‘SOILpak in 2016:
What Information is Still Relevant; What Needs Updating; What Needs to Go?’

Report for: Cotton Research and Development Corporation, Narrabri

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Executive Summary

The successful SOILpak concept was developed in 1986, but the most recent version of the manual ('*SOILpak for Cotton Growers: Third edition*', 1998, and the accompanying Pocket Notes) is now eighteen years old. Valuable ideas for updating SOILpak were presented in the reviews by Shaw (2005) and EA Systems (2006) approximately ten years ago.

Other soil-related PAKS developed by the Australian cotton industry also remain important but some sections are out of date; they include NUTRIpak, WATERpak, MACHINEpak and NORpak.

Precision Agriculture techniques associated with soil management are very valuable – particularly yield mapping and elevation data – but there has been an over-dependence on EM surveys, and a lack of attention given to 'yield gap' mapping.

There are several problems with SOILpak that need to be addressed:

- Machinery wheel pattern descriptions are outdated; there is no mention of the new and heavy JD7760 pickers and high capacity wheat harvesters that have the potential to create much deeper compaction than previous harvesting equipment.
- SOILpak sampling depths are compatible with modern schemes such as GlobalSoilMap, but are not well integrated with NUTRIpak and WATERpak – consistency is required.
- SOILpak and associated decision support systems collectively are not "Big Data" ready; cotton soil data across the different valleys tend not to be in a format that can be clearly tabulated and mapped.
- The planned technical updating process for SOILpak as new research results became available did not occur.
- The case study section with cost-benefit analyses was never developed properly, despite the introduction of excellent new software technologies such as Wikis and easy video delivery via the Internet.
- The soil structure assessment section requires refinement/clarification through the use of modern communication and diagnostic tools.
- The low-budget black & white presentation style in '*SOILpak for Cotton Growers: Third edition*' is unattractive; an easily updated e-book format would be more practical and appealing.

Other topics in SOILpak that are still relevant but require expansion include:

- Optimal packaging of available components (ranging from direct observations of soil structure in pits to 'precision agriculture' inputs) to provide accurate cost-effective soil assessment frameworks for cotton farmers across all valleys.
- Cost-effective management of soil constraints in variable cotton fields.
- Soil biology.
- District land resource summaries expanded to include Riverina & northern Australia; linked to an interactive Web-based repository of soil information, and possibly referred to as LANDpak.

What should be discarded?

- MACHINEpak is redundant; it requires upgrading via the use of web-based video resources.
- The SOILpak promotional video containing farmer testimonials is very outdated and, apart from being an interesting piece of history, is no longer required.

A critical issue is human resource management. The Australian cotton industry needs descriptions of who is responsible for what when assessing and managing cotton soil, including the respective competency requirements of farmers, agronomists (soil management "General Practitioners"), precision agriculture engineers, and soil science specialists. This needs to be supported by appropriate training and accreditation systems, and industry encouragement for entrepreneurial soil-related business networks. 'Advisory soil scientists' need to be appointed within CottonInfo to facilitate this process.

Contents

1. Introduction

Relative to other rural industries in Australia, the cotton industry is well endowed with soil-related extension products. They include SOILpak (Daniells and Larsen 1991, McKenzie 1998), MACHINEpak (Schoenfisch 1999), NUTRIpak (Rochester 2001), WATERpak (Dugdale *et al.* 2004) and NORpak (Davies *et al.* 2007). Information in SOILpak and NUTRIpak is linked with the soil health module in 'myBMP' for growers (www.mybmp.com.au/home.aspx).

Excellent yield improvements have occurred since the 1970s and current lint yields are the highest in the world. Better management of water (including soil water and its interactions with soil structure) has been responsible for 50% of the yield increases seen in Australia, with 50% attributed to plant breeding (Cotton Australia 2014).

However, the extension materials have become outdated: '*SOILpak for Cotton Growers: Third edition*' and the accompanying pocket notes are now eighteen years old.

This report – initiated by Allan Williams, Cotton Research and Development Corporation (CRDC) – provides suggestions about the best way forward.

2. SOILpak Development

2.1 The SOILpak manual

Growers strongly influenced the development of SOILpak, which commenced in 1986, and the eventual production of '*SOILpak for cotton growers, Third edition*' in 1998. An Auscott Ltd. agronomist (Dave Anthony) co-founded the SOILpak concept in 1986 then pushed strongly for industry funding and support over the following 14 years. Leading farmers helped the contributors from a diverse range of soil-related R&D organisations to be part of an effective team focussing on cotton industry priorities. The farmers argued in favour of a loose-leaf SOILpak manual rather than predictive computer models.

The main participants initially were from NSW Agriculture at Trangie and Narrabri. The history of the development of the SOILpak manuals is described by Daniells *et al.* (1996) and in proceedings of annual 'Cotton Soil Coordination Meetings', Narrabri in the early 1990s. The release of the third edition of SOILpak in 1998 was accompanied by pocket notes, a DVD, internet access via NSW DPI website (http://www.dpi.nsw.gov.au/content/agriculture/resources/soils/guides/ soilpak/cotton), and a SOILpak promotional video with cotton farmer testimonials. Improved methodologies for soil structure assessment were developed by David McKenzie in conjunction with colleagues from University of Sydney and NSW Agriculture. SOILpak™ is a registered trademark of NSW Agriculture / NSW Department of Primary Industries.

There were numerous direct and indirect contributors to SOILpak – including Jim Brownell (California State University, Fresno, USA); Tom Batey (University of Aberdeen, Scotland), Arthur Hodgson, Yin Chan, David Larsen, Ian Daniells, Greg Constable, Ian Rochester & Nilantha Hulugalle (NSW Agriculture, Narrabri), Des McGarry (CSIRO/QDPI, Brisbane), Don MacLeod, Alf Cass, Pat Hulme & Neil McKenzie (University of New England, Armidale), David Hall, Suzie Greenhalgh, Tracy Willis & Neville Gould (NSW Agriculture, Trangie), Hans Woldring (Hassall & Associates, Trangie), Peter Buss (Sentek, Adelaide), Peter Cull (ICT, Armidale), Guy Roth (University of Canberra), Tony Koppi, Alex McBratney, Damien Field, John Triantafilis & Brett Whelan (University of Sydney), Mac Kirby (CSIRO Canberra), Adam Kay & Gus Shaw (NSW Agriculture, Warren) – whose inputs led to a practical and credible outcome.

Key issues for NSW and Qld. cotton growers on black cracking clays (Vertosols) in the mid-1980s when SOILpak was conceived included:

- Poor yields caused by compaction damage associated with wet soil at picking.

- Decision support information relating to soil management was very fragmented.
- The valuable soil management experiences of leading growers was poorly documented and underestimated by researchers.
- Leading growers were concerned about the lack of a clear framework for soil research and extension in Australia.

The topics in SOILpak include:

- Soil sampling for yield map interpretation (topsoil and subsoil; physical/chemical/biological testing) – see Table 1.
- Compaction assessment and management.
- Overcoming dispersion/sodicity with gypsum, lime, organic amendments.
- Improvement of water use efficiency.
- Prevention of salinity and erosion.
- Soil survey prior to development or re-development.

McKenzie *et al.* (2015) have noted that the SOILpak decision support system provides target specifications for a reference state, that is, the 'ideal' soil for cotton production. It is based on an appreciation of Liebig's 'Law of the Minimum'. Where limitations to cotton growth are identified, soil amelioration strategies with potential to improve depth of rooting and non-limiting water range are considered, thereby improving the chances of producing yields close to the genetic potential for the crops being grown under the prevailing climatic conditions. Soil sampling locations are strongly influenced by yield/profitability map information. Objectives that can be achieved through successful management of soil structure under cotton crops include: substantial water entry and storage without development of severe waterlogging, avoidance of excessive soil hardness for root extension and function, and creation of suitable habitat for soil biota.

