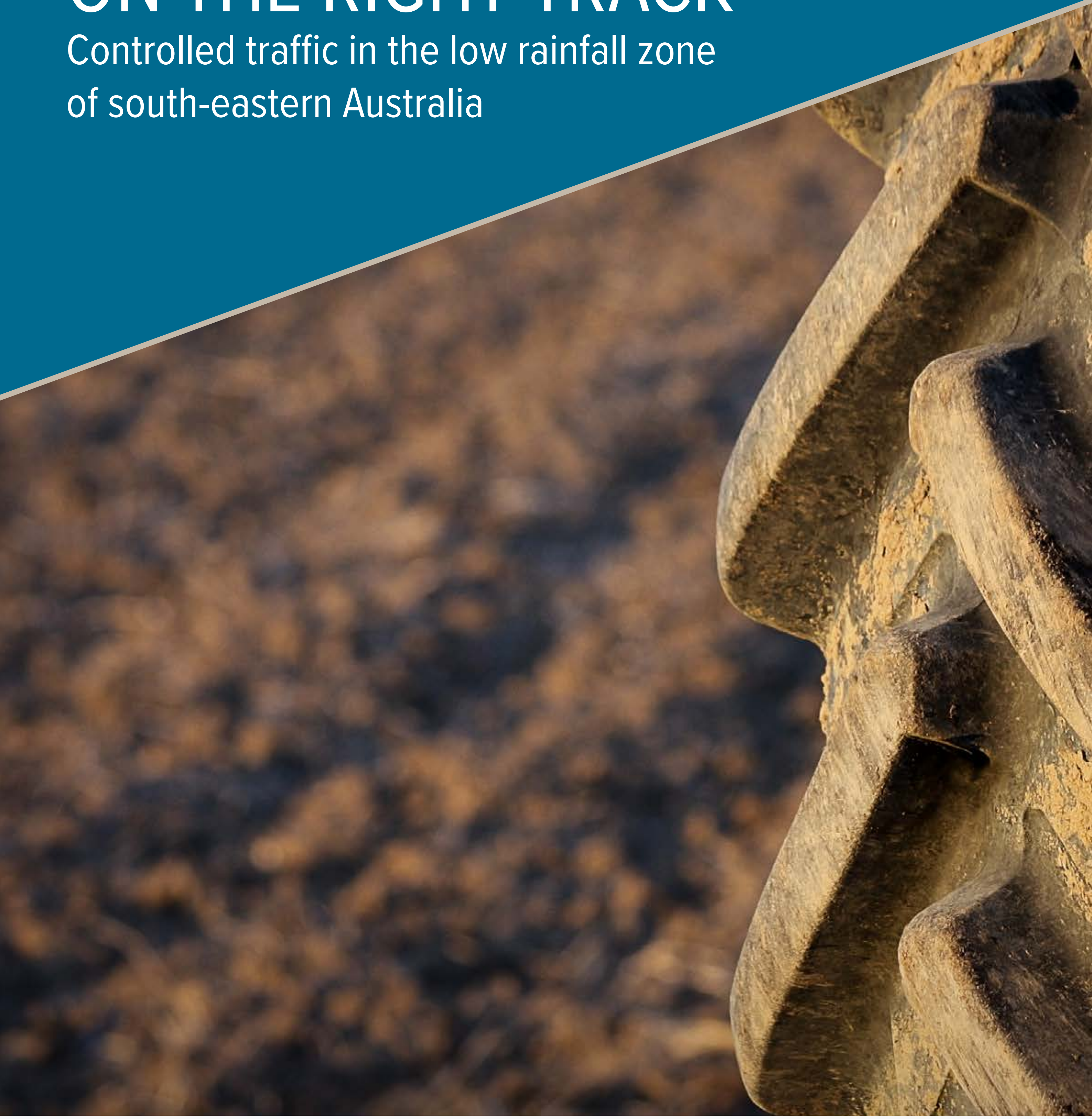
ON THE RIGHT TRACK

Controlled traffic in the low rainfall zone of south-eastern Australia



ON THE RIGHT TRACK

Controlled traffic in the low rainfall zone of south-eastern Australia

ABOUT THIS PUBLICATION

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Specifically, the authors and GRDC would like to acknowledge the work of Colin Aumann and Melissa Cann from Agriculture Victoria, Claire Brown, Tim McClelland and their colleagues from Birchip Cropping Group, Tanja Morgan and Michael Moodie and their colleagues from Mallee Sustainable Farming, Helen MacMillan and others from Central West Farming Systems, Naomi Scholz and staff from Minnipa Research Station and Eyre Peninsula Agricultural Research Foundation, and Matt McCallum and all the staff at Upper North Farming Systems.

The enthusiastic involvement of these five farming systems groups was vital to the success of this project.

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FOREWORD

Controlled traffic farming (CTF) is becoming widely adopted in the Australian grains industry, with a national average of around 30 per cent of farms using the system, but the low rainfall zone (LRZ) of south-eastern Australia, with an adoption rate of only around 5 per cent, is a marked exception.

In 2014 the Grains Research and Development Corporation (GRDC) sought to invest in gaining a better understanding of this low CTF adoption rate in the LRZ. The tender recognised that compaction from machinery damages production, and that CTF could reduce that damage, but it noted that CTF had not been evaluated in the LRZ and growers there had no evidence to guide decisions, and no experience to help with adoption.

The tender asked for a project that would resolve unanswered questions that lead to a lack of confidence in the practicality and benefits of CTF in the LRZ. Typical questions were:

- Do LRZ soils self-repair or is amelioration work needed?
- Does CTF reduce power and fuel use in light LRZ soils?
- Is CTF feasible in low intensity systems with very wide machines?
- Is CTF compatible with livestock in the system?

The Australian Controlled Traffic Farming Association (ACTFA) formed a consortium (see right for partners) that successfully tendered for a five year project to answer such questions and enable LRZ grain growers to make informed decisions about CTF and its possible benefits on their farms.

