

How Far Has Soil Health Come in the Cotton Industry?

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On the 2nd May 1908 the Agricultural Gazette of NSW quoted that 'Cotton will grow in almost any soil, but is more productive, and there for profitable, in a deep sandy loam. The Moree soil was a stiff black clay, which was not altogether favourable for the plant'. It was also recommended that 'the ground is best prepared by deep ploughing in the winter and left rough to weather down. The plot should be cross ploughed in spring, and rolled and harrowed to bring it to a fine tilth.' (Fry, 1908). With the research and successes from the cotton industry it is clear we have come a long way in the past 99 years and learnt to appreciate and how to manage those 'stiff black clays' around Moree which are some of the most productive in the industry.

As the skill in growing cotton has increased, so has the health of the soil. However, when the most limiting factor in soil health has been addressed, another factor becomes more apparent. This paper outlines the major soil health issues which have arisen in the cotton growing soils of NSW and QLD, how the cotton industry has addressed these issues and the current and future soil health interests.

Where are we?

Australian average yields are now the highest of any major cotton producing country in the world and yields have continued to edge upwards from 1200 kg/ha in the 1970s, through 1400 kg/ha in the 1980s to 1600 kg/ha in the 1990s and are now above 1800 kg/ha (Figure 1). Research and development, combined with its practical implementation by Australian cotton growers has under-pinned these significant increases in production.

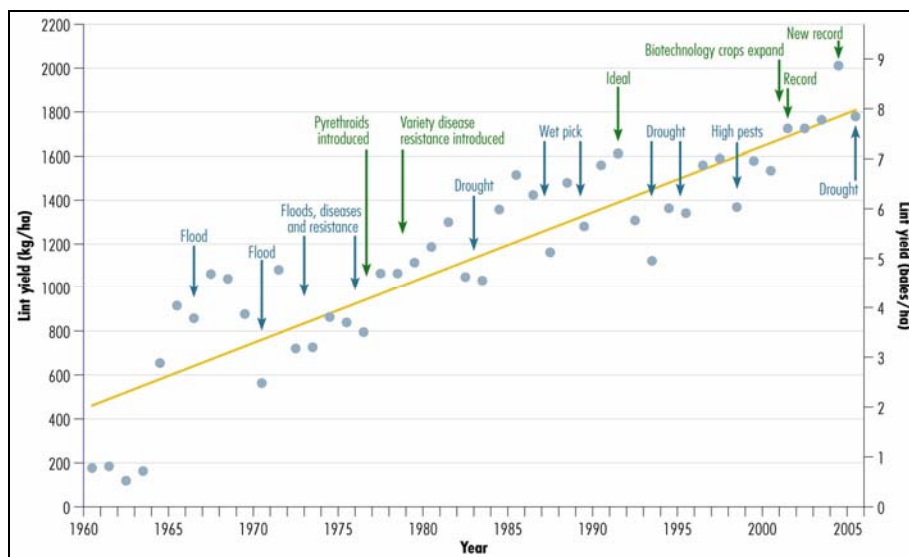


Figure 1. Australian Cotton Industry average lint yields with reference to major environment effects

The completion of Keepit Dam on the Namoi River and the subsequent introduction of irrigation into northern New South Wales during the 1960's and 1970's was the major trigger for the development of the Australian cotton industry. The NSW Water Resources commission conducted a number of surveys in the lower catchments in NSW to determine the irrigation potential of these areas (Stannard and Kelly, 1977). Currently seventy per cent of Australia's cotton is grown in New South Wales (the Macquarie Valley, the Namoi Valley, the Gwydir Valley, Bourke, Murrumbidgee, Lachlan & Menindee) with the remainder grown in Queensland (the Macintyre Valley, Darling Downs, St George, Theodore, Biloela and Emerald regions). Currently, trials are underway in the Ord (WA) and Burdekin Valley (Qld).

Depending on water availability about 400,000 hectares of irrigated cotton is grown in Australia. The area of dry land or rain grown cotton varies considerably from year to year depending on commodity prices, soil moisture levels and rain. The area of dry land crop can vary from 5000 to 120,000 hectares. The major soil types on which cotton is grown are grey, brown and black Vertosols (~75%) and Chromosols, Sodosols and Dermosols (15%) (McKenzie *et al.*, 2003).

