KIT 1.6

Reduce the impacts of water repellence, compaction, hard-pans and other barriers to the capture and storage of water in soils

Impact	**Growers have access to management options that optimise the capture and storage of available water to improve yield.**
Summary	• Growers and their advisers understand the impact of soil constraints on the capture and storage of water. • Growers have access to knowledge and tools to address identified constraints on the capture and storage of water in soils. • Growers have the tools to financially analyse the costs and potential returns of investment in addressing those constraints.

OVERVIEW

Across large areas of Australia's cropping regions, various constraints to the capture and storage of soil water reduce plant available water (PAW) and crop uptake of nutrients, while also reducing production and long-term profitability. It has been estimated that in some situations overcoming constraints to the capture and storage of water can double productivity. Water repellence (or non-wetting) is an important constraint on sandy soils over much of Western Australian (WA) and South Australia (SA), with minor areas affected in Victoria and southern NSW. Soil compaction is a constraint that occurs across most soil types in all regions. Water repellence and soil compaction often occur where other soil constraints are also present (see KITs 1.7-1.9), and this makes it difficult to achieve profitable returns through the amelioration of any individual constraint. For example, water repellence, soil compaction and acidity occur together on more than 50 per cent of WA soils and these interacting constraints are estimated to cost growers approximately $1.2 billion per year in WA (Peterson, 2016). It has been shown that in some circumstances, amelioration of all three of these constraints can be undertaken simultaneously in one operation with significant increases in production.

Water-repellence affects more than 10 million ha of sandy cropping soils across Australia, but tends to be a seasonal issue, most noticeable under marginal moisture conditions in autumn/winter when the topsoil is dry. Water repellence is caused by hydrophobic organic compounds that coat soil particles with low surface charge and area (i.e. coarse sandy soils). Hydrophobic compounds include waxes, alkanes (paraffins) and long-chain fatty acids remaining behind following microbial breakdown of organic matter. It is most severe in organic-rich topsoils, whereas subsoils generally have low organic contents, have less hydrophobicity and hence, wet up more readily. Water repellence can lead to increased run off, decreased infiltration, poor plant establishment, low PAW, reduced nutrient use efficiency, and poor conditions for weed management. At present there are three main management approaches to overcoming water repellence constraints:

1. mitigation introduces low cost tactical practices that benefit crop production in the short term;
2. amelioration involves more expensive options that change the soil characteristics with medium to long-term benefits; and
3. avoidance where cropping is removed from severely affected areas that regularly fail to deliver a profit.

Compacted soils generally have high soil strength, high bulk density, low soil porosity, and poor hydraulic conductivity. These factors can contribute to waterlogging following intense rainfall events. Plant roots can also have difficulty in penetrating compacted soils resulting in shallow root systems, reduced uptake of water and nutrients, poor shoot growth and low yields. In addition, soil compaction can increase machinery power requirements as well as increases in wear and tear on seeding and tillage equipment. Dense soils can be broken up with strategic tillage or ripping, but tillage on clay soils can create further structural issues, especially on poorly structured sodic soils. The mechanisms that cause compaction and the magnitude and longevity of compaction vary with clay type and chemistry, organic matter, biological activity and presence of cementing agents (e.g. silica, iron and manganese). While some soils are naturally dense, the repeated use of heavy machinery exacerbates compaction especially when the soil has a high moisture content. Machinery inflicted compression forces depend on axel load; the shape, size and pressure of tyres or tracks; the frequency of traffic; and soil water content. Tillage hardpans are caused by shearing and smearing forces during repeated cultivation (e.g. conventional tillage) in wet soils, resulting in a sudden transition between layers of low and high compaction just below the tilled layer.

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Given the widespread adoption of no-tillage in recent decades, hardpans are not widespread.

Key Investment Target (KIT) 1.6 addresses new innovations and solutions to increase the capture, storage and availability of soil water and their targeted integration into farming systems. This will achieve this by:

- enhancing our understanding and diagnosis of water repellence, compaction and other barriers to the capture and storage of water in soils,
- developing new and improved solutions for constraint management, and prioritising the value of different management options, especially where multiple soil constraints are present; and
- providing information to support rapid adoption of solutions to soil constraints including the impact on farming systems and profitability.