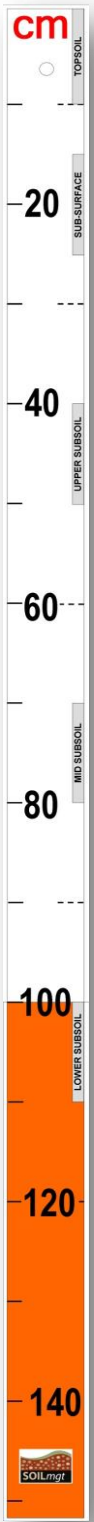
The rapidly assessed 'SOILpak score' (a measure of soil structural form; Kay 1990) is linked to soil degradation thresholds (McKenzie and McBratney 2001) and the numerical results can be mapped easily with red-amber-green 'traffic light' colour coding. The aggregate stability in water (ASWAT) score used with 'SOILpak' (Field *et al*. 1997) is a test for soil structural stability in water that can also be mapped easily with colour coding. The process of applying a SOILpak score rather than measuring soil physical properties was adopted because there was no single technique (eg. penetrometer, bulk density cores, dyes, shrinkage of clods, resin impregnation of soil) that could robustly quantify soil structure throughout the cotton industry.

ASWAT and 'SOILpak score' maps showing both lateral and vertical changes in soil quality can be related to maps of 'soil amelioration requirements' (e.g. loosening of compacted layers, either mechanically or via shrink–swell cycles; gypsum application) and 'cost of repair of soil constraints', which can then be linked to crop yield maps and farm profitability maps.

Soil structural resilience is a measure of the ability of soil to regain a desirable soil structural form through swelling and shrinkage induced by wetting and drying cycles, and can be assessed by observing soil shrinkage patterns when the soil is dry.

The 'SOILpak score' procedure for assessment of soil compaction severity has achieved global recognition alongside VESS, VSA, Profil Cultural and SubVESS (Batey *et al*. 2015). Field demonstration of the SOILpak score has occurred at meetings of International Soil & Tillage Research Organisation (ISTRO) Working Group F (Visual soil examination & evaluation) in Peronne France (2005), Flakkebjerg Denmark (2011) and Maringa Brazil (2014). McKenzie and Batey (2006) described the soil structure assessment schemes from around the world that were compared in France.

Table 1. Soil sampling guidelines in SOILpak, in relation to NUTRIpak and associated publications.

DECISION SUPPORT SYSTEM	**DETAILS**	**COMMENTS**
SOILpak 	The recommended main sampling depths in SOILpak are: • 0-10 cm (topsoil), • 10-30cm (sub-surface), • 30-60 cm (upper subsoil), • 60-90cm (mid subsoil), • 90-120cm (deep subsoil) (optional) Sampling locations in developed cotton fields should include: • High yielding zone, • Average yielding zone, • Low yielding zone. Sampling locations for new cotton fields ~150m pit spacing (this recommendation was influenced by the South Australian Government's 'Irrigated Crop Management Service' protocol for soil pit assessment). Soil factors under consideration include: • Compaction, • Sodicity/dispersion, • CEC, • pH, • Organic matter, • Salinity, • Nutrients. Examples of SOILpak-related 'key soil factor maps' are shown in Figure 1.	The SOILpak system has sampling depths that are similar (but not identical) to the 'standard depths' for GlobalSoilMap and 'Soil & Landscape Grid of Australia' (see Section 6.2), and NSW Government's soil sampling protocol for Biophysical Strategic Agricultural Land (BSAL; see Section 6.3), ie. 0-5cm, 5-15cm, 15-30cm, 30-60cm, 60-100cm. (*similar to 'ApSoil': 0-15cm, 15-30cm, 30-60cm, 60-90cm*) **Possible 2016 Refinements:** Use the following standard depth intervals for all soil-related measurements in the Australian cotton industry: **0-10 cm, 10-30cm,** **30-60cm, 60-100cm.** Despite the high current cost of soil testing (see Section 7.4), aim for a comprehensive soil sampling spacing of approximately 400m across all cotton farms, ie. one sampling site per ~16 ha (**1:25 000 mapping scale**). Use the sampling grid in a flexible manner that allows the soil sampling plan to be adjusted to include high and low yielding areas and other zones where cotton growers are making both strategic & tactical soil management decisions. Maybe have a closer sampling spacing for tactical decisions like soil N management, eg. one per ha (topsoil focus) as in parts of US for soil nutrients; = ~100m pit/core/spade spacing (**1:10 000 mapping scale**). (see Section 6.1)

NUTRIpak (Rochester *et al.* 2001)	N: 0-30cm; sometimes additional soil sample to 1m for NO_3-N analysis. P: 0-30cm; S, 0-30cm; K, 0-15cm Sampling locations: Zigzag pattern and sample bulking within zones*. This approach is closely linked with 'Australian soil fertility manual" (Glendinning 1999), and is used by Fertcare (www.fertilizer.org.au/Fertcare). Local calibrations (0-30cm soil test data v. crop performance information) and experience documented by companies such as 'Back Paddock' are important.	Griffiths (2016) noted that the 0-10cm Colwell test historically has been the cotton industry's key method of ascertaining soil P status). In addition to this test, it is now recommended that the following be added: 10-30cm BSES-P and Colwell-P tests. In the grain industry's northern region, the suggested sampling increments for key nutrients and salinity are: 0-10cm (N, P, K, S), 10-30cm (N, P, K, S), 30-60cm (N, S, EC), 60-90cm (N, EC), 90-120cm (optional) (N, EC) (GRDC 2014).
WATERpak (Dugdale *et al.* 2004)	The combined use of EM surveys and coring is recommended to assess leakiness at potential dam/channel sites It is suggested that locations of soil sampling and moisture monitoring tubes be guided by EM patterning.	It is stated that an EM survey is better than soil investigation via backhoe pits because it is "more detailed", but the issue of poor 'accuracy of prediction' of some key soil factors via EM data is not mentioned.
Precision Agriculture soil sampling recommendations, as described in the 2013 Cotton Production Manual, p. 64	There is emphasis on the location of soil sampling sites via EM mapping patterns. CSIRO advice about the serious limitations of EM surveys is disregarded (see Section 5.3 below). It is correctly noted that elevation/slope maps are invaluable .	Yash Dang (*pers. comm.*) has described problems with unreliability of soil sampling site locations in southern Qld, defined via EM survey patterning, as soil moisture status changes seasonally.
CottonInfo (2014)	It is noted that sampling soil at 0-30cm is ideal for all nutrients, particularly N, P and K, and salinity and sodicity indicators, with sampling of subsoil (30-100cm) for sodicity, salinity, nitrate-N and chloride approx. every 5 years in the same place.	This recommendation is based strongly on NUTRIpak guidelines, but acknowledges the need to also sample subsoil thoroughly, and to avoid zigzag patterns / bulking when sampling soil.
New combined approach (2016 Cotton Production Manual)	See Section 5.3 below.	The 2016 approach has many good features, but the NUTRIpak, SOILpak and WATERpak manuals require updating to provide consistency of advice for cotton growers.

* It is noted that, in general, at least 10 samples should be collected within a 200 ha area. "Cores from similar soil types may be bulked" (to reduce the cost of testing). It is also stated that the number of samples required depends on soil variability within the field, and that the concentration of most nutrients (especially N and P) can vary widely, even in apparently uniform fields.

