- ► Treatment of subsoil alkalinity at this depth is not practical. An understanding of potential nutrient deficiencies is important for management decisions.

Distribution

Although soil acidity is the main pH related problem in the FarmLink region, pH levels increase with depth to such a degree in some areas that subsoil alkalinity was found below 40cm. (19% of sites at 40-60cm, *Fig. 3d* and 27% of sites at 60-80cm, *Fig. 3e enlarged*). These areas mainly correspond to the heavier black and grey clay soils to the south and west of the region. A limited number of samples taken to 180cm indicated that alkalinity generally only increased to around pH_{Ca} 8.5.

Effect

While root growth may only be restricted once pH levels exceed 10 (not common), the main effect of alkaline soils is nutrient deficiency. pH levels greater than 8 can result in a tie-up of phosphorus and zinc, making them unavailable to the plant. Soils with pH above 8 also tend to have large amounts of sodium bicarbonate as well as high quantities of sodium attached to the clay (sodic). Hence the alkaline areas shown in *Figures 3d and 3e* relate closely to the sodic areas shown in *Figures 5d and 5e*.

Soils with pH above 9 (highly alkaline) are usually strongly sodic and contain toxic amounts of some ions (bicarbonate, carbonate and aluminate).

References:

Diagnosis and management of soil constraints: Transient salinity, sodicity and alkalinity, 2006. (J. Kelly, P. Rengasamy, The University of Adelaide).

Subsoil constraints to crop production: Impact, diagnosis and management options (Queensland Department of Primary Industries & Fisheries).