This publication presents the findings of that project's extensive body of research and development work across four main soil types found in the LRZ of NSW, Victoria and South Australia. Among the key results discussed in this book is the evidence that farm machinery traffic can, and does, cause yield-limiting soil compaction across the LRZ.

The project concluded that across the south-eastern LRZ, in most soil types, conventional equipment on damp soil caused soil compaction, which was worse under repeated passes or with high tyre pressure. If this compaction exceeded thresholds for root growth, significant yield declines were observed. Yield reductions occurred at most sites in the year following repeated trafficking of damp soils, but the use of very low tyre pressure at one site resulted in no yield decline, and even a yield increase in some seasons. In the heavier soils, compaction was limited to the surface, with yield loss likely to be for a single season, whereas sandy soils were at greater risk of deeper compaction and persistent yield losses for many seasons.

The project has also demonstrated other benefits from CTF adoption, including some energy and fuel savings, protection of investment in soil amelioration (e.g. ripping on deep sands) and reduced loss of available nitrogen from nitrous oxide greenhouse gas emissions (GHG). For growers who do not wish to adopt CTF, soil compaction can be significantly reduced, and therefore potential yield losses avoided or minimised, by keeping axle weights as low as possible, using low pressure tyres on the heaviest equipment, and minimising machinery use when soils are wet and their strength reduced.

The project has already had an impact in the southern LRZ. A survey of 101 growers across the LRZ in 2019 suggests that 27 per cent more growers are aware of the potential benefits of CTF than in 2014, and there was also a greater acknowledgement of the seriousness of soil compaction. The survey results are summarised in this book.

PROJECT PARTNERS

Project partners are the Australian Controlled Traffic Farming Association (ACTFA), Agriculture Victoria, South Australian Research and Development Institute, Birchip Cropping Group, Eyre Peninsula Agricultural Research Foundation, Upper North Farming Systems, Mallee Sustainable Farming, Central West Farming Systems and Society of Precision Agriculture Australia.

Another section of the book discusses the findings from the four research sites on the effect of soil compaction on soil water and on crop growth and yield. We also present the findings of several studies including one that showed crop rows on wheeltracks do indeed yield less than rows on uncompacted soil between the tracks. Other studies measured the reduction in power requirements and fuel use in CTF systems and how to avoid, or fix, compaction in topsoil and subsoil.

As well as general information about CTF in the LRZ that will help with decision making, the book is packed with practical information that will help interested grain growers to adopt the system as smoothly and inexpensively as possible. There are many case studies of growers who have grappled with the adoption of CTF. These growers hope that their experience will help others achieve a smooth transition into CTF.

The project partners were the Australian Controlled Traffic Farming Association, Grains Research and Development Corporation, Agriculture Victoria, South Australian Research and Development Institute, Birchip Cropping Group, Eyre Peninsula Agricultural Research Foundation, Upper North Farming Systems, Mallee Sustainable Farming, Central West Farming Systems and Society of Precision Agriculture Australia.

The project was completed with significant input from all of these partner organisations and their staff. It would also not have been possible without the generous help of a number of grain growers, agronomists and other interested people.

Stephen Loss
Manager for Soils and Nutrition, South
GRDC – Grains Research and
Development Corporation

Chris Bluett
Chair
ACTFA – Australian Controlled
Traffic Farming Association

CTF may offer a range of benefits to growers in the south-eastern LRZ.

HOW TO USE THIS E-BOOK

The intention of this book is to support deliberations about controlled traffic farming (CTF) in the low rainfall zone (LRZ) of south-eastern Australia by providing locally developed insights into its impacts and tips on how best to implement it.

The book is designed to make it easy for you to move between sections and access information related to topics of most interest to you. Use the side menu to navigate or follow the links within the text that will take you to more detailed information. **Look for this symbol** »»

You can 'return to contents' using the link at the bottom of any page.

PRACTICAL GUIDES »»

You will find general information about certain aspects of CTF in the 'how-to guides'. This section is designed to highlight the benefits and possible constraints, and suggest solutions to these constraints in the LRZ. There are links from these sections to detailed research findings and practical examples from growers who have already adopted CTF.

GROWER EXPERIENCE »»

These case study growers are from different locations within the LRZ and are at various stages of implementation of CTF on their farms. You can look for growers who have similar soil to your farm or are located near your district. You can also look for growers who have faced a similar problem or concern that you may have.

RESEARCH FINDINGS »»

This book also includes research findings from sites around the LRZ representing the four main soil types. This research has established that soil compaction does impact crop production in the LRZ.

STUDIES »»

A number of studies were established to investigate specific questions of interest to growers. These studies have helped build the body of knowledge about the benefits to be gained through the adoption of CTF in the LRZ.

An easy way to find out how much of your farm is being trafficked with heavy machinery is to use the »» **CTF Calculator**, an online tool that uses the facts and figures from your farm to calculate the potential impact of soil compaction. You can also test the effect of changing to different machinery configurations before investing.

If you run into a term that is unfamiliar, you can »» check for it in the **glossary**. There are many fantastic resources available to help you piece together a planned adoption of CTF on your farm. We have provided a »» list of highly relevant and useful **resources** for this purpose.

A WORD ON SOIL COMPACTION

There is a growing interest in the potential for controlled traffic farming (CTF) to help reduce the impact of soil compaction on the productivity and profitability of grain farms in the southern low rainfall zone.

Compaction at depth usually develops as a result of heavy machinery traffic over many years. Traffic or cultivation during wet conditions is the most damaging to soil structure. A single pass with a heavy machine in wet conditions, when the soil is 'plastic' and easily moulded, can cause yield-limiting compaction. Some soils have naturally-occurring layers of high bulk density and poor structure.

When machinery traffic is randomly 'applied' across a paddock it only takes a few years of farming to create a compaction layer fairly evenly across the paddock. This makes it hard to notice an effect on yield because there are often no uncompacted areas of the paddock to compare with the potentially compacted areas.

Identifying soil compaction layers involves observing changes in soil bulk density and strength throughout the crop root zone and below. At the same time it is necessary to understand any other subsoil constraints to crop root growth such as extreme pH or salinity.