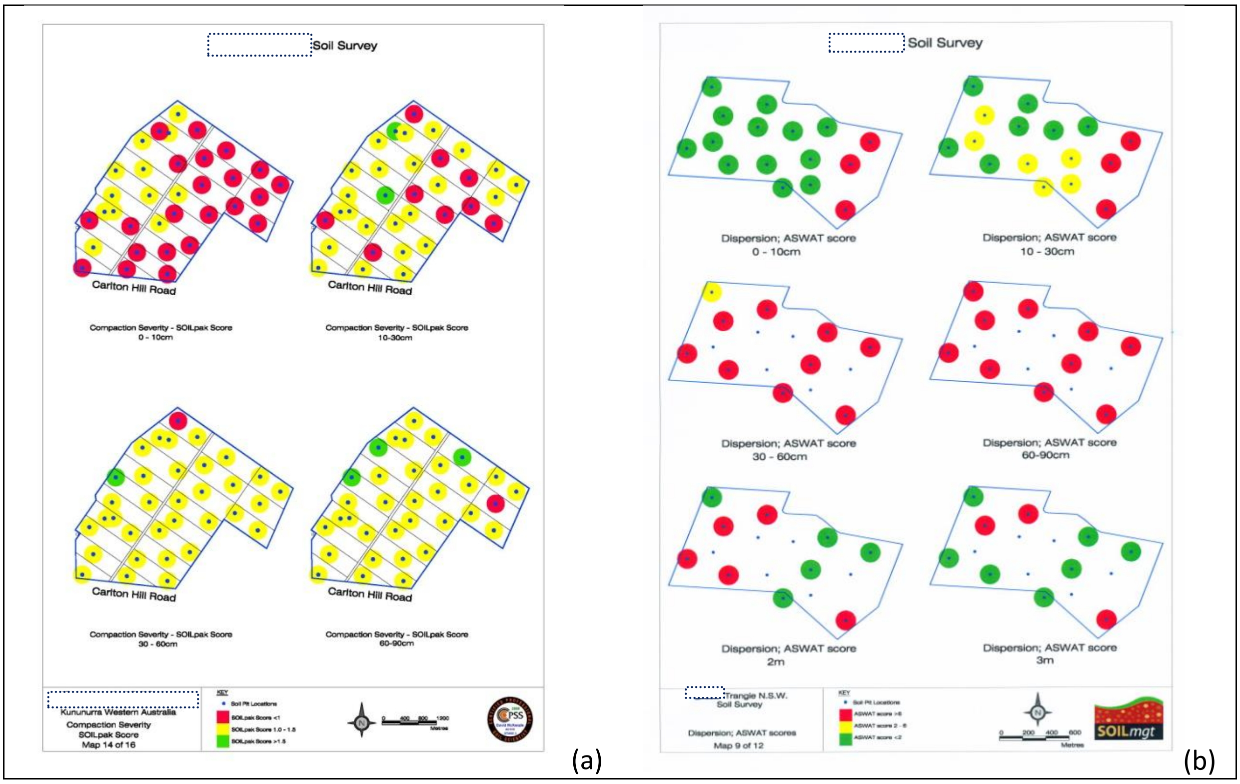


Figure 1. Examples of 'key soil factor maps' for (a) A new furrow irrigation development near Kununurra WA, and (b) A cotton field near Trangie NSW about to be converted from flood irrigation to linear move spray irrigation. Remote sensing techniques (eg. colour air photos, EM surveys) can sometimes be used to provide extra details in-between the dots where strong correlation exists; red dot colour = action required by soil managers, green dot colour indicates favourable conditions for cotton root growth.

The Cotton SOILpak concept has been modified for use by producers of other crops, for example, dryland wheat (Anderson *et al*. 1999) and vegetables (Anderson *et al*. 2007).

SOILpak, however, now has some serious problems that require rectification:

- Machinery wheel patterns and planting width descriptions are outdated; there is no mention of the new and heavy JD7760 pickers and high capacity wheat harvesters that have the potential to create much deeper compaction than previous harvesting equipment.
- SOILpak sampling depths are compatible with modern schemes such as GlobalSoilMap, but are not well integrated with NUTRIpak and WATERpak – consistency is required.
- SOILpak and associated decision support systems collectively are not "Big Data" ready; cotton soil data across the different valleys tend not to be in a format that can be clearly tabulated and mapped.
- The planned technical updating process for SOILpak as new research results became available did not occur.
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- The soil structure assessment section requires refinement/clarification through the use of modern communication and diagnostic tools.

2.2 SOILpak training courses

McKenzie and McGarry (2000) provided an overview of the nature and extent of soil constraints in the cotton industry using data from a series of eleven SOILpak training courses (mainly yield map interpretation exercises) from Emerald in the north to Warren in the south. The results are shown in Table 2.

This preliminary assessment of soil constraints adversely affecting cotton yields represents an early attempt at 'Big data' collation across the entire industry. It was not widely publicised at the time because of concerns by some of the participating landholders about possible adverse reactions from bank managers and rural land valuers about their soil constraints.

3. NUTRIpak

NUTRIpak (Rochester 2001) (see sampling details in Table 1) was published in 2001. It was strongly influenced by:

- Glendinning JS (1999). Australian soil fertility manual (FIFA & CSIRO) – derived from AFL Fertiliser Handbook; it is linked strongly with the Fertcare Handbook.
- Peverill KI, Sparrow LA, Reuter DJ (1999). Soil analysis: an interpretation manual. (CSIRO / ASPAC).

It has been an important repository for results of the cotton industry's large investment in crop nutrition research over the previous 20 years.

The soil sampling details for NUTRIpak (Table 1) are not fully consistent with SOILpak. This problem needs to be rectified, particularly where long-term strategic soil assessment is being carried out.

Because grain crops are grown in rotation with cotton, the soil sampling schemes for these two industries need to be compatible. The soil sampling depths recommended by GRDC (2014) for their northern region are the same as for Cotton SOILpak, but are different to NUTRIpak – see Table 1.

4. Other Relevant PAKS and Associated Resources

Other cotton industry PAKS and associated resources include:

- WATERpak – see Table 1.
- MACHINEpak – defunct; needs easily-updated modern graphics and videos.
- NORpak – only includes a small and incomplete sub-section about soil conditions for cotton production in northern Australia.
- 'Best Management Practice' (BMP) guidelines.

The WA Government developed a document entitled 'Ord SOILpak' in 2005 but it was not followed up by an effective soil extension program.

There is scope to broaden SOILpak to include landscape rehydration processes described by authors such as Tongway and Hindley (2004). The concept of having a LANDpak manual to include this type of information was discussed at Cotton Soil Coordination Meetings in the early-1990s. The 'terraGIS' website managed by John Triantafilis (UNSW) (www.terragis.bees.unsw.edu.au) presents soil data for small sub-sections of some cotton growing areas in northern NSW. There is interest amongst growers about how to combine airborne EM surveys and regional geomorphology information to improve their understanding of subsurface water flows and salt dynamics beneath cotton farms (Pat Hulme, pers. comm. 2016).

Another possible cotton industry manual mentioned at one of the coordination meetings was 'PRECISIONpak'.

Table 2. Proportion of farmed sites in each of the districts that had soil factors likely to restrict cotton growth if left untreated (McKenzie and McGarry 2000).

Soil problem	District – % of farmed sites affected by each soil condition											Overall affected sites. %
	Narrabri (4 sites)	Warren (5 sites)	Moree (4 sites)	Emerald (4 sites)	Dalby (4 sites)	Wee Waa (5 sites)	G'windi (4 sites)	Gunnedah (4 sites)	Theodore (5 sites)	Walgett (4 sites)	Bourke (4 sites)	
Soil compaction – topsoil	25	0	0	0	25	0	25	25	20	25	25	15
Soil compaction – subsoil	25	20	50	0	0	20	0	0	50	0	25	17
Natural sodicity in subsoil	0	0	25	25	0	20	80	25	20	100	50	30
Topsoil sodicity, apparently induced by the use of bore water	66	0	0	0	25	50	0	0	0	0	0	11
Lack of electrolyte in low ESP soil (causes dispersion)	25	60	50	0	50	60	0	50	0	50	50	36
TOTAL STRUCTURE LIMITATIONS	***50***	***60***	***75***	***25***	***50***	***60***	***75***	***75***	***40***	***100***	***75***	***64***
Acidity	0	0	25	0	0	20	0	25	40	0	0	13
Alkalinity	50	0	25	25	0	40	50	50	20	100	75	38
TOTAL pH LIMITATIONS	***50***	***0***	***50***	***25***	***0***	***60***	***50***	***75***	***60***	***100***	***75***	***51***
Excess subsoil salinity (natural)	0	0	50	25	0	0	25	25	20	25	0	15
Evidence of perched water table	25	0	0	25	0	20	25	0	0	0	0	9

Definitions:

1. A soil is referred to as being compacted if the lowest SOILpak score under the plant lines is less than 1.0,
2. For this exercise, the subsoil is said to be sodic (excessive swelling, dispersive) if Exchangeable Sodium Percentage is greater than 15,
3. For this exercise, the topsoil is said to be sodic (dispersive) if Exchangeable Sodium Percentage is greater than 5,
4. Soil with ESP less than 5, but Electrochemical Stability Index (ESI) less than 0.05, is said to be lacking in electrolyte – this condition causes soil dispersion (demonstrated in field),
5. Acidity is defined as pH (water) less than 6.5; Alkalinity is defined as pH (water) greater than 9.0,
6. Excess salinity is associated with a subsoil electrical conductivity value (1:5 soil:water, dS/m) greater than 1.0.

5. Industry Reviews and Recommendations: 2005-2016

5.1 Gus Shaw review

Shaw (2005) prepared a survey report for CRDC entitled 'Soil health issues for Australian cotton production, growers perspective'. Thirty cotton farmers were interviewed during July 2005 from Hay in the south to Emerald in the north.