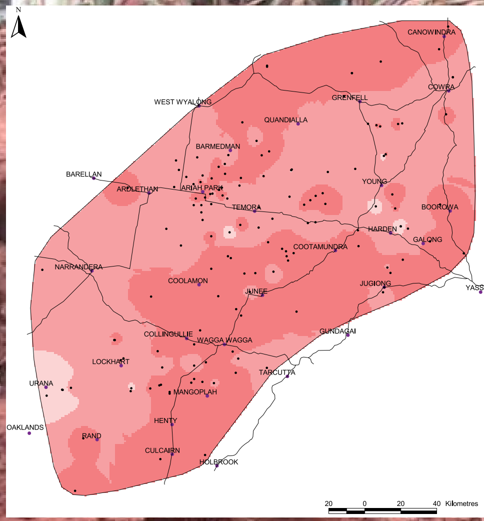


Fig. 3a*: 0-10cm

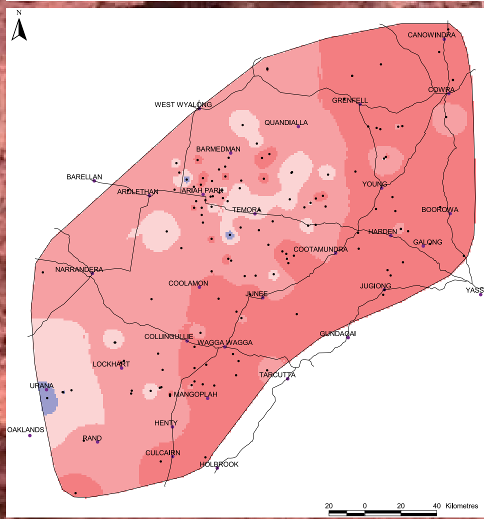


Fig. 3b*: 10-20cm

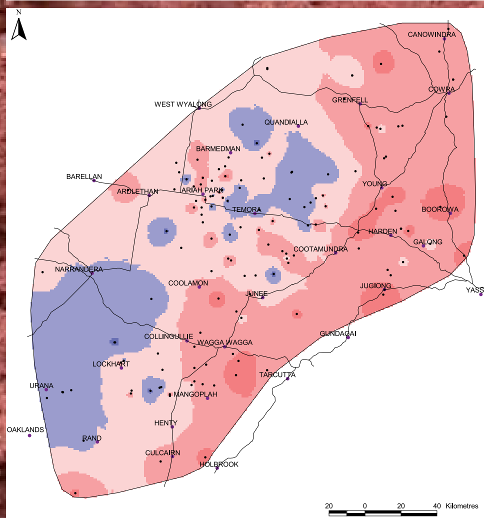


Fig. 3c*: 20-40cm

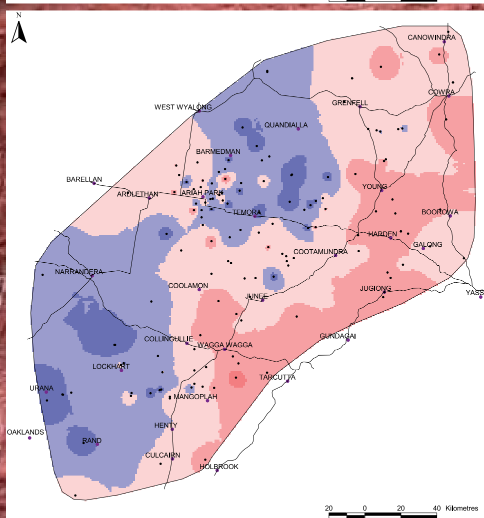
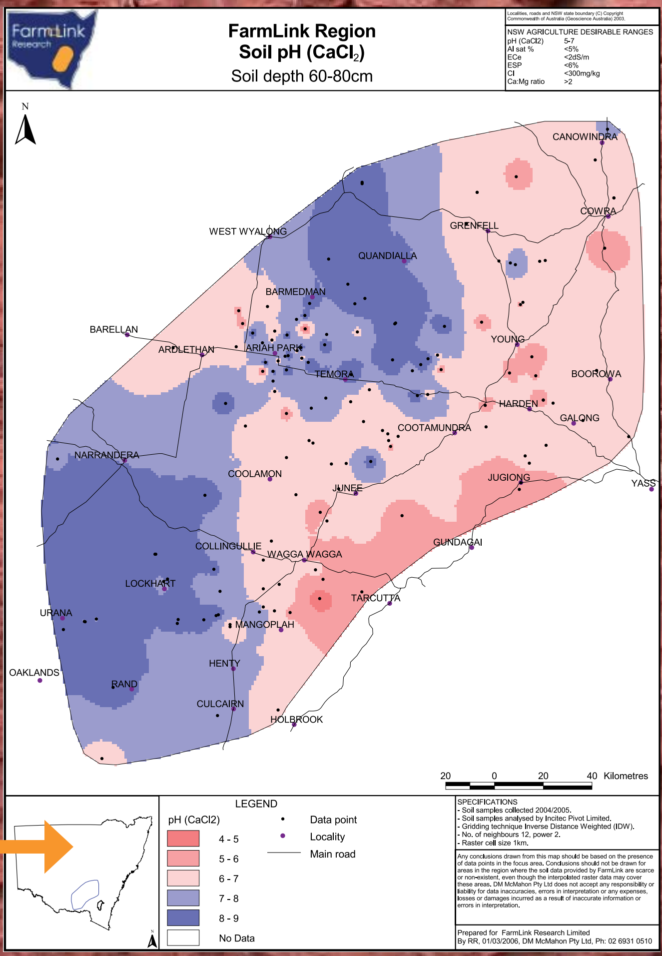


Fig. 3d*: 40-60cm

60-80cm

*see Legend Figure 3e

Fig. 3e: Soil pH_{Ca} at 60-80cm showing subsoil alkalinity



Collecting subsoil samples for pH testing at a FarmLink Subsoil Workshop, Grenfell 2005

Subsoil...
salinity

- Salinity defined as EC*$_{se}$ greater than 2 dS/m (severe if greater than 8 dS/m), but depends on type of salts present.
- Chloride may be a better indicator of subsoil salinity, defined as marginal at 300-600 mg/kg, toxic at greater than 600 mg/kg.
- Results in low water uptake (osmotic effect) and salt toxicity.
- Subsoil salinity, probably transient salinity, found mostly below 40cm (8% of sites had toxic chloride levels), generally on heavier clay soils to the south and west of the region.
- Management of subsoil salinity should focus on the use of deep rooted, salt tolerant species.

**EC = electrical conductivity*

Distribution

High electrical conductivity (EC$_{se}$) levels below 40cm indicate areas of subsoil salinity on the clay soils to the south and west of the FarmLink region (*Figures 4d and 4e enlarged*). High chloride levels found in the same areas (*Fig. 4f enlarged*) indicate the EC levels are due to (NaCl) salt. This is more damaging than, for example, gypsum salt which would also cause high EC readings. 8% of sites recorded toxic chloride levels below 40cm, while a further 8% recorded marginal levels. Of the 25 sites tested down to 180cm, only 1 showed marginal chloride levels below 80cm (none toxic).

Effect

Recent theories suggest that salts found in the FarmLink region are more likely to be from transient salinity, rather than salinity due to rising water tables. Transient salinity occurs when salts accumulate in the root zone due to reduced water movement through the profile. It often occurs in addition to sodicity (*Fig. 5e*), which can be a contributing factor.