Many growers have observed positive effects following deep ripping, particularly on sandy soils. This effect is mainly due to amelioration of subsoil compaction. Implementing CTF practices after a deep ripping event is the best way to preserve the benefits and maximise the return on the investment. Keep in mind that not all soil types will respond positively to deep ripping. Heavy clay soils that self-repair once machinery traffic is confined to permanent wheeltracks are rare in the LRZ.

If you are unsure whether compaction is limiting productivity on your farm, there are several ways to investigate, starting with small soil pits dug using a shovel, and using blue dye and water to see where water infiltration occurs, or collecting data using a penetrometer.

Even if soil compaction is not affecting crop productivity, or the effect is minimal compared to other constraints, there may still be practical and economic benefits in adopting CTF. This book aims to help growers assess the likely costs and benefits for their particular farming system.

RESEARCH PROJECT INSIGHT

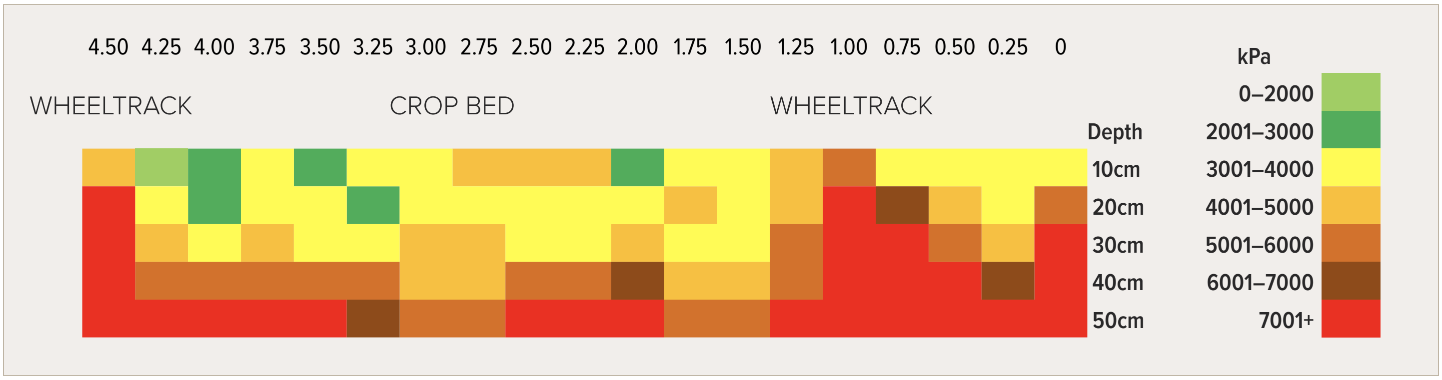
Over 50 per cent of growers surveyed considered that they have moderate to serious soil compaction in all soil types.

Survey results

Deep soil compaction following intensive (3-pass wet) trafficking.

JUMP TO

- N benefits study
- Energy savings study
- Yield increase study



Manipulated data showing soil resistance readings taken along a transect every 25cm.

COMPACTION OF LOW RAINFALL ZONE SOILS

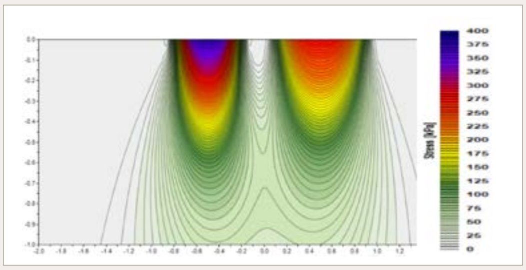
Whether CTF is adopted or not, it pays to consider ways to minimise soil compaction, particularly at depth. Following the principles below will benefit all farming systems.

The compacting effect of heavy machinery is most serious if soils are trafficked when moist. As this is sometimes unavoidable, other measures should be in place to minimise the damage caused. The impact of machinery traffic on the soil is less when growers choose machinery with low axle weights and use tyres with low pressure and large contact area.

On **sandy soils**, even in dry soil conditions, high axle load can cause a compacted layer to form at depth, especially if there are multiple machinery passes. This compacted layer can produce persistent yield decline for many years after the trafficking.

In **soils with a higher clay content**, trafficking when the soil is dry usually limits the compaction effect to the soil surface, and yield penalties are limited to the year of trafficking. In extremely wet conditions, which only occur episodically in the LRZ, trafficking clay soils is likely to cause far more severe damage.

Establishing permanent wheeltracks confines heavy machinery traffic and its associated compaction to a small and defined portion of the paddock. This turns the compacting effect of machinery into a positive for efficient machinery operation on the wheeltracks and protects the cropping zone from damage. With the advent and widespread adoption of guidance systems, growers have easier access to one of the basic technologies underpinning CTF.



Modelled soil stress (kPa) at Loxton site below tyre (m) under an axle load of 12 t for tyre sizes: 600/65R28 (bottom line, left wheel) and 900/60R32 (top line, right wheel) for dry soil (-100kPa matrix potential).

JUMP TO
Research report

Taking steps to reduce compaction are beneficial even if you decide not to implement CTF.

CRITICAL COMPONENTS OF CTF SYSTEMS

The idea underlying CTF is simple: plants grow better in soft, uncompacted soil; and wheels work better on hard, compacted soil.

CTF aims to confine all machinery traffic to a minimum area of permanent wheeltracks while maximising soil health and crop productivity in the crop zone between these wheeltracks. When correctly implemented, this farming system should minimise machinery and input costs and hazards such as erosion.

Implementing CTF on a farm requires some planning, because it is rare to 'start with a clean sheet of paper'. Many growers take a staged approach to the transition over a period of several years, often fitting in with the replacement of key pieces of machinery.

Below are tips to assist with the planned transition to CTF, with a focus on the likely changes to machinery and the farming system.