The following key findings indicated a strong acceptance by cotton farmers and their advisers of the information contained within SOILpak:

a) 90% of growers conducted some form of soil health monitoring, 10% did not monitor at all.
b) 21% percent of farmers had a comprehensive soil health monitoring program that included visual observations of crop growth and disease, soil testing for nutrients and organic carbon, and compaction assessment via soil pits and capacitance probes.
c) 11% of growers relied on their consultant to monitor crop progress and soil chemical and physical condition.
d) All growers had soil management programs in place to minimise and manage compaction.
e) Waterlogging was identified as a major yield limiting factor by 76% of the growers. Yield mapping and modified field architecture had gone a long way towards correcting this.
f) 60% of growers conducted some form of soil testing prior to new developments. A few used soil pits, some in conjunction with a consultant soil scientist.
g) Growers used a range of tools to assess soil structural qualities. These included soil pits (backhoe and spade), 'feel and smell' of the soil, sodicity testing, yield, infiltration and internal drainage, friability, capacitance probes and root activity.
h) Farmers felt that they were receiving inadequate extension information about soil health issues from CRDC/CRC who they trust as being independent and supported by good science. Growers did not, however, feel as confident about commercial information from resellers and salesmen.
i) Approximately 20% of growers had mapped yield, overlayed elevation data and were in the process of or had completed laser levelling the country, plus had other ideas for field architecture. Two growers had progressed to variable rate fertiliser application. Another two were applying variable rate gypsum. Two growers had progressed to "cost of repair" maps. Four growers had developed "key soil factor" maps including yield, elevation and EM survey data.
j) All growers indicated that a comprehensive soil test for cotton covered the major elements N, P, K and S and minor elements Zn, Fe, Mg, Mo. Five growers included organic carbon, three mentioned sodicity and two mentioned bulk densities and soil structural tests.
k) For 42% of growers, soil sampling locations were influenced by crop yield mapping.
l) Fifty four percent of farmers interviewed have had their country EM surveyed. Most <u>did not</u> believe that the results of EM surveys could be used to estimate all of the soil quality factors relevant to cotton production. Only one grower said EM data could be used for this purpose.
m) 72% of growers took samples in the same place; 28% of growers simply took random field samples.
n) 43% percent of growers kept samples separate for analysis, ie. no bulking.
o) 42% of growers tested soil to 30cm depth; 3 growers in this group occasionally tested to 90-100cm. 42% of growers tested to depths of 0-30cm, 30-60cm and 60-90cm. 11% did 0-30cm

and 30-60cm tests; one grower did a 0-30cm and 30-90cm test. Deep tests were for nitrogen and sodicity.

p) Several growers said soil testing was very expensive and this acted as a deterrent to undertaking extensive soil testing.

q) 92% of growers use soil references that include SOILpak, consultant soil scientists, soil pits, consultant/agronomist/IDO, neighbouring farmers, field days/seminars, and company experience on corporate farms, researchers, CRDC, state government DPIs, Australian Cottongrower magazine and the Crop Production Course.

r) SOILpak was praised as a good manual and reference point for soil management. One suggestion was how could it be used more effectively, and how can SOILpak be made more relevant, given that growers have "moved on from the early days".

s) 93% percent of growers asked for more information on soil biology.

t) Approximately 15% of the interviewed growers were involved in utilising "alternative" approaches to biological soil health.

In conclusion, Shaw (2005) found that:

- Most Australian cotton growers in 2005 were supportive of SOILpak (*although it should be noted that only about 3% of Australian cotton growers took part in the survey*).
- Most growers understood the limitations of data generated by EM surveys.
- Soil sampling intervals of 0-30cm, 30-60cm and 60-90cm were used widely, ie. similar to SOILpak specifications, and beyond the requirements of NUTRIpak (*this conclusion was disputed recently by one of the reviewers*).
- The comment from one grower about the supposed need to "move on from the early days" indicates presumably that compaction (the dominant topic in SOILpak) was well understood and under control in 2005. The recent introduction of much heavier harvesters, however, means that compaction is "back on the agenda".
- Gus Shaw's survey of grower's attitudes to soil assessment and management needs to be repeated so that the developers of a possible new version of SOILpak have up-to-date and accurate information about client requirements and current practices.

5.2 Cooperative Research Centre soil science achievements

Cattle and Field (2013), in their review entitled '*A review of the soil science research legacy of the triumvirate of cotton CRC*', concluded that: "As the third edition of SOILpak is now some 15 years old, there is a strong case for this successful extension tool to be updated with a fourth edition, including relevant findings from cotton 'Cooperative Research Centre' (CRC) research." This includes the large amount of recent and valuable NSW DPI research work carried out at Narrabri by Dr Nilantha Hulugalle, and soil-related precision agriculture publications such as Stewart, Boydell and McBratney (2004).

In recognition of the need to improve extension of soil health information for the cotton industry, EA Systems (2006) prepared a paper entitled '*Accelerating adoption of integrated soil management practices in irrigated cotton and grain*'. The following conclusions were made:

a) Define the soil management outcomes that are required across the cotton industry, eg. 'Soil health indicators well documented and leading to an improvement in soil condition over time rather than degradation.'

b) Define the required soil management competencies for farmers, private advisers, government advisers and specialists in commercial soil science.

c) Provide cotton farmers with access to skilled and accredited soil management consultants ('GPs' and Specialists).

d) Design and trial training courses and course notes for both advisers and farmers, with an emphasis on soil biology. Focus on a stronger awareness of available soil assessment procedures and appropriate soil management options based on "good science".
e) 'Re-badge' relevant soil information via new brochures and magazine articles. For example, the development of a "Myth Busters Column" in a magazine such as *The Australian Cottongrower* is likely to be popular.
f) Document farmer case studies, backed up by economic data.
g) Plan a 'Regional Soil Health' symposium.
h) Make the most of new web-based systems for information delivery.

5.3 Recent soil assessment recommendations for growers

2013 'Australian Cotton Production Manual'

There is a strong need to move on from the following non-standardised approach described in 2013 Australian Cotton Production Manual (p38): ie. use of soil sampling kits (from accredited laboratories or service providers) that give instructions on where to sample the soil in order to provide a representative sample.

Another problem with the 2013 manual is that it over-emphasises the value of EM surveys for cotton soil assessment and management (see comments in Table 1). There is disregard of the following advice from CSIRO (McKenzie and Ryan 2008): "When used appropriately, ie. with thorough checking in the field, the (EM) method is invaluable for mapping some soil properties in particular landscapes. However, total reliance on EM survey as a surrogate for soil survey is unwise, as even a rudimentary understanding of the technique and insight into natural variation will show."

2016 'Australian Cotton Production Manual'

The 2016 Australian Cotton Production Manual correctly points out (p32) that "Money spent on a soil survey usually is repaid several times over because of the potential management problems that it highlights. Soil survey information provides a benchmark that can be used to check progress with soil quality management as the cotton farming project proceeds." and that "Good quality soil survey information provides the opportunity to minimise the impact of soil variation within each management unit."

Under the heading 'Monitor your soil' (p42), it is noted that "It is important to monitor your soil because farming practices impact on the chemical and physical properties. While there are no hard and fast rules about when to do this, a good start would be to do comprehensive cropping soil tests in **increments of 30cm down to depths of 60-90cm** once within the farming rotation. This would be best done before a cotton crop is planted given that it has the highest nutrient requirement. In a continuous cotton cropping rotation this would be done once every three-four years. Monitoring can then be used to identify new or changes in existing issues and prevent the development of any further issues within the production system. This can be particularly important in the subsoil layers that impact on nutrient and water availability in the later stages of crop development. Problems associated with subsoil constraints include compaction, soil dispersion, high or low pH, waterlogging and erosion. These soil related problems can result in poor seedling emergence, poor plant growth, loss of bolls and poor boll set, reduced yields, erosion, increased land management costs and other management issues."

It is noted that in conjunction with the use of EM surveys, this leads to "Creation of zone or grid based prescriptions for the use of seed, water, fertiliser, insecticide, fungicide, herbicide and growth regulators".

This 2016 approach has many good features, but the NUTRIpak, SOILpak and WATERpak manuals require updating of their soil sampling methodology sections to provide consistency of advice for cotton growers.