Subsoil salinity can substantially reduce crop yields and pasture growth, particularly in dry seasons. The presence of salts in the root zone result in reduced water uptake, and some salts, eg. sodium and chloride, can have a direct toxic effect on plant growth.

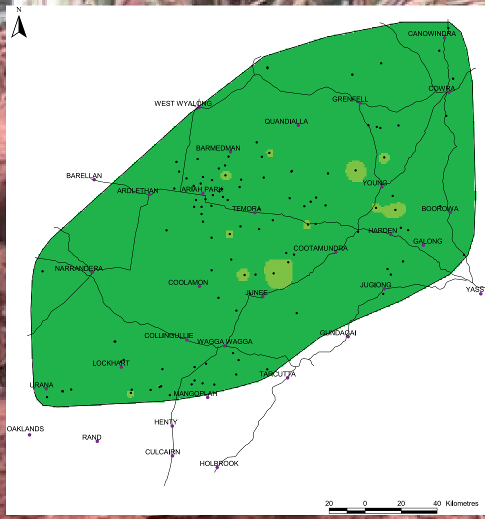


Fig. 4a*: 0-10cm

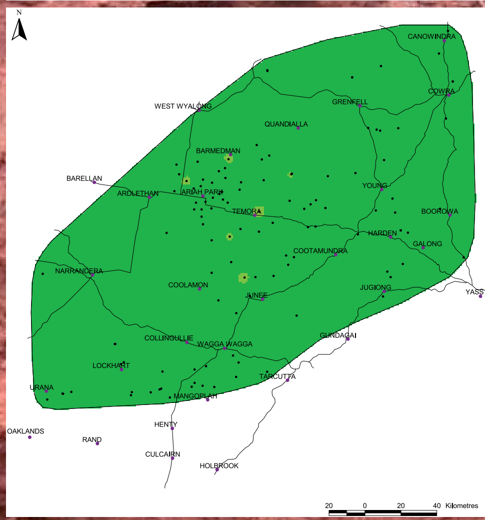


Fig. 4b*: 10-20cm

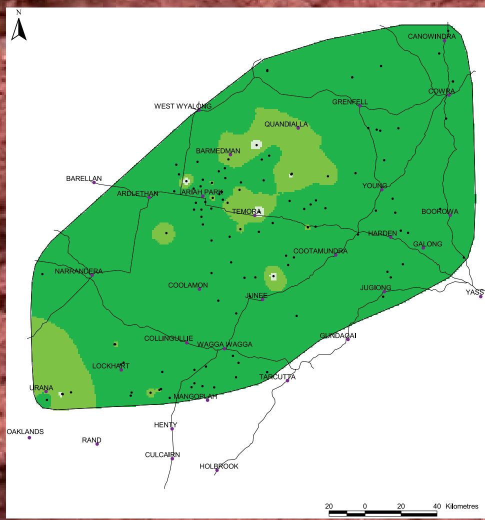


Fig. 4c*: 20-40cm

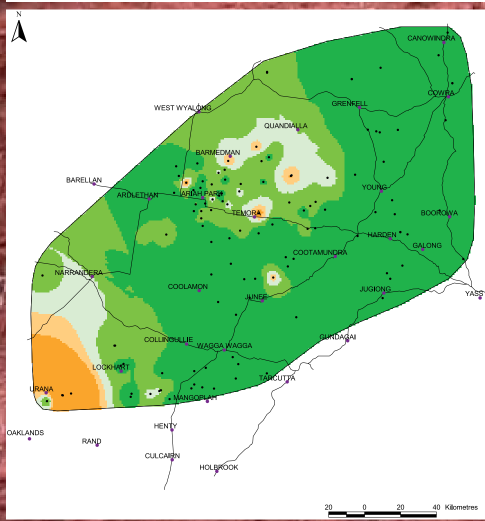


Fig. 4d*: 40-60cm

60-80cm

*see Legend Figure 4e

Fig. 4e: Electrical conductivity$_{se}$ at 60-80cm showing subsoil salinity

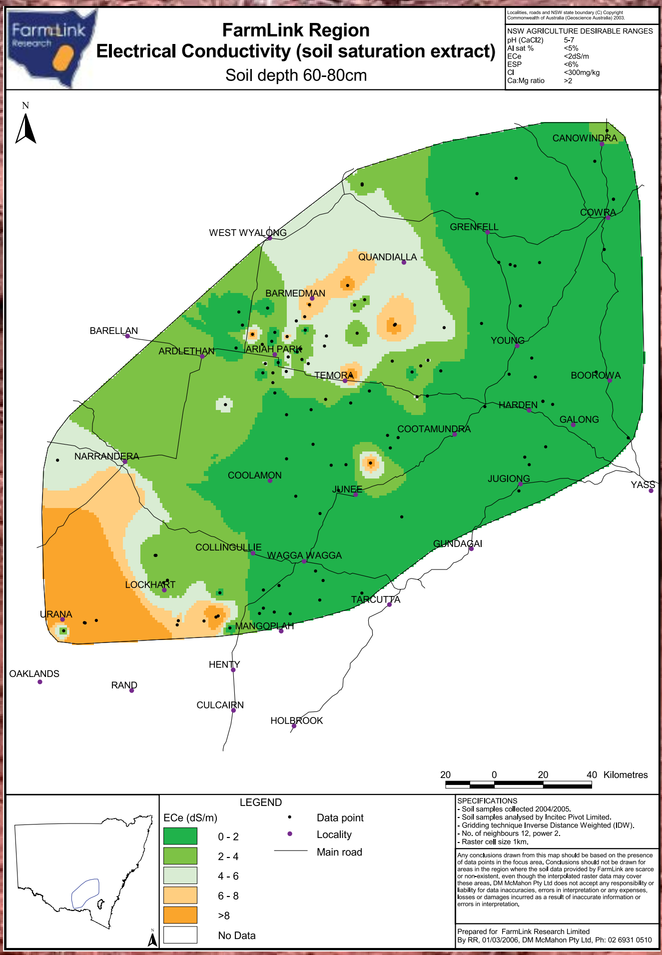
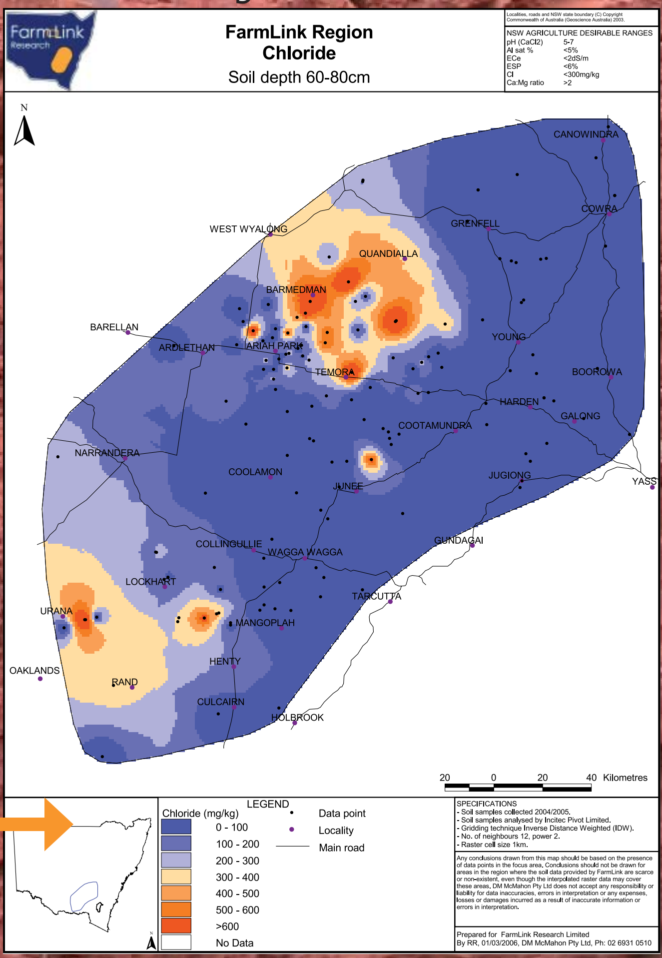


Fig. 4f: Chloride at 60-80cm showing subsoil salinity



Management

Subsoil salinity may be managed by growing deep rooted, salt tolerant species (*Table 2*) to improve soil structure and allow leaching of salts below the root zone.

Table 2 - Salinity tolerances (EC$_{se}$) of selected crops and pastures

Crop / pasture	threshold (dS/m)	25% yield loss (dS/m)
barley	8.0	13.0
tall wheatgrass	7.5	13.5
canola	6.5	11.5
wheat	6.0	9.5
perennial ryegrass	5.6	8.9
oats	5.0	6.3
phalaris	4.2	7.8
strawberry clover	2.1	4.0
lucerne	2.0	6.2
berseem clover	1.5	5.9
subclover & white clover	1.5	3.6

References:

Diagnosis and management of soil constraints: Transient salinity, sodicity and alkalinity, 2006. (J. Kelly, P. Rengasamy, The University of Adelaide).