Machinery

The objective is simple: minimise the proportion of the paddock that is subject to heavy field machinery traffic. Achieving this requires:

1. Precise machinery guidance – this usually means precision autosteer ('2cm' RTK GPS). Experience has demonstrated that investment in this technology is often recouped through increased efficiency within two years.
2. A common operating width ratio – most CTF growers use the operating width of either their harvester front or seeder as the basis of their ratio. The operating width of sprayers and spreaders is usually set at two or three times the base operating width.
3. A common wheeltrack gauge – the harvester usually has the least flexibility in terms of wheeltrack gauge, so growers often base the track gauge for all machines on the gauge of the harvester.

A planned and staged change-over to CTF could take 5 to 10 years, depending on when existing machinery is due for replacement. A transition to CTF can involve choosing smaller horsepower tractors and there may be less need to choose the widest-possibly operating width implements. It is very important to consider the long-term machinery requirements rather than be confined to the restrictions of current machinery. Any significant off-set of implements can be a major problem.

Precise machinery guidance

An increasing number of growers in the LRZ have already adopted RTK autosteer technology. Some growers also use implement guidance systems to reduce implement 'creep' on sloping paddocks and to enable precision farming techniques such as inter-row sowing. Most growers who transition to CTF will invest in this technology if they do not already have it installed.

A common operating width ratio

Ideally, the operating width of the harvester front will already be similar to the seeder. If not, one is usually modified to match the other. Removing or adding seeder rows or trading a harvester front can be relatively easy, but it is worth considering if this is the best long-term solution. In some instances it may be better to upgrade to machinery that is fully compatible with the CTF system planned for the farm.

The most common and easiest machinery operating width ratio is 3:1. For example, a 9.1m airseeder and harvester front fits well with a 9m or 18.2m spreader and a 27.3m sprayer. Another common 3:1 combination is a 36m sprayer and 12m airseeder, spreader and harvester front.

Bulla Burra, *Loxton, SA*

Have your goal firmly in mind when you replace machinery so that the change fits with your CTF system. It may take 10 years, but you will get there.

David Greig, *Tottenham, NSW*

Starting CTF was easier than I thought, but an early hurdle I encountered was teaching staff and contractors to stay on the wheeltracks. Other people often do not understand what you are trying to achieve.

Using this ratio, 9 to 15 per cent of the paddock will be wheeltracks. This might increase to 30 per cent if just one of the machines is not matched, but is still a big improvement on the 40 to 50 per cent wheeltracks of most non-CTF systems.

In the LRZ there is some resistance to narrowing the seeder width to match the common 12m harvester front width. This may change in the near future as harvester fronts of up to 18m are now available, and compatible straw spreaders are starting to come to market. Another option open to growers is to use a 2:1 ratio with a 12m harvester front and a 24m seeder.

Several growers featured in this book have changed to a narrower seeder without negatively impacting on their businesses.

If the decision is to reduce the seeder width to match the harvester front then seeding efficiency can be maintained using one or more of the following strategies:

- plan for a greater proportion of crop area to be 'dry planted',
- increase seeding speed using 'bentleg' tynes designed for greater speed, or a disc seeder,
- increase effective working hours per day with improved seed and fertiliser handling.

If it is necessary to use a seeder wider than the harvester front during the transition phase, a good compromise is to have the seeder 1.5 times the harvester width. This involves some increase in wheeled area and some reduction in harvesting efficiency, but retains many CTF benefits.

If it is not possible to match with the harvester immediately, it is important to match the spraying and seeding equipment because these machines are most likely to be used when the soil is moist and most prone to compaction.

Wheeltrack gauge

The wheeltrack gauge is usually set by the harvester, with all other equipment modified to suit this track gauge. The most common wheeltrack gauge used in CTF is 3m on all machines.

Adjusting wheeltrack gauge is not a problem with the large equal-wheel 4WD tractors, but smaller units often require front axle modification. Aftermarket 'cotton reel' hub extensions are a useful short-term solution, but engineered axle extensions are better in the long-term. Axle modifications to aircarts and chaser bins can often be done locally, and at low cost. Most harvester manufacturers can supply delivery auger extensions, and some chaser bin manufacturers supply them with a catching belt area, to ensure that chaser bins can stay on the permanent wheeltracks.

Modifying the wheeltrack gauge on the seeder and sprayer is often a good move early in the transition period, because these units are commonly used on moist soil.

It is worth remembering that manufacturers often advertise nominal, rather than precise operating widths. Take extreme care to check farm equipment widths as big problems can occur when metric and imperial units are mixed. It is advisable to stick to one or the other for the system and use a tape measure to ensure measurements are correct. There is nothing worse than finding the new harvester front won't reliably pick up the seeder's outer row.

Track gauge adjustment of both front and rear machine wheels is also important. A variety of compromises will almost certainly be needed during the CTF adoption process, but the most important factor is that each change occurs in the context of a long-term CTF plan.

Hayden Wass, *Nyngan, NSW*

In hindsight, I would consider establishing 4m wheeltracks to accommodate the larger machinery now available. I'd also look at a 15m planter and 45m sprayers. The increase in proprietary GPS systems with in-built firewalls might raise issues for growers when changing machinery plant brands.

Linc Lehmann, *Birchip/Kinnabulla, Vic*

The greatest benefits from CTF have been lining up all the machinery, resulting in less crop trampling, more standing stubble, the ability to own and use smaller tractors that are more versatile as machinery is easier to pull and there is no need for dual wheels.

Wheeltrack gauge

Tyres v tracks, narrow v wide

Tyre and or track width is a significant factor affecting the wheeled area. A narrow tyre or track footprint is optimal, provided flotation is adequate.

Using narrow tyres will reduce the area of permanent wheeltracks, but may not be practical on undulating, sandy soil paddocks. Rubber tracks provide an excellent way to achieve better flotation with a narrow footprint, but rapid wear can be a problem when both tyres and tracks are used on the same wheeltracks.

Dual tyres should be avoided if possible, but growers have been known to use a smaller-diameter outer dual as an insurance policy against getting bogged on soft headlands.