6. Important New Trends that are Relevant to SOILpak

6.1 'Big Data' and 'Precision Agriculture' ideas

Keogh (2016) has explained recent developments and commercial uptake trends in digital agriculture' and 'big data' in Australia and USA. He described '**digital agriculture**' as the use of five years of yield maps from a specific paddock by an agronomist to develop variable rate planting and fertiliser strategy; '**big data**' can be described as the analysis of all the yield maps from all the grain harvesters operating in Australia over a five year period, together with weather data to identify yields and WUE trends.

Keogh's ultimate objective is to have the following layers of information for a farm:

- Yield maps,
- Rainfall,
- Temperature,
- Soil type,
- Soil nutrients,
- Slope,
- Seed variety,
- Fertiliser,
- Disease risk.

The US corn belt precision agriculture system noted by Keogh has been developed on the back of:

- **Very high resolution national soil maps** (**1:25 000**)**,
- High density rainfall & climate data,
- Extensive mobile phone network.

There are data ownership questions and privacy issues that are in the process of being resolved.

According to Keogh (2016), a key issue in Australia is: "Is it feasible to improve the quality of soil testing, and to use this and other information to develop comprehensive national soil mapping?"

Nigel Corish made the following comments after a recent Nuffield scholarship tour (Corish 2015): "Another key finding from Nigel's scholarship was that farmers in other countries, particularly the US, are sampling fields on a far smaller scale (**down to a one hectare grid**) than Australian cotton growers, to determine variability across a field and create smaller management zones. Technology and computer programs are then used to determine fertiliser requirements in each zone and fertiliser is applied using variable rate technology."

Oliver and Robertson (2013) have illustrated how yield maps from grain harvesters, collected under dryland conditions in Western Australia, can be combined with APSIM modelling of expected grain yields under the prevailing weather conditions to create 'yield gap' maps (Figure 2). This information, in conjunction with a soil type map drawn by the farmer, is used to define where soil sampling sites should be located. This approach has great relevance to the dryland cotton industry, and should be included in the next version of Cotton SOILpak.

Also of relevance is the Green Precision 'vegetation analysis' website, a joint venture involving CSBP Fertilisers and NGIS Australia (www.greenprecision.com.au). It shows month-by-month NDVI (Normalized Difference Vegetation Index) values across all of Australia with 30m x 30m pixels for the years 2013-2016.

** Gallant *et al.* (2008) have noted that a soil map with a publication scale of **1:25 000** has an intensity level of 'moderately high (detailed), and an inspection density of 1 site per 5ha to 25ha. (Objective = 'moderately intensive uses at 'field' level', detailed project planning').
A soil map with a publication scale of **1:10 000** has an intensity level of 'high (intensive)'; inspection density of 1 site per 0.8ha to 4ha. (Objective = 'intensive uses, small fields, urban land, sample areas, engineering works').

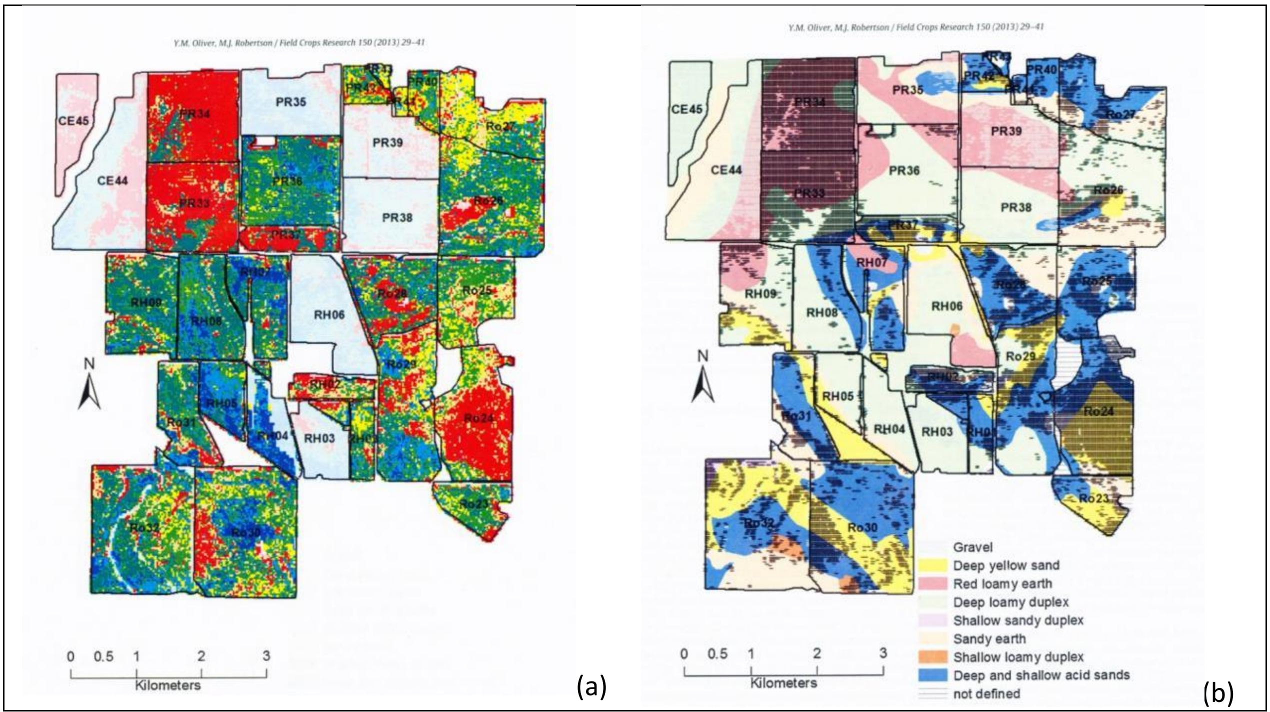


Figure 2. A combination of (a) yield gap analysis, and (b) farmer soil maps, to define representative soil sampling sites under dryland wheat in WA (Oliver and Robertson 2013)

6.2 Global soil mapping protocols

Predictions across Australian cotton farms of soil condition via GlobalSoilMap (www.globalsoilmap.net) (Figure 3) and the associated 'Soil and Landscape Grid of Australia' (www.clw.csiro.au/aclep/soillandscapegrid) are unlikely to have the required accuracy for comprehensive within-field soil management decisions. However, this modelled information is likely to become more refined in the future and needs to be monitored by the cotton industry.

The 'standard depths' for GlobalSoilMap need to be taken into account when defining soil sampling depths for SOILpak and NUTRIpak – see Table 1.

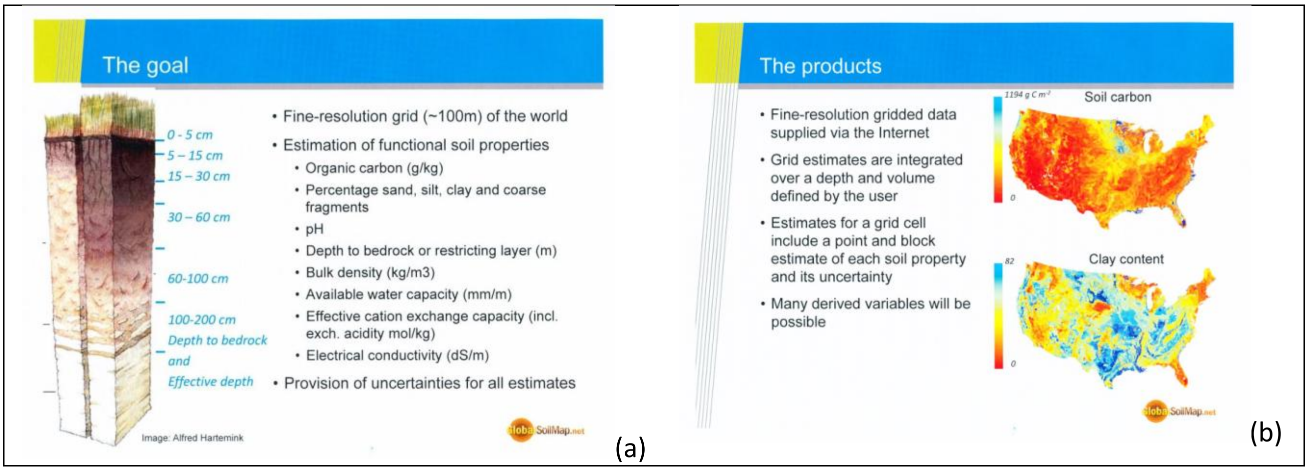


Figure 3. Ambitions of the GlobalSoilMap project (McKenzie 2012, Arrouays *et al.* 2014): (a) goals, (b) the products.