Subsoil constraints to crop production: Impact, diagnosis and management options (Queensland Department of Primary Industries & Fisheries).

Soil & Water Salinity Calculator (Salt Action).

Testing subsoil samples for EC at a FarmLink Subsoil Workshop, Grenfell 2005

Subsoil... sodicity

- Subsoil sodicity defined as ESP* greater than 15% (topsoil is sodic if greater than 6%).
- Can result in a 'massive' soil structure, poor water infiltration and limited root growth.
- Subsoil sodicity found mostly below 20cm (26% of sites), generally on heavier clay soils to the south and west of the region.
- Treatment of subsoil sodicity can be difficult - gypsum has been used in combination with deep ripping or direct placement, with variable results. 'Primer crops' show potential as biological ameliorants.

**ESP = exchangeable sodium percentage*

Distribution

Although 15% of sites tested in the FarmLink region showed sodic topsoils (*Fig. 5a*), subsoil sodicity appeared more common, particularly on the heavier clay soils to the south and west of the region. 16% of sites were sodic at 20-40cm (*Fig. 5c*), expanding to 24% of sites at 60-80cm (*Fig. 5e enlarged*). Of the 25 sites also tested down to 180cm, 5 were sodic to depth.

Effect

Subsoil sodicity can cause significant yield reductions in both crops and pastures, with effects more evident in wet years. The attachment of accumulated sodium to clay particles (ie. 'sodicity') can cause the soil to swell when wet, dispersing the particles and blocking soil pores. The soil then forms a hard, dense ('massive') structure when dry. This dense structure prevents water and air movement into the soil profile, restricting root growth.

Management

Treating subsoil sodicity can be costly and time consuming, with variable results. Deep ripping can be used to break up compacted layers close to the surface, with gypsum applied if the soils are dispersive, ie. lose structure when wet. Controlled traffic has been proven to help prevent the compacted surface layers from re-forming. Direct placement (eg. air injection) of gypsum into sodic subsoils has also been trialled with some success, although it has proven difficult to inject sufficient quantities. Recent research by CSIRO has shown