This KIT recognises that growers and advisers continue to be guided in their management of soil constraints by their experience of inconsistent economic responses and uncertain payback periods. It acknowledges that gaps in understanding, diagnosing and managing multiple soil constraints are restricting our ability to realise the benefits of soil management.

FUTURE RD&E FOCUS

SCOPE – Understanding of soil constraints

Improved soil constraint diagnosis methods and tools are developed and the mechanisms by which soil constraints impact the capture and storage of water are better understood.

A key focus area of KIT 1.6 (and other soils KITs) is improving the mechanistic knowledge of soil constraints and their diagnosis so that growers can easily assess the impact of these on the capture, storage and utilisation of soil water. This improved knowledge will be achieved by (1) gaining a better understanding of the mechanisms causing water repellence, compaction and other constraints, and (2) developing in-field spatial diagnostic tools and standardised testing protocols relevant to specific soil types which assess soil variability and inform profitable management decisions. This KIT strategy includes development of innovative diagnostic tools and technologies that account for seasonal and/or annual variation and interactions with temperature, rainfall intensity and uncertainty, and soil water content.

While water-repellence and soil compaction limit the capture and storage of water, several other simultaneous constraints may limit root growth and water uptake. The identification of the key constraint(s) in any specific locations is critical to developing a cost-effective management strategy. Diagnosis and management of these constraints to water uptake are dealt with in other KITs – acidity (1.8), sodicity (1.7), waterlogging (1.9), nutrient deficiencies (3.6), root disease (3.3), herbicide damage (3.1). Interactions of these with repellence and compaction will be between the KITs.

Much is known about the development of soil water repellency, soil compaction and other constraints to the capture and storage of water, but there is a disconnect between the technical understanding and quantifiable implications of soil amelioration practices on whole farm profit within a risk framework. Many growers and advisers also believe that the difference between our technical knowledge of constraint management and extensive implementation on-farm must be addressed through improved diagnostics that account for soil variability, the impact of interacting constraints and localised insights.

Investment Outcome 1.6.1 – Growers have access to field diagnostic tools that efficiently measure the severity of soil constraints impacting water capture and storage.

Most Australian growers know that their soil characteristics are restricting the capture and storage of water, but many are unwilling to act because the constraints are poorly diagnosed, and/or they have low confidence in the capacity for current management practices (mitigation, amelioration or avoidance) to deliver cost-effective and profitable increases in profitability. Diagnosis is critical to informing any soil management strategy. Most diagnostic tools are specific to individual constraints, are considered time consuming and expensive, and often require specialist technical advice for interpretation and recommendations. Tools to understand spatial variability tend to be limited in use due to technical requirements, a lack of user-friendly software, and/or perceptions of poor return-on-investment. This means that while growers might suspect that crop production is limited by soil constraints, they are unwilling to prioritise investment into diagnosis and soil constraint management. GRDC will support the development and commercialisation of improved

field-based tools and technologies for the diagnosis of soil constraints that limit the capture and storage of water. Growers need the ability to diagnose constraints where water infiltration and storage are limited, and where stored soil water is not fully exploited by a crop. This includes:

- Simple low-cost methods and guidelines to inform identification of constraints and subsequent management, and
- New options for spatial mapping of constraints, including proximal or remote sensing technology.

GRDC will consider opportunities to provide growers and advisors with practical and economical tools for identifying the impact of soil constraints on crop performance relative to yield potential, and informing economic frameworks needed for implementation and delivery of management options.

Investment Outcome 1.6.2 – Growers understand the causes of soil compaction, water repellence and other constraints impacting water capture and storage at farm level.

Linking the causes of soil compaction, water repellence and other constraints to rainfall capture, storage and availability at a sub-paddock and farm scale is fundamental to improvements in crop productivity, yield stability and profitability. Apart from landscapes that regularly experience waterlogged conditions, grain growers recognise the need to maximise the water available to crops and the enormous opportunity to increase productivity and profitability, especially in seasons with average to below average rainfall. There is an R&D opportunity to understand at the farm level how different soil constraints combine to impact water capture, storage and access, and therefore, the effect on farm operations, interaction with other enterprises (e.g. livestock production) and whole farm profit.