6.3 Interactions between mining/CSG activities and agriculture

Cotton Australia (2012) had problems with NSW Government when attempting to justify their assertion that much of the cotton growing soil in north-western NSW is high quality – ie. 'Biophysical Strategic Agricultural Land' (BSAL) status – and deserving of special protection from coal mining and coal-seam gas (CSG) exploration and production.

This highlights the importance of having cotton industry soil data in a consistent, accurate and well-organised format that can be quickly combined and used to protect grower's interests. The 2014 BSAL mapping carried by BHP Billiton in the southern Liverpool Plains, using GlobalSoilMap sampling protocols associated with the NSW Government (2013) 'Interim Protocol for BSAL assessment', shows what is possible; see http://www.mpgp.nsw.gov.au/index.pl?action=view_job&job_id=6474

6.4 Global challenges relevant to cotton soil management in Australia

New cotton harvesting equipment (the JD7760 in particular) has the potential to create major new soil compaction challenges that, when interacting with possible long-term global challenges described in Table 3, could have a major negative economic impact on Australian cotton growers. An updated SOILpak manual would help growers to prepare for and cope with these possible threats.

Table 3. Global changes with the potential to impact strongly on managers of soil in the Australian cotton industry.

Global trends	Implications for cotton soil management in Australia	How can SOILpak help?
Hotter and longer droughts (likely)	Water holding capacity (WHC) of compacted soil is about 50% of WHC for uncompacted soil (Fig. 5b); drought risk is therefore aggravated, particularly in dryland systems	Provide improved systems for the assessment, control and management of soil compaction damage
More intense scrutiny by regulators of emissions of nitrous oxide (likely)	The risk of nitrous oxide losses is greatest in compacted/waterlogged soil	Provide improved systems for the assessment, control and management of soil compaction damage – and associated nutrient and field architecture issues
Encouragement of growers to at least minimise further losses of soil carbon (likely)	Poor root growth associated with compaction damage, and soil disturbance associated with deep ripping, are not conducive to carbon sequestration	Provide improved systems for the assessment, control and management of soil compaction damage
World food shortages that may make food crop production more attractive to some Australian farmers than cotton growing (possible)	Growers need to maintain soil condition on cotton farms in a state that provides flexibility for production of alternative crops such as cereals and pulses	Provide improved systems for the assessment, control and management of soil compaction damage (possibly in conjunction with Grains R&D Corporation)
Shortages of easily-extracted low-cost crude oil, leading to an increase in diesel fuel costs (possible)	Deep ripping will become more expensive as liquid fuel prices increase, leading to higher break-even values for cotton production when the soil is badly compacted	Encourage the creation and maintenance of favourable soil structure via well-maintained controlled traffic farming systems and stubble retention
Shortages of easily-extracted crude oil and natural gas, leading to an increase in nitrogen fertiliser costs (possible)	Increase in nitrogen costs, even though it currently is not a big percentage of cotton production costs	Reduce the need for very large nitrogen inputs through reduced compaction and high-quality soil fertility monitoring

7. SOILpak Upgrade Suggestions

7.1 SOILpak target audience

As indicated by the dot points on the cover of '*SOILpak for cotton growers, third edition*', cotton farmers and their consultants were the target audience when it was written. However, easy access to this document via the internet means that it may also be used by other consumers of the information such as:

- Land managers in government agencies, eg. Local Land Services in NSW.
- Students.
- Research scientists planning technical investigations.

The range of end-users to be catered for in the future will strongly influence the style of presentation and contents of any new version of Cotton SOILpak. However, troubleshooting of soil related issues by cotton growers and their consultants to improve farm profitability and minimise adverse environmental impacts is likely to remain the main focus of SOILpak. It has been suggested by NSW DPI (Ashley Webb, pers. comm. 2016) that SOILpak should be more decision support tree than manual, and that it should be linked in more tightly with current cotton industry products such as 'myBMP' and the annual Production Manuals. The SOILpak manual would be a lot more user-friendly and easier to update if it was in an electronic format.

In previous decades, production of soil factor maps across entire farms and regions was considered to be a role of government. Unfortunately, much of the government soil mapping in NSW (presented, for example, via web-based systems such as eSPADE) is lacking in detail and not comprehensive. Funding to overcome this problem in cotton growing areas is unlikely to be provided by government. Therefore, the practical way forward is for Australian cotton growers and their consultants to collect the required soil data themselves in a way that allows merging of information for whole-of-farm, regional and industry-wide land quality assessments. Most importantly for growers, well-organised soil factor maps are an invaluable starting point when carrying out yield map interpretation and soil management planning on a field-by-field basis. Storing soil data in a clear and systematic fashion for this on-farm mapping gives discipline to what often is a very disorderly filing process within farm offices.

Nilantha Hulugalle (pers. comm. 2016) has noted that right at the outset, aim to have a brief section in SOILpak clarifying that "soil health" is not solely nutrient management and fertiliser application but the interaction of physics, chemistry and biology.

Mike Braunack (pers. comm. 2016) has noted that the 1998 version of SOILpak seems to be reactive in addressing soil management; especially as it resulted after a series of wet picks. We have the opportunity to be proactive in developing a version looking at maintaining soil condition under the pressure of the new pickers and climate change, ie. making soils more resilient to perturbation.

7.2 SOILpak manual contents

New SOILpak chapters are recommended for the following topics:

- Part B: Quick Help; Machinery wheel configurations for successful CTF.
- Part B: Quick Help; How best to manage with a JD7760.
- Part B: Quick Help; Field architecture management to minimise waterlogging.
- Part B: Quick Help; Growing cotton on soil that is both sodic and saline (longer-term strategic practices v. seasonal tactics).
- Part B: Quick Help; Irrigation with saline water; short- and long-term impacts on soil properties.

- Part B: Quick Help; Application of recycled solid waste products (gin waste, manures, etc) on soil properties and economics.
- Part B: Quick Help; Minimising soil structural degradation when pupae busting.
- Part B: Quick Help; Soil sampling and data processing checklist for yield map interpretation and whole-farm planning (maybe divide into two sections; soil structure and crop nutrient supply).
- Part B: Quick Help; Making the most of yield maps by converting them into 'yield gap' maps (via crop growth models such as APSIM), which in turn can be converted to '$-value of lost production' maps for individual cotton fields under the prevailing climatic conditions.
- Appendix: Profile trimming, lighting and 2D/3D photographic techniques to obtain useful soil structure images (horizontal remote sensing). Virtual reality headsets (eg. VRBox) are available to view the imagery in 3D, either remotely in real time or via stored images.

Existing SOILpak chapter that should be split or combined to create new chapters:

- Part B: Quick Help; Soil survey for development or redevelopment;
  - Soil survey for water storages & channels based on EM surveys,
  - Soil survey for cotton fields.
- Part C: Diagnosing soil condition; 'C1 Soil assessment: where, how and when?' and C9 'Using moisture probe data';
  - Soil pits for appraisal of compaction damage,
  - Soil coring for analysis of soil chemical properties,
  - Moisture probe data for assessment of rooting depth/vigour and soil water holding capacity.
- Part C: Diagnosing soil condition; 'C3 Soil moisture (before tillage), soil texture and available water;
  - Soil moisture status when planning deep tillage,
  - Estimation of water holding capacity based on texture and structure – focus on the fact that that there is a halving of soil waterholding capacity through serious compaction (Moore *et al.* 1998) (see Figure 5b).

Major re-writing is required for the following sections:

- Managing soil constraints in variable cotton fields– expand greatly.
- Extra notes for dryland growers, whose soil constraints tend to have a greater impact on cotton lint yields than under irrigated cotton.
- Case studies – expand greatly; produce web versions with a focus on economic costs and returns associated with cotton soil assessment and improvement.
- Background information: E1 Australian cotton soil – add existing soil survey and landscape information for Swan Hill district (northern Victoria), Riverina (particularly near Hay where very little government soil survey data are available), North Queensland and the Kimberley Region WA.
- Background information: E5 Organic matter and soil biota – add more about crop management practices (rotations, stubble management) and their benefits/costs with respect to soil management.
- Appendixes: 2. Further reading – lots to be added following three CRCs and associated initiatives.
- Appendixes: 6. Soil pit description sheets – simplify; use colour photo reference standards where possible (see example from New Zealand in Figure 4, which could be presented in a 3D format); aim to have electronic versions.