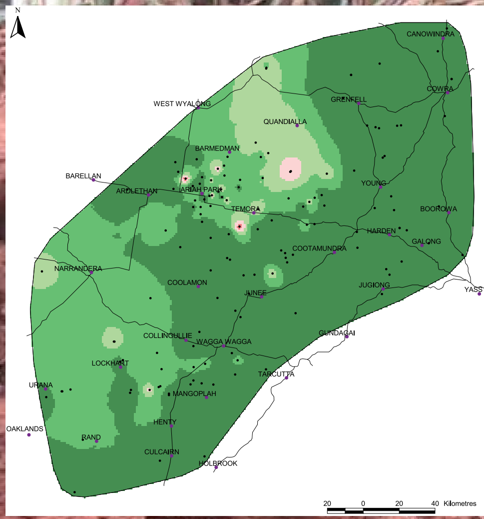


Fig. 5a*: 0-10cm

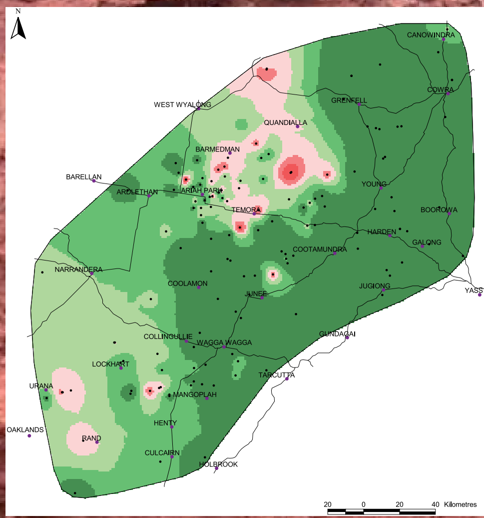


Fig. 5b*: 10-20cm

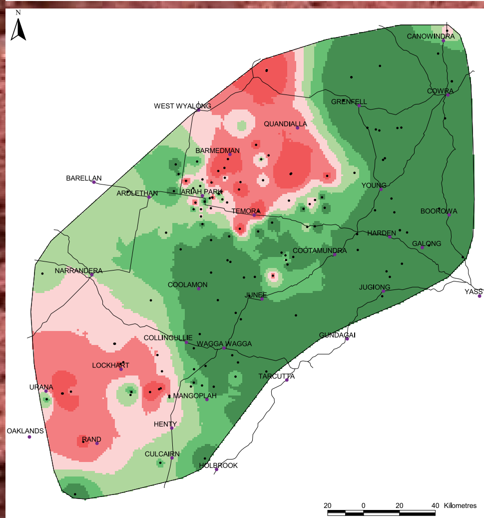


Fig. 5c*: 20-40cm

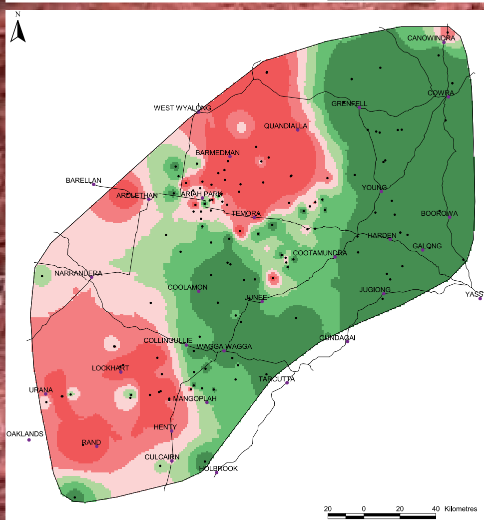


Fig. 5d*: 40-60cm

60-80cm

***see Legend Figure 5e**

the potential for 'primer crops' using plants that can penetrate hostile subsoils and modify the area adjacent to their roots to create a more favouable environment for following crops.

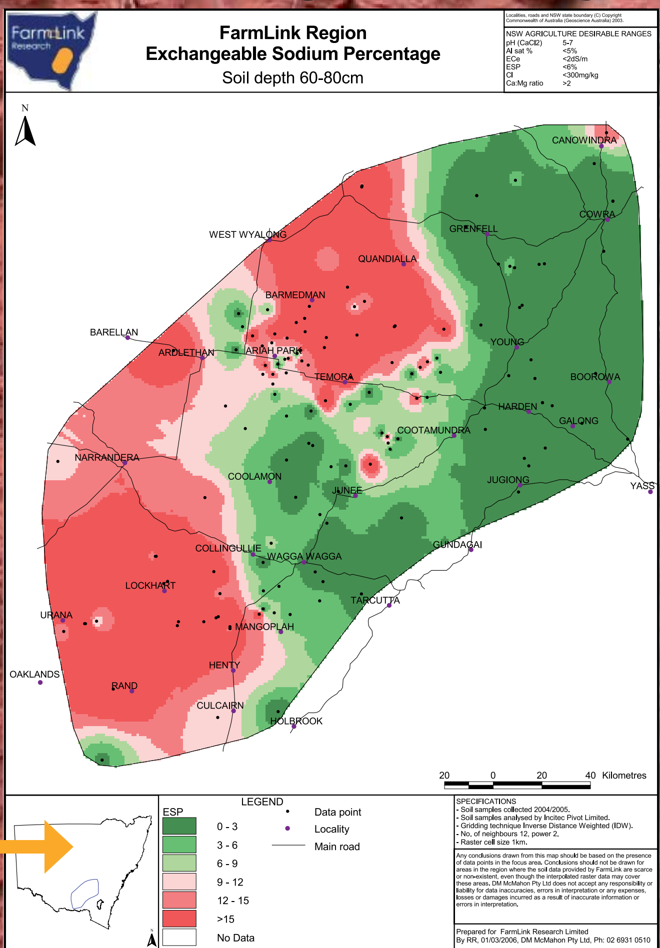
References:

Diagnosis and management of soil constraints: Transient salinity, sodicity and alkalinity, 2006. (J. Kelly, P. Rengasamy, The University of Adelaide).

Subsoil constraints to crop production: Impact, diagnosis and management options (Queensland Department of Primary Industries & Fisheries).

Crop primers for hostile soils. In Proceedings of GRDC Southern Cropping Systems Update, 2003. (M. Peoples, S. Davies, J. Kirkegaard, M. McCallum, J. Nuttall, R. Armstrong).

Fig. 5e: Exchangeable sodium at 60-80cm showing subsoil sodicity



Yeomans deep ripper, modified with air hoses and cart for 'injecting' gypsum/lime to depth (FarmLink Zone Management project, 2005)

Farm Link Research

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