System design and logistics

To extract maximum benefit from a transition to CTF, it is important to look at paddock layout and the logistics involved in key operations. If the current layout of the farm is already highly efficient then the implementation of CTF will be quite straightforward. If there is room for improvement then the addressing any problem areas will improve the overall returns from the transition to a new farming system.

Keep in mind the 'permanent' nature of a CTF paddock layout. Once the permanent wheeltracks are in place there are less opportunities to fix problems such as low spots or erosion damage. The system also relies on machinery travelling the full length of the row before exiting the paddock.

While the most efficient direction of work in a non-CTF system is normally parallel to the longest fence, but this is not always the best option for a CTF layout. When designing the CTF paddock layout, consider:

- Direction of prevailing winds if the soil is prone to wind erosion.
- Water flow across the paddock and drainage of the wheeltracks.
- Row orientation and length of run.
- Paddock access for emptying chaser bins and re-filling sprayers and spreaders.
- Operation of machinery on cross-sloping paddocks.

Many problems can be avoided if these issues are discussed with experienced CTF farmers and consultants.

The CTF Calculator is a free app that growers can use to work out the impact of changing axle and implement widths and tyre size. Compromise is often required during the CTF conversion process, so this calculator can be used to calculate the cost associated with the compromise. The calculator provides a way to consider the impact of extra wheelings against the cost of changing to a fully matched system and can assist in the planning of a staged implementation of CTF.

Key resource

The Controlled Traffic Farming Technical Manual by Bindi Isbister, Paul Blackwell, Glen Riethmuller, Stephen Davies, Andrew Whitlock and Tim Neale is an excellent key resource when planning the transition to CTF on any farm.

Mark Kentish, *Piangil, Vic*

I did a considerable amount of 'homework' before making any changes to our farming system and this has helped us to make the right decisions. This included being willing to sacrifice some machinery width to achieve gains in other areas.

Paul Adam, *Tottenham, NSW*

The conversion to CTF allowed for consolidation of machinery assets with four items of machinery that were either due for replacement or surplus to requirements being sold and replaced by two new machines. This reduced depreciation and maintenance costs.

Robert Pocock, *Lameroo, SA*

Upgrading to CTF can be achievable at little extra cost when purchasing new equipment. Ask for advice from other farmers doing similar things in the same environment and do what works for you at the time.

JUMP TO

CTF Calculator

How to – Field operations

How to – Erosion control

How to – Harvest efficiency

How to – Seeding efficiency

CTF CALCULATOR

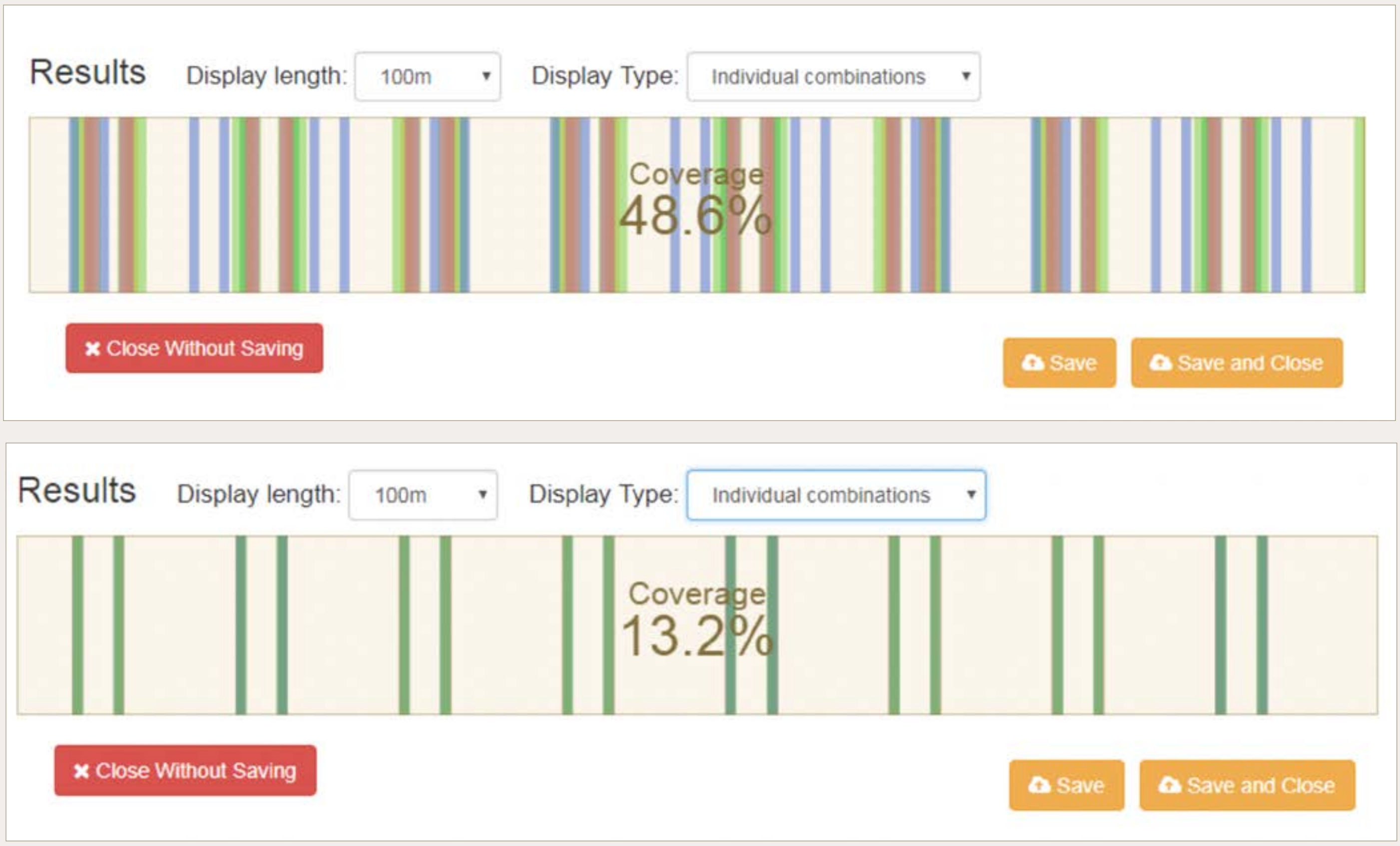
www.ctfcalculator.org

The aim of CTF is to reduce the trafficked area of your paddock as much as possible. A fully matched system is trafficking about 9 to 12 per cent of the paddock. A standard no-till system commonly wheels 40 per cent of the paddock (Figure 1).