Our Soils Path

The subject of crops and soils can be compared to the iceberg analogy. That is, the 10% on top is where we focus our attention and the remaining 90% underneath we worry about only when it causes grief! This has probably resulted in an "out of sight - out of mind attitude" to the soil systems that supports and feeds most agricultural systems. Reduced soil structure was one of the first such issues that plagued the cotton industry.

Soil Structure

The early stages of commercial cotton in Australia in the late 1960's and early 1970's there were large decreases in cotton yield following harvest and land preparation under wet conditions (figure 1). Flooding caused erosion problems and farm infrastructure damage. This led to wet farming operations that caused serious soil compaction and smearing and resulted in

- a significant reduction in the amount of water available to cotton plants,
- strong changes to soil structure visible in the soil profile, and
- smaller cotton plants with up to 50% fewer green bolls

This led to the beginning of soil research in the cotton industry with particular reference to soil structure amelioration for compaction.

After the big wet seasons of the late 1980's it was apparent that soil compaction due to wet land preparation and harvest was still causing great concern to the industry and led to the development of the first edition of SOILpak™ in 1990. The outcomes from all industry-funded soils research, as well as grower experiences, were used in the SOILpak™ manual which is a decision-support system for irrigated cotton production on cracking clay soils with particular emphasis on soil structure. In 1998 another wet winter brought about the third edition of SOILpak™ with an additional smaller paddock friendly ute guide that summarises the larger manual along with a video to help in identifying soil conditions. Soil management techniques to prevent or reduce compaction were

introduced and rolled out via a large extension program using soil pits and field days that markedly improved cotton yields. Current market research conducted across the industry with growers and consultants noted that many still refer to this manual for guidance in relation to soil compaction issues.

The research conducted on the benefits of compacted versus non-compacted clay soils under cotton production brought about the introduction of controlled trafficking. Research in this area started in the early 1980's but it wasn't until the 1990's with the rapid expansion of technology that made it more compatible to the cropping industries. Figure 3 shows an example of the impact of wheel traffic that increased bulk density and decreased plant height, dry matter production and consequently reduced yield. Controlled traffic is now used in most cotton farming systems to reduce compaction by remaining on permanent wheel tracks as well as retaining permanent beds.

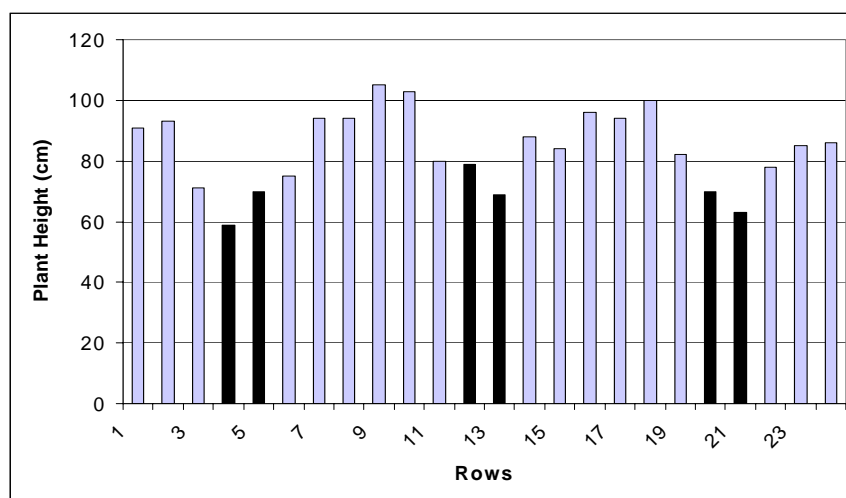


Figure 3. Plant height in a cotton crop showing wheel track compaction effect. Wheel tracks between black rows.

Salinity and Deep Drainage

In irrigated cotton soil salinisation can occur as a consequence of excessive deep drainage, which can create rising water tables, or through the direct application of saline or sodic water. Since the late 1980's soil salinisation has been recognised as a potentially threatening problem in many irrigated cotton growing areas. In recent times new technology such as electromagnetic mapping has enabled the identification of potential saline and deep drainage areas to be more easily recognised before irreversible and costly (in both environmental and economic terms), damage occurs.