GRDC will support RD&E that enables growers to understand the causes of soil compaction, water repellence and other constraints and their impact on soil water at farm level. There may be a need to better quantify water infiltration, water run-off, storage, leaching losses, and crop water use on a range of soils under a range of rainfall patterns. Investments will provide a spatial understanding of the impact of these constraints on water capture and storage and on PAW.

SCOPE – Options to overcome soil constraints

Options to overcome soil constraints that impact water capture and storage are identified and developed.

Growers are seeking improved and more reliable options to manage soils and crops impacted by water repellence, compaction, and other barriers that restrict the capture, storage and availability of soil water. The current options for treating compaction focus on tillage, addition of ameliorants (including gypsum and organic matter) and controlled traffic farming (CTF) to minimise subsequent re-compaction by machinery. Some soils have a natural capacity to recover from compaction via shrink and swell behaviour, while soil biological activity and fauna can also help to reduce soil density and increase porosity. In these situations, there may be limited on-going management beyond best cropping practice. Current options for treating water repellence include; short-term and low cost mitigation (e.g. chemical soil wetters, and on-row or edge-row planting); medium to long term and high cost amelioration (e.g. soil inversion or cultivation to bury the repellent topsoil, delving and addition of clay); or avoidance (e.g. minimising losses by taking the most severely repellent areas out of production).

Growers and advisors are looking for low cost and novel management options to improve the use of rainfall on soils constrained by water repellence, compaction and other structural issues. While some innovative growers are actively adopting and adapting soil amelioration techniques, most are cautious in their approach to high-cost practices because they believe that trial results and return-on-investment are inconsistent, and, in some cases, there is a significant risk of causing more damage than good. This is particularly the case for growers that have adopted long term no-till practices on fragile sandy soils prone to erosion. Caution is likely to increase with uncertain climatic conditions as growers continuously seek to manage any downside risks.

GRDC will target investment to enable growers to profitably manage soils and crops with multiple and spatially variable constraints. This will focus on grower co-design of RD&E and development of improved tools and technologies to reduce soil and other mechanisms causing specific constraints, stabilise and enhance topsoil and subsoil structure; and overcome individual or multiple constraints either simultaneously or in a logical prioritised order.

Investment may include development of new machinery or other technologies to increase rainfall infiltration and minimise water run-off during intensive rainfall, improve storage and enhance water uptake by crops.

Investment Outcome 1.6.3 – Growers understand the options to overcome soil constraints impacting the capture and storage of water.

Grower confidence in the profitability and longevity of current soil and crop management options available to overcome soil constraints is thought to be limiting their adoption and in turn the productivity of Australian grain producers. Some other growers may not be aware of the current management options available. This investment outcome is focused on empowering growers to act based on sound evidence for productivity and profitability improvements (e.g. return on investment) for currently available options that overcome primary and secondary soil constraints.

GRDC will invest to enable growers and advisors to raise awareness and confidence in current management options for soil constraints that limit water capture and storage. This will focus on the development, communication and extension of current management solutions for different soil types and constraints through active grower participation and development of pathways that deliver information in a format most suited to Australian growers. Grower co-design alongside investments in outcome 1.6.4 will assist integration into farming systems.

Investment Outcome 1.6.4 – Researchers develop new tools for addressing identified soil constraints on farm.

The purpose of this investment outcome is to provide growers with new or improved soil management practices that boost crop yield potential by addressing multiple constraints to water capture, storage and availability, in the context of rainfall variability and risk management. This includes:

- Building a better understanding of soil management implications in delivering improved crop resilience to edaphic stresses (e.g. low rainfall, cold, heat, nutrient availability).
- Management options to address variable soil constraints at a field scale (e.g. precision agriculture approaches).

GRDC will invest in R&D to improve current practices and explore new and reliable approaches to address soil constraints at a field scale. Innovative constraint management could include radically modifying soils to depth through ‘re-engineering’ to address multiple constraints (e.g. compaction, water repellence and subsoil acidity), non-tillage approaches to break up compacted layers and crop genetic tolerance. Specific innovations for cropping on water repellent soils could include improved seeding systems to enhance crop establishment. GRDC may also invest to use organic matter or other amendments to improve soil structure and water holding capacity at a field scale where these lead to low cost constraint management alternatives that deliver profitable productivity gains. Appropriate paths to market need to be established for each novel solution.