The CTF calculator can help you estimate the percentage of your paddock currently trafficked and assess compaction management options for your farm including controlled traffic farming and deep tillage.

The calculator assists by comparing the trafficking percentage of current machinery setups to potential future machinery configurations. This information is helpful for making decisions about machinery investment for minimising the risk of compaction and setting up controlled traffic farming system.

Changing over machinery in line with the farm machinery investment plan is a good approach to develop a fully matched CTF system. Many successful CTF farmers have taken 8 to 10 years to develop a fully matched CTF system.



Example of the wheeling percentage of a typical non CTF system (left) with a 55ft seeder, 45ft header and 100ft sprayer compared to a CTF system (right) with a 40ft seeder, 40ft header and 120ft sprayer calculated by the ctfcalculator.org

CTF Calculator was developed by the Department of Primary Industry and Regional Development and GRDC investment DAW00243 'Minimising the impact of soil compaction on crop yield'. The calculator is an enhanced version of 'Trackman' originally developed by Queensland DPI, NCEA and initially made available on-line by Precision Agriculture Pty Ltd and other partners.

HOW TO CTF – CROP YIELD

A single machinery pass under dry conditions will not usually affect crop yield, but intensive trafficking does cause yield-limiting damage to soils found in the LRZ.

CTF trials in LRZ report variable crop yield responses. Measured and estimated yield benefits in the LRZ are between 2 to 16 per cent, depending on soil type and local climate.

Soil compaction increases the bulk density of the soil, reducing the air-filled pores within the soil and sometimes the plant available water capacity (PAWC) of a soil, all of which can limit crop growth and yield. Plants growing in high bulk density soils must expend extra energy to force their roots through hard soil. Often roots are confined to a smaller volume of soil with restricted access to moisture and nutrients. Compacted soils are also associated with poor drainage and crops can be badly affected by waterlogged conditions.

Alleviating historical soil compaction will have a beneficial effect on crop growth. In soils that respond well to deep ripping, growers can expect an increase in crop yield and a reduction in inputs following a deep ripping operation.

Some LRZ soils have hazardous sub-soils that should not be disturbed, even if compaction layers are present. On these soils, long-term strategies to improve the soil structure of the topsoil are likely to provide the greatest benefits for crop productivity. When soil structure improves it is often necessary to re-assess nutrient management practices to gain the full benefit of greater crop yield potential.

When growers implement CTF they often also implement several other changes such as stubble retention and minimum tillage, which combine with CTF to preserve limited soil moisture and potentially increase crop yield and reliability. Having implemented several changes at once often makes it difficult to attribute yield gain to one practice alone.

The yield increase achieved in the crop bed area of the paddock is generally expected to compensate for lower (or nil) yield from the wheeltracks.

When sampling wheat growing in trafficked soil compared to wheat growing in untrafficked soils across the southern low rainfall zone there was a 14 per cent yield penalty observed across varying regions, soil types and machinery. This translates to an estimated 7 per cent potential yield improvement from implementing a fully-matched CTF system.

In this research most benefits were derived from increased grain production rather than any difference in quality. Other studies have suggested that the improvement in crop performance is commonly a combination of higher yield (larger grain) and improved grain quality (and reduced screenings), and more oil in canola. Either way, improvements in grain yield can fund the investment in CTF, particularly if the change is implemented over several years with machinery change-over done when existing equipment is due for replacement. The reduction in fuel use on firm wheeltracks may also help with repayments.

The wheeled area of a non-CTF paddock is around 50 per cent in a single season, but since the wheeltracks are not normally in the same place each year, most of the paddock is subject to varying levels of compaction after several years, suppressing yield but providing few visible signs of the impact. Since increasingly heavier machines have trafficked all cropping

RESEARCH PROJECT INSIGHT

The trafficking treatments imposed reduced yields by up to 20 to 60 per cent in different seasons and at different sites.

Research results

Linc Lehmann
Birchip/Kinnabulla, Vic

The combined effect of no-till and CTF has generated an increase in lentil yields as the lentils stand up and trellis better on crop stubbles. Lentils are now grown on paddocks where they never would have been considered five to 10 years ago.

Soil moisture probes confirm that crops are now accessing water from deeper in the profile. It is difficult to determine a percentage increase in yield as varieties are also improving significantly and many things, including CTF, have helped to improve crop yields.

RESEARCH PROJECT INSIGHT

Deep ripping responsive soils, such as deep sands, can generate a wheat yield increase of 0.3 to 1t/ha.

Deep ripping study

RESEARCH PROJECT INSIGHT

Yield benefits from reducing the number of wheel tracks in a paddock could be as high as nearly 7% when moving from a conventional to a fully matched CTF system.

On/Off wheeltrack study

paddcks for many years, it is difficult to detect the impact of recent soil compaction events, unless they are extreme. In a CTF system the wheeled area is 12 to 15 per cent or less, which means more of the paddock can achieve a higher yield from the same inputs.

When tracks are matching and used for all operations, growers can expect to come close to achieving the yield increases measured in research trials.

In the LRZ, CTF may not deliver the same yield benefits as those reported from higher rainfall zones. For example, better fertiliser efficiency and reduced leaching benefits may be only rarely observed in the LRZ. Some benefits will only be apparent on certain soil types, for example more timely spraying for weeds and better trafficability are less apparent on sands but still relevant on loams and clay soils in low rainfall environments.

Matt Burkitt, *Parkes, NSW*

I estimate that crop yields are 20 to 30 per cent higher under the CTF, minimum tillage, stubble retention system at Northparkes Mines, compared to the district average for conventional farming.