The Cotton CRC, CRDC, NHT and The University of Sydney have worked collectively to map the cotton soils of Australia. This, along with other industry funded research, has helped in identifying areas within the cotton catchments that are more susceptible to salinity. One such outcome from these studies is the development of terraGIS. This is a web-based Geographic Information System (GIS) that allows cotton growers, farm managers, consultants, extension staff, researchers, state and federal government agency personnel and policy analysts access to digital biophysical data (e.g. soil, water and hydrological properties) as part of a series of projects entitled "Understanding the salinity threat in the irrigated cotton growing areas of Australia." Biophysical

data is available in seven irrigated cotton growing areas (i.e. Toobeah, Ashley, Wee Waa and Gunnedah, Trangie and Warren & Bourke) located in five catchments (Macintyre, Gwydir, Namoi, Macquarie & Darling) (Triantafyllis, 2007). This information was also compiled onto a CD by Sydney University (Dr I Odeh) and is available for use. There is also a large body of work on deep drainage underway.

Sodicity

Much of Australia's cotton crop is grown on soils of high subsoil sodicity and some soils also have surface layers that are considered sodic (exchangeable sodium percentage (ESP) > 6%). The effect of sodicity in relation to its negative effects on soil structure have been well documented by Vervoot *et al* (2003) who found substantially decreased soil hydraulic conductivity and increased soil bulk density with increased soil ESP. Sodium's negative effect on the physical structure of the soil affects plant nutrition by decreasing root growth and thus water and nutrient uptake. This poor soil physical structure also increase the incidence and severity of waterlogging events. Dr Hulugalle, NSW DPI and Dr I Rochester, CSIRO have published many papers related to sodicity.

Sodium also changes the chemistry of the soil solution, which alters the availability of nutrients to the plant. As the level of sodium in the soil increases, there is a corresponding decrease in the uptake of phosphorus and potassium by the cotton plant, with these nutrients reaching deficient levels as the crop matures. (Dodd, 2004).

The amelioration required to reduce the sodicity impact, particularly from a nutrient as apposed to structure perspective, is currently the focus of many current industry funded research projects in the cotton and grains industries.

Nutrition

In the past decade a greater focus has been on improving the crops nutrition to reach those higher end yields that previously seemed out of reach. Nitrogen fertiliser management has always been a topic of interest to the industry as it is the main nutrient that limits cotton growth. The creation of NUTRIPak™ in 2001 was developed as a practical guide to cotton nutrition (Rochester 2001). This manual followed the same structure as SOILpak™. It was designed to inform cotton growers and consultants the importance of providing their crops with a sufficient supply of nutrients and improving their fertiliser management. It provides guidelines to the critical levels of nutrients in soil and plant material, which indicate nutrient deficiencies or excess. The NutriLOGIC™ tool which contains models that analyse soil and petiole tests and recommends the nutrient amount of required to achieve an optimum yield is available for agronomists and growers on the internet.

Nitrogen was the first focus of crop nutrition research. Next it was phosphorus, and zinc and now it is potassium. There has always been some tinkering with various micronutrients.

Greenhouse Gas

Plant roots exist in a very humid environment (>98%) in irrigated crops. Waterlogging of cotton soils produces an anaerobic environment, which affects the functionality of soil organisms. It also produces large amounts of nitrous

oxide, a greenhouse gas. Nitrous oxide emissions have been measured on Australian irrigated cotton farms by Dr Peter Grace (QUT) and Dr Ian Rochester (CSIRO) at ACRI and are on average well below the IPCC default benchmark (Rochester, 2003). However there is the potential that as nitrogen rates increase (either through applied nitrogen and/or organic sources) there will be a rapid increase in nitrous oxide emissions resulting in poorer nitrogen use efficiency. This has been particularly evident as nitrogen fertiliser rates exceed 200 kg of nitrogen per ha.

Reducing the potential loss of nitrogen to the atmosphere will have both environmental (reduction of greenhouse gas output) and economic (improvement in fertiliser use efficiency) benefits. Generic rules and management strategies recommended and adopted in the cotton industry include:

- Increasing soil carbon levels by reducing cultivation
- Reducing the opportunity for water logging
- Using legume cropping and green manures to reduce the application rates of nitrogen fertilisers
- Reducing the time between applying pre-plant fertilisers and planting and increasing the amount of nitrogen applied later in the season relative to pre-plant applications
- Matching fertiliser applications to plant demand
- Setting realistic yield goals based on the capacity and characteristic of the farm.