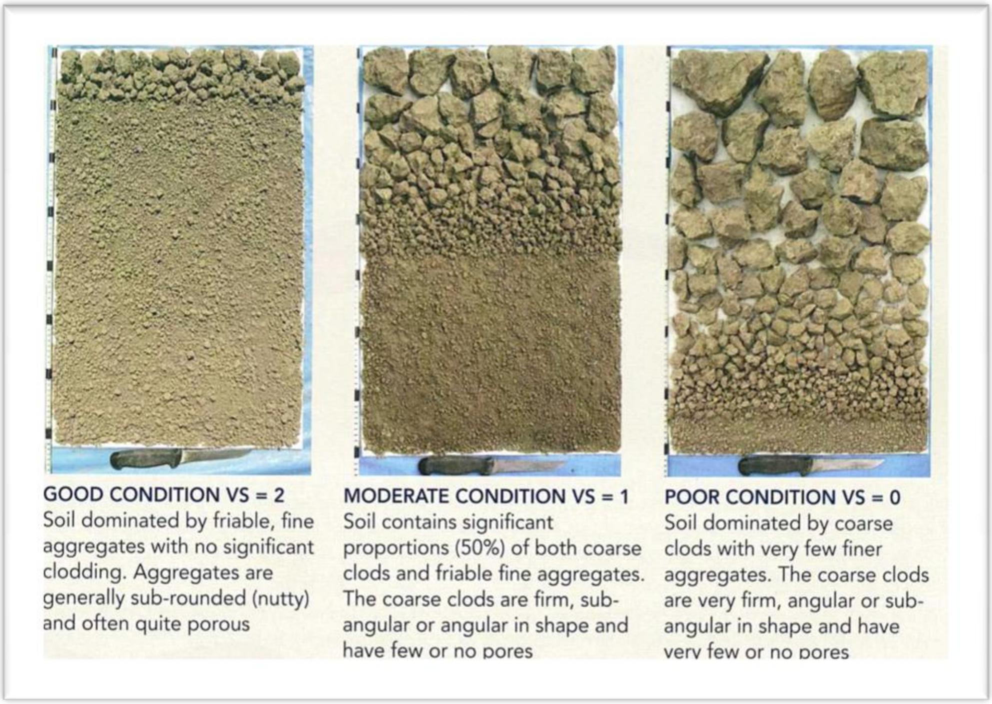


Figure 4. Clear photo reference standards developed by Shepherd (2009) for the assessment of topsoil structure.

Other requirements:

- Include recent ideas regarding dispersion/sodicity assessment – particularly the need to pay more attention to exchangeable magnesium and potassium (Bennett *et al.* 2016).
- Emphasise dispersion aggravation when working wet soil.
- Ideal soil for cotton – expand to include examples with capacitance probe moisture data.
- PRECISIONpak and LANDpak ideas combined into SOILpak?

There is confusion between the terms "SOILpak Decision Support System" and "SOILpak score", so maybe change the "SOILpak score" to a cotton-specific version of the "VESS" and "SubVESS" scoring systems as described by Ball *et al.* (2007, 2015). However, it is important to note that the scientific quality of SOILpak procedures associated with 'soil structure assessment in relation to plant root growth' remains credible.

7.3 Proposed protocol for soil factor assessment when using SOILpak and NUTRIpak

A soil sampling protocol is needed that allows the following objectives to be achieved by cotton growers, their advisers and industry leaders:

- 'Yield gap' map interpretation.
- Systematic soil management response to the soil factor information collected after inspection of yield maps and associated information.
- Nutrients monitored accurately/comprehensively and applied sensibly.
- Organic matter dynamics quantified – linked to N management and carbon sequestration planning.
- Effective decompaction (mechanical, biological) where required.
- Cost-effective application of gypsum/lime where required.

- Water holding capacity measurements to assist with irrigation system design and irrigation scheduling.
- Salinity dynamics understood.
- Land forming and raised bed construction to reduce waterlogging.
- "Big Data" analytical capacity for the entire Australian Cotton Industry (grower confidentiality issues to be resolved first) NB. Only possible with soil sampling standardisation.

The following scheme is presented for consideration by CRDC and CottonInfo:

1. SOILpak sampling depths (0-10cm, 10-30cm, 30-60cm; 60-100cm rather than 60-90cm) on a ~400m flexible grid (maybe less intensive for compaction pattern assessment, in situations where a particular machinery wheel configuration is used right across a farm).
2. Comprehensive soil data, collected using sampling sites on a ~400m flexible grid, would allow production of soil maps on Australian cotton farms with an accuracy similar the very high resolution national soil maps (1:25 000) in USA mentioned by Keogh (2016).
3. Place the soil sampling sites in a way that lines up with high, moderate and low yielding areas on yield maps, where possible.
4. Focus on the use of 'key soil factor maps', rather than 'soil type maps'.
5. Where strong correlations are likely to occur, for example, between EM survey data and subsoil salinity, fill in the gaps between sampling sites via landscape modelling to produce very detailed maps of the relevant soil factors.
6. Maybe have intensive NUTRIpak grid sampling with a spade and/or corer (100m spacing) for selected soil factors such as topsoil nitrate-N; 0-10cm, 10-30cm (or perhaps 0-30cm soil testing with use of algorithms to predict values for 0-10cm and 10-30cm).
7. In addition to this, encourage providers such as Back Paddock/Fertcare to continue with the building up of their nutrition correlation knowledge – particularly soil N content v. plant tissue N content v. yield/quality of cotton and associated rotation crops (part of NUTRIpak).

7.4 The cost of soil testing – a major issue for cotton growers

Anecdotal evidence suggests that cotton growers appreciate approximately one soil observation per hectare where possible, but are unwilling to spend more than about $10-20 per hectare per annum on soil assessment. Grower surveys are required to check these figures. The recommended soil sampling scheme shown in Table 1 (one pit per approx. 16 ha) would involve a one-off cost of about $60 per hectare. It is hoped that the future introduction of 'proximal soil sensing' (eg. portable XRF spectrometer to scan exposed faces of soil pits; Adamchuk *et al.* 2015) will greatly reduce the cost of soil assessment without compromising accuracy too greatly.

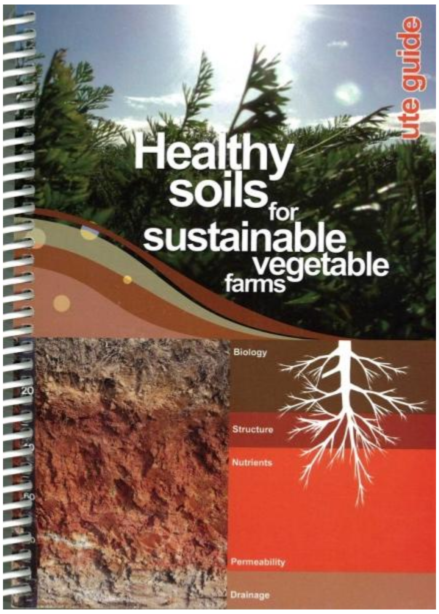
An alternative view is to carefully consider the cost of not facing up to soil problems. Chris Dowling (pers. comm. 2016) has noted that coefficients of variation of lint yield performance should be examined within each field to determine if there is sufficient variability to get a cost-effective outcome from a more intensive/expensive soil sampling regime.

It is important to note that EM surveys are attractive to growers because of their low cost, but actually can be very expensive if they provide inaccurate soil assessments that result in an inability to overcome major soil-related yield losses. Benefit-cost analyses of available soil testing alternatives therefore are required urgently.

7.5 Presentation options for SOILpak

The AUSVEG Ute Guide (Anderson *et al.* 2007) (Figure 5) has a successful presentation style that should be taken into consideration if re-designing SOILpak and its Pocket Notes.

A Wiki system for 'open source knowledge-sharing operations' would provide an excellent framework for soil-related case study management in the cotton industry. An example of available software is 'MediaWiki', which is used for the hosting of 'Wikipedia'. Links with YouTube videos would assist with case study presentation and soil description demonstrations.