JUMP TO

Penetrometer study

A word on compaction

Hayden Wass, *Nyngan, NSW*

The combined benefit of CTF, no-till and stubble retention are most apparent in drier-than-average years where the benefit of increased moisture retention is more fully expressed compared to a conventional farming system. In wet years, there is probably little difference in yield between the two systems.

David Greig, *Tottenham, NSW*

There is much more consistency across all soil types and crop types since switching to CTF. He is now much more confident in predicting crop yields based on available stored moisture and also more confident with new crop varieties.

One example is a paddock that slopes upwards to a hill where, in the past, the hill area would consistently yield 1t/ha less than the lower section of the paddock. Since switching to CTF nine years ago in that particular paddock the yield difference is now only 0.2 to 0.3t/ha.

HOW TO CTF – POWER AND ENERGY

It always requires less power to travel on compacted soil and to pull implements through non-compacted soil. By separating the wheeltracks and the beds growers can reap benefits through improved machinery operating efficiency.

Fuel consumption varies from farm to farm, but savings of 15 per cent or more are often observed by CTF growers in the LRZ.

Growers with established CTF systems find they need less power, and use less fuel for most farming operations. CTF reduces power requirements in two ways:

1. The motion resistance effect – In a CTF system, less effort is needed for vehicles to travel on the compacted permanent wheeltracks that are only disturbed at seeding (if at all).
2. The tillage draught effect – CTF reduces the effort required to pull implements such as seeders through the soil in the permanent beds that are never driven on.

Seeding, spraying, spreading and harvesting on the firm wheeltracks of CTF, and seeding into better structured soil, reduces the power and fuel wasted in soil disturbance and re-compaction. The outcome is reduced fuel consumption and greater power available for the machine to operate efficiently.

Motion resistance accounts for 15 to 20 per cent of harvesting fuel use, a larger proportion of seeding fuel, and 80 to 90 per cent of the fuel used in spraying. When machines run on random lines, extra fuel is used to compress the soil under the wheels.

Farmers in the LRZ often plant their wheeltracks to protect them from erosion. This means that draught reduction of the seeder will be rather less than that found in the northern region where traffic lanes are generally un-seeded. And regardless of traffic system, it's important that tractor power is adequate to cope with difficult areas like steep sand hills.

Tractors running on permanent wheeltracks always experience less wheel slippage and cause less soil deformation than they would on non-wheeled soil. CTF ensures that less fuel and power will be wasted in this way, but the effect might be rather less in the LRZ than in the generally softer soil conditions of higher rainfall zones.

The magnitude of the fuel reduction in CTF can be checked quite easily by noting tractor fuel use when driving on and off wheeltracks. If CTF is not in place, motion resistance can be checked by setting up temporary wheeltracks with at least two runs across a paddock, following the same wheeltracks.

In one trial, the average effort required to pull seeder openers through wheeled soil was 26 per cent greater than through non-wheeled soil. If openers were the only contributor to seeder power requirement, CTF would reduce the draught of the seeder by about 10 per cent. The effort required to pull no-till seeder openers will be less in CTF than in a conventional system.

A further benefit could be expected where the CTF crop beds provide more consistent soil conditions and so reduce the down forces required on depth wheels and/or press wheel, for both tyne and disc seeders.

RESEARCH PROJECT INSIGHT

Agricultural machinery operating in a CTF system were observed to use about 25 per cent less draft to pull a seeder tyne through soil in the crop zone and 25 per cent less motion resistance had to be overcome when the wheels operated on firm, permanent wheeltracks.

Energy study

Mark Kentish, *Piangil, Vic*

The change to CTF has achieved about a 15 per cent increase in fuel efficiency. In our self-propelled sprayer this equates to covering an additional 100ha per tank of fuel.

Linc Lehmann, *Birchip/Kinnabulla, Vic*

While I haven't measured a change in fuel usage, the seeder is much easier to pull through the soil in a CTF system.

Given these potential reductions in power requirements, consider the possible savings in up-front costs, fuel consumption and depreciation of lower horsepower tractors. Lower powered tractors are often more versatile in their uses on-farm and enable growers to operate extra units to cover large areas at peak times, rather than moving to wider gear.

JUMP TO

How to – In-crop wheeltracks

How to – Field operations efficiency

RESEARCH PROJECT INSIGHT

A tractor wheel in front of a narrow tyne opener increases the power required to move the tyne through the soil at 8km/hr by 26 per cent in representative southern LRZ soil types, compared to a conventionally farmed soil.

Energy study

Hayden Wass,
Nyngan, NSW

A major part of our change to CTF was the reduction in size of tractors required, enabling us to sell 300 and 400 horsepower tractors and replace them with 250 horsepower tractors. This meant there was very little actual cost in terms of machinery for the change to CTF.

The reduced tractor size and the switch to no-till has meant less fuel is required for sowing operations and the compacted wheeltracks reduce the rolling resistance for all operations, resulting in less fuel usage.

Operating machinery on firm CTF wheeltracks reduces power requirements and fuel use.

Paul Adam,
Tottenham, NSW

The conversion to CTF has resulted in a 30 per cent reduction in fuel costs, due to the tracks being harder, providing better traction.

HOW TO CTF – SEEDING EFFICIENCY

A foundational principle of CTF is the separation of machinery traffic and the crop beds. This provides the best conditions possible for plant growth in the beds and optimal traction and speed on the wheeltracks.

In the LRZ it is necessary to sow large areas of land in a short time. It is also immensely important to maximise the value of limited rainfall through improved water infiltration and storage.

Once implemented, CTF should extend the value of investments in agronomic practices that benefit the soil, such as zero tillage, stubble retention, deep ripping, nutrient management (including liming for pH correction) and harvest weed seed control within the bed area.

Having firm and permanent wheeltracks in a CTF system sometimes allows more timely access to paddocks after rain for seeding and other in-crop operations, with less risk of losing traction or getting machinery bogged. Although this may be less important for growers who dry sow, having greater flexibility at sowing time means that growers can choose a seeder that suits their farm's CTF ratio without sacrificing efficiency.