Crop Rotations

Cotton production systems have evolved, from growing continuous cotton, to the introduction of winter cereal crops, fallowing and more recently legume crops. Australian research into the effects of cotton-rotation crops systems on soil quality commenced during the late 1970's, focusing mainly on indices such as soil structure and nitrogen balance (Hulugalle and Scott 2007). While it is acknowledged that lint yields have not declined, even from fields having produced cotton crops continuously for up to ten years this can largely be attributed to improved varieties and management practices. Cropping systems are changing to preserve the soil resource. The introduction of legume crops is a good example where organic nitrogen is fixed, and soil tilth improved and there is a considerable body of research by Dr I Rochester, CSIRO on this. In the future we may see other crops such as mustards for biofumigation purposes.

How do we monitor

The Cotton Industry's Best Management Practices (BMP) Program is a voluntary environmental risk management program based on a process of continuous improvement using a 'plan – do – check – review' management cycle. BMP provides the opportunity for the cotton industry to demonstrate and provide more confidence to the community, governments and markets its ability to use and manage various technologies such as pesticides and gene technology (Anthony 2004). The BMP Program provides a systematic process for the Cotton Industry and its growers to contribute to the catchment planning and natural resource management goals of Government. The recent Land and

Water module to the BMP Program addresses the key soil health issues across the industry. Growers are ranked depending on their farming practices with 1 being the optimum management for a particular component and 4 being the lowest.

In 2006, increased impetus to BMP by Cotton Australia lead to a 128 new growers entering the BMP program and undertaking pre certification audits. The rankings of soil management components by these 128 farms have been compiled and are presented in table 1. The main message is that the BMP system can provide a quantitative way of monitoring soil management trends

Table 1. 2006 BMP Land and Water Module Rankings relevant to soil health (Source Roth 2007).

Management Component	Ranking
Soil Management – Structure and Operations	1.71
Soil Management - Nutrition	1.48
Soil Management – Salinity and Sodicty	2.08
Soil Management – Erosion	1.86
Efficient Irrigation – Storage and Distribution	1.84
Efficient Irrigation – Application	1.65
Efficient Irrigation – Water Use and Efficiencies	2.28
Native Vegetation – Assess and Map	3.05
Native Vegetation – Management	2.32
Riparian Zone – Veg and Weed Management	1.73
Riparian Zone – Regional Considerations	1.80
Riparian Zone – Stock Management	2.38
Riparian Zone – Water Quality	1.81
Riparian Zone – Bank Stability	2.32

Farming systems forums previously run in the cotton industry have reviewed research and integrated knowledge in a range of specific topics including stubble management (Narrabri, 1997), Ultra-Narrow Row cotton farming systems (Hillston, 2001), Soil health (Narrabri, 2001), Salinity, Sodicty and Hard Setting Soils (Narramine, 2002) and Crop Nutrition (Narrabri, 2004). Other forums (Narrabri, 1998 and Dalby, 2000) have been more general, covering a wide range of agronomy, environmental, soils, water, precision agriculture, nutrition, pathology, and pest management topics. These forums bring together growers, agronomists and researchers and allows issues to be challenged, developed and adopted from multiple perspectives. In November 2007 farming systems forums will be held at Goondiwindi, Narrabri and Hillston addressing soil health issues relevant to those regions with information updates from researchers and farmer experiences.

Current Priorities

In 2005, a study (Shaw, 2005) was commissioned by CRDC & the Cotton CRC to determine what farmer’s current knowledge and understanding of soil health and management issues were and to identify the cotton industry’s ‘soil health’ needs in order to enhance the research and extension effort in this area. The

survey found that farmers understanding of what soil health means varied and that they felt that they were not receiving adequate extension information about soil health issues. The five main areas of concern were measurement of VAM (Vesicular Arbuscular Mycorrhizae), measurement of other soil biota, soil structure, nutrition and organic carbon. Other issues raised with a need to extend information on were residual herbicides, green house gases, managing sodic sub-soils, nutrient recycling and sodium.

In 2006 a grower survey benchmarking the industry was conducted (Doyle and Cohen 2007). This identified methods of extension of how growers prefer to receive information from the industry (figure 4). The combination of this survey and the study conducted in 2005 is the driving force for priority areas in Healthy Soils for Sustainable Farming program in the irrigated cotton and grain industries.