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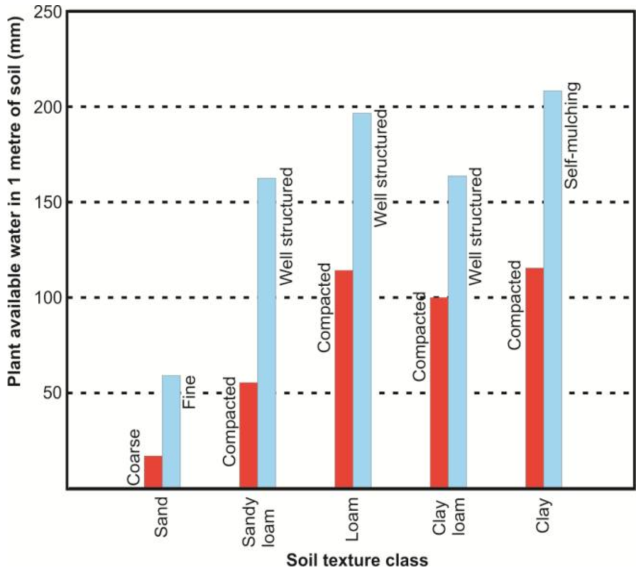

(b)

Figure 5. Soil management Ute Guide developed for the Australian vegetable industry (Anderson *et al.* 2007): (a) Front cover of the booklet, (b) An example of one of the Figures.

Use of a WordPress website, for example, provides the ability to show a new version of SOILpak on not just PCs but also tablets and mobile phones. This format would be particularly useful for an abbreviated version of SOILpak, ie. 'Pocket Notes'. An associated detailed version SOILpak could be presented via the Internet as an easily updated e-book.

MACHINEpak should be converted to a web-based system that hosts video-based materials, eg. drone footage of an Auscott JD7760 picker in the field following conversion to narrow wheels (no duals), in conjunction with 1.5 meter beds and tracked wheat harvesters that fit the same wheel tracks. John Bennett (USQ Toowoomba) demonstrated what is possible with drone-based videos at the July 2016 '*Cotton Soil Constraints Forum*' in Moree.

7.6 Human resource management for cotton soil management

A critical issue is human resource management. The Australian cotton industry needs descriptions of who is responsible for what when assessing and managing cotton soil, including the respective soil competency requirements of:

- farmers,
- agronomists (soil management "General Practitioners"), many of whom have Fertcare accreditation (www.fertilizer.org.au/Fertcare) and use accredited laboratories for soil analysis,
- soil science extension specialists, with accreditation from organisations such as Soil Science Australia and their 'Certified Professional Soil Scientist' (CPSS) scheme (www.soilscienceaustralia.com.au/careers/certified-professional-soil-scientists),

- soil science researchers,
- precision agriculture engineers,
- irrigation engineers, and,
- hydrogeologists.

This 'community of soil management professionals' (Figure 6) needs to be supported by appropriate training programs, and industry encouragement for entrepreneurial soil-related business enterprises.

This organisation of human resources for soil-related work in the cotton industry – which is akin to the arrangement and equipping of an army in a time of national emergency – would (if carried out successfully) allow cotton industry leaders, their associates in other industries such as grains and horticulture, and natural resource planners in government agencies to carry out their work more efficiently and effectively.

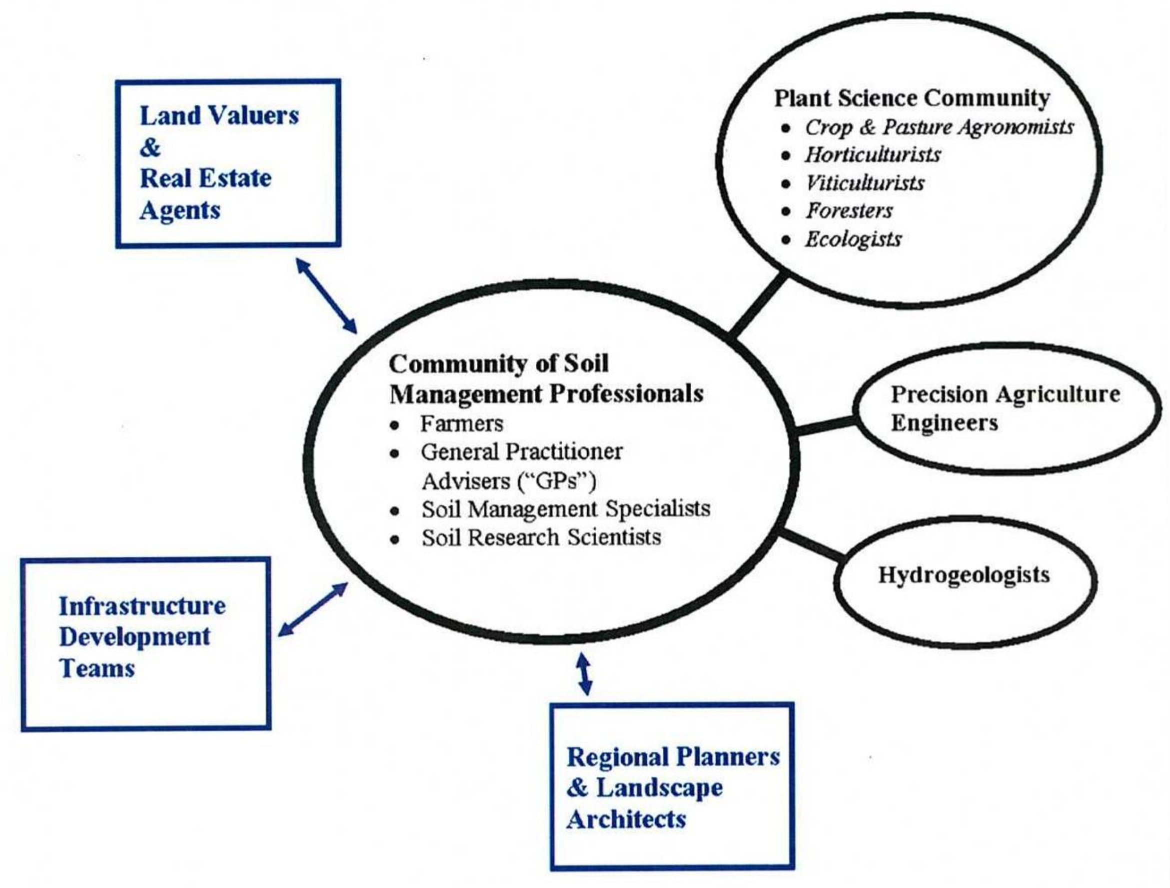

Figure 6. A proposed community of networked professionals for managing the soil resources in the cotton industry (based on McKenzie 2013).

It is important to seek the views of all interested soil science and agronomy colleagues before making major decisions about the future of 'SOILpak for Cotton Growers' and associated manuals.

7.7 Integration of SOILpak with other cotton industry information

The following quote from Allen *et al*. (2001) is pertinent: "It is relatively easy for cotton pathologists to develop and recommend an Integrated Disease Management strategy. The real challenge is for growers and consultants to integrate these recommendations with the recommendations in ENTOpak, SOILpak, NUTRIpak, MACHINEpak and WEEDpak. All of this information then has to be further integrated with current weather and weather forecasts, market forecasts and economic forecasts from the bank manager or shareholders! Growers and consultants are the real integrators! We wish them well!!"

The CottonInfo team (www.cottoninfo.com.au) is well placed to take the lead with practical inter-linkage of upgraded versions of SOILpak and associated manuals using the latest communication tools.

They also need to facilitate the building of improved human resource networks that will allow the Australian cotton industry to build on its past achievements in soil science and make the most of future opportunities. Consideration should be given to Tom Batey's idea (pers. comm. 1990) of recruiting independent 'Advisory Soil Scientists' to the cotton industry – possibly within the CottonInfo team. Apart from having on-going responsibilities for extension leadership and case study development, they would be well placed to develop new R&D plans for researchers that would feed new information into SOILpak and overcome the inevitable soil-related knowledge gaps that will arise in the future.

8. Acknowledgements

Allan Williams, Cotton Research and Development Corporation, Narrabri, provided clear instructions and excellent support for the SOILpak review process.

The CRDC/CottonInfo '*Cotton Soil Constraints Forum*' in Moree on 14 July 2016 had excellent presentations and discussions relating to soil compaction management in the cotton industry. The grower and consultant presentations in particular provided an excellent update for attendees.

Valuable comments about an earlier draft of this report were received from DPI (Ashley Webb, Abby Jenkins, Warwick Dougherty, David Larsen), Dave Anthony, Chris Dowling, Pat Hulme, Mike Braunack, Nilantha Hulugalle and Neil McKenzie.

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