A seeder operating on firm wheeltracks and planting into un-compacted soil requires less horsepower and uses less fuel.

In a CTF system, growers can maximise the benefits of investments in RTK guidance at seeding. Within the crop bed area growers can readily implement a variety of sowing configurations such as:

- Inter-row sowing to minimise root disease carry-over effects and use stubble to trellis and or support crops (reduce lodging and improve harvestability).
- On-row or near-row sowing, particularly on non-wetting sands to take advantage of the moisture, organic matter and nutrients that accumulate in the row. On Mallee soils there is evidence that edge-row sowing could also be beneficial in managing brome grass.

Although these configurations are not CTF-dependent, they are easily implemented when permanent wheeltracks are established.

Very wide airseeder bars can be difficult to match into a CTF system and can have problems with seed depth control if the wheeltracks become deep or uneven. For maximum efficiency, look for the widest practical airseeder bar that fits with the chosen machinery operating width ratio for the farm. Matching the air cart with the seeder tractor wheeltrack gauge also helps to reduce compaction at sowing.

Choosing a narrower seeder bar to suit the CTF system does not necessarily mean a compromise on seeding efficiency. Some growers choose to run two smaller seeders and others look for other ways to maximise efficiency through increased operating speed or loading capacity. For example:

- Changing from 9 to 12km/hr operating speed gives a 33 per cent increase in capacity – the equivalent of moving from 12m to a 16m seeder. To achieve this, it may be necessary to make some changes to opener or press wheel design. If even greater speed is required (e.g. 15 to 18km/h), a disc seeder is usually required.
- Growers can use the trafficability advantages of CTF to start seeding sooner after rainfall or continue operating in moist conditions.
- For some growers, the use of dry sowing extends the planting window and relieves some of the pressure to cover large areas after the breaking rains.
- When planning the CTF layout, there are often opportunities to effectively increase the area sown per hour or per day through more efficient seed and fertiliser handling.

Mark Kentish, *Piangil, Vic*

The combined effect of the disc seeeder and CTF is achieving good, even germination right across all soil types. I also find that there is less root disease, and that crops appear to be extracting more moisture from the soil.

RESEARCH PROJECT INSIGHT

About 4L/hr less diesel is used, when a 15t tractor operates on permanent wheeltracks.

Energy study

Robert Pocock, *Lameroo, SA*

I started CTF in 2015 using RTK and implement guidance, mainly to keep standing stubble integrity, help trash flow and enable edge-row sowing. We fitted a Protrakker implement steering system to help achieve edge-row seeding.

If the only option is a seeder wider than the harvester, consider making it 1.5 times the harvester width. This way alternate harvester runs are on seeder wheeltracks, or (to avoid paddock-edge clean-up issues) all seeder runs will have one wheel on a harvester wheeltrack. In either case, with the sprayer on seeder or harvester wheeltracks, the total wheeltrack area will only be 18 per cent of the paddock area – a big improvement on the non-CTF alternatives.

Tynes on the seeder bar do not have to be evenly spaced. In most dryland situations with relatively wide row spacings (300mm and above) a simple 50 to 75mm hitch offset can be used for near-row seeding. Some growers accept varying guess-row widths, while others choose to adjust the position of the outside tynes.

If the wheeltracks are uneven or depressed, it can be difficult to maintain accurate seeding depth. It is important to maintain and repair the wheeltracks and, if necessary, use seeding units that have individual depth control for each row (or row pair). Where seeding depth is set by the frame height, running frame depth wheels on beds is perhaps the best compromise, unless wheeltrack depression is very even.

Deep working seeding points can alleviate surface compaction to a depth of about 20cm, and under the right soil conditions, can achieve some mixing of ameliorants in the crop bed. Deep working points can be placed on some tynes one year and rotated to other tynes the following year. It is best to avoid using deep working points on permanent wheeltracks.

Some CTF growers leave the wheeltracks unsown while others apply all operations across the whole paddock. Keeping the wheeltracks as narrow as possible is a balance of maintaining a firm surface for machinery to operate while minimising yield loss and weed pressure. Many growers find that the rows adjacent to bare wheeltracks compensate for any yield loss from not seeding the wheeltracks. Others find that sown wheeltracks can help minimise erosion risk.

JUMP TO
Energy savings study
Critical components of CTF
Wheeltrack renovation
Wheeltracks in-crop

Bulla Burra,
Loxton, SA

CTF has improved the consistency of inter-row sowing at Bulla Burra. Paddocks are sown west or north on even run lines and east or south on odd run lines. This means the seeder can be nudged and more easily follow through the previous stubble lines, compensating for the slight machine row variances and the tendency to crab on hillsides.

Linc Lehmann,
Birchip/Kinnabulla, Vic

We introduced CTF in 2010 on 3m wheel spacings to establish a more suitable way of cropping with bare wheeltracks to keep crop trampling to a minimum.

Matt Burkitt,
Parkes, NSW

The increases in water infiltration and water storage in the soil profile have had a large impact on soil health and the property's capacity to grow crops.

Avoiding trafficking the crop zone provides optimal conditions for crop growth.

HOW TO CTF – WHEELTRACKS IN-CROP

Wheeltracks can be unsown, sown, broadcast seeded or used to 'store' weed-seed laden chaff. This is one decision that can change from year to year, depending on the season, crop or weed pressure. For example, some growers plant the wheeltracks in cereal crops and leave them unsown in broadleaf crops. The pros and cons for different wheeltrack treatment options are outlined in the table.

Keeping the wheeltracks unsown provides the best conditions for machinery operation and paddock access as the wheeltracks become very hard over time. However, in the low rainfall zone, some soils are prone to wind erosion and this must be taken into account when deciding whether or not to sow the wheeltracks.

Leaving the wheeltracks unsown was the original CTF concept and involves simply removing the tynes behind the wheels of the seeder bar, with some growers splitting the seed and fertiliser of the missing row between the rows each side. Keeping the wheeltracks as narrow as possible reduces the potential for increased weed pressure.