SCOPE – Integration of solutions to soil constraints in farming systems

The enduring economic implications and risks of different options to overcome constraints on the capture and storage of water in soils are better understood.

A key challenge for this KIT strategy is to build grower and advisor confidence through solutions to soil constraints matched to their farming system, financial situation, and likely patterns of use. Soil constraints can require long-term management and investment in amelioration, yet many farm businesses put greater priority on reliable short-term financial returns, particularly where uncertainty and risk with the amelioration options are high. Compaction, water repellence and other constraints impact water capture across a wide range of soil types, farming systems and environments across Australia, and optimum solutions are likely to be site specific. Based on the solutions tailored to each situation, growers need sound advice on expected impacts to annual profitability and the farm business balance sheet. This needs to include payback periods, implications for land valuation and risk management for the most appropriate soil and crop constraint management options.

Soil and crop management decision frameworks are needed that include considerations of variable soil types and understanding when and where constraints to water capture, storage and availability can be profitably addressed by management practices. Broader business and farming systems considerations (e.g. implications for management of heat and frost, crop protection, acidity/toxicity, water use efficiency, and crop agronomy) must be included.

Investment Outcome 1.6.5 – Growers have access to tools to assess the enduring economic impacts (including trade-offs) and risks of different options to overcome soil constraints that impact the capture, storage of water.

A gap for the grains industry is access to robust information and tools that assess the economic impacts of soil constraints, identify priority issues to be addressed on soils with multiple constraints, and provide realistic insights on profitability, pay-back and risks for each soil and crop management option. The decision tool *Ranking Options for Soil Amelioration* (ROSA) was developed in WA and provides insights for compaction/poor structure, water repellence and acidity constraints. At present ROSA does not adequately address multiple simultaneous constraints and has not been calibrated or evaluated in other regions.

GRDC will invest to provide growers with sound information and decision support tools to assist in gaining an improved understand the economic impacts, profit scenarios and likely risks of soil and crop amelioration practices. This in turn will increase grower confidence in adopting constraint management methods. This also includes the provision of practical local examples of constraint diagnosis and successful implementation of cost-effective practices. These examples or case studies and decision support tools will enable growers to understand the likely return-on-investment for each constraint and management practice, customise practices for each of their paddocks/scenarios, and increase crop yield potential. In the case of a soil amelioration program, growers will also be interested in the impact on land value.

Investment Outcome 1.6.6 – Growers have access to crop types and farming systems to optimise yield and profitability on soils where the constraints that adversely impact the capture and storage of water have been overcome.

Soil mitigation and/or amelioration practices and crop management must be adapted for individual farms and paddocks, and this may require changes to the farming system to maximise benefits and longevity of impact. For instance, poor rooting depth due to soil constraints and unused subsoil water after harvest represents a lost opportunity. In this situation growers will not be able to realise the full potential crop yields by addressing the constraint in isolation. They will also need to consider improving crop agronomy (e.g. exploiting early sowing opportunities, increased N rates or inclusion of legumes in rotations). In addition to general management of crops and soils to enhance water capture, storage and availability, there are some important related areas requiring further investigation including:

- Gaining an improved understanding of the implications on crop protection related issues (e.g. crop damage can occur on sandy soils with low organic matter content where the activity of some residual pre-emergent herbicides is enhanced when brought to the surface through soil inversion).
- Increased knowledge that enables growers to optimise soil and crop management practices to increase the longevity of soil amelioration practices and reduce the frequency of repeat treatments (e.g. CTF to reduce re-compaction). Improved genetics and crop management are required that exploit the increased crop yield potential achieved following the adoption of solutions to constraints.

GRDC will focus investment on crop management and systems RD&E to enable growers to optimise crop profitability on soils where water repellence, compaction and other barriers to the capture, storage and availability of water have been addressed through mitigation or amelioration. This includes investments that reduce erosion risk and groundwater recharge, especially on sandy soils. The purpose of these investment outcomes is to enable growers to capture the unrealised productivity of soils under a range of rainfall distributions, to stabilise crop yields and profits in seasons with dry starts and springs, and to increase long-term profitability.