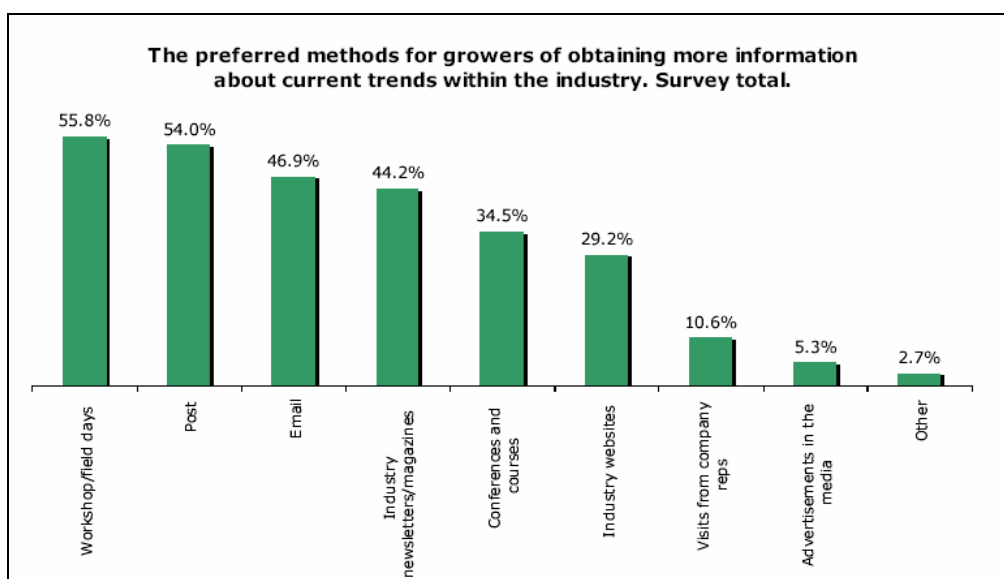


Figure 4. Output from survey conducted in 2006. (Doyle and Cohen 2007).

The Future Direction

Although there is more to learn the cotton industry has grasped the physical and chemical aspects of its soils health, but now needs to direct greater efforts into the more unknown field of soil biology. Major constraints of biological activity in irrigated cotton soils identified already include the lack of carbon and the presence of agrochemicals. High levels of spatial and temporal heterogeneity, soil type effects, sampling problems and interpretation difficulties are some of the challenges with benchmarking the biological components of the soil. There is a need for more research in the biological area of soil management and greater cross linkages between the chemical, physical and biological disciplines. If we could understand the biological component for benchmarking and incorporate this with the chemical and physical attributes then growers would have an overall soil health score for their farming system.

Higher yields also mean more nutrients are being removed from the farm. Fertiliser rates are increasing and new diseases may become apparent in cotton farming systems. The challenging environment for soil created by some farming activities such as high nitrogen use, irrigation, and herbicides maybe

masking the soils ability to perform to its maximum capacity. This makes it difficult for crop managers to diagnose problems. Future research is aiming to address the impact of large applications of various fertilisers and their different forms on soil health.

The cotton (& grain) industry and its catchment partners are currently developing an integrated suite of learning and extension activities for sustainable farming in the irrigated cotton and grains industries. These will improve the capacity of growers and advisors to assess soil health status and to select and implement management practices to improve soil health from accredited soil health.

The formation of a series of soil health workshops is currently being developed and will be delivered across the industry along with case studies which combines existing soil research focusing on improving soil health and soil management with grower's experiences who have implemented a change to their farming system.

Conclusion

The main changes which have occurred in the management of cotton soils over the last 40 years have been an overall reduction in tillage, widespread adoption of controlled traffic permanent bed farming systems, and increased application of nutrients (NPK). The industry-funded research has also changed its focus over that time. In 1970's, the focus was on irrigation timing, nutrition and soil physical aspects. In 1990's, the research has a multidisciplinary approach including engineering for controlled traffic, nutrition, salinity and rotations. The now and the future is looking into the soil biology field, fertiliser efficiencies, and whole farming systems to maintain or improve our farming resources. We will be using the Cotton Catchment Communities CRC framework to bring scientists and advisers from different disciplines and institutions together as well as growers, agronomists, catchment bodies and other industries such as grains to focus our future efforts.

While water might be the trendy topic during this drought, we will never grow successful crops if our soil management is not performing.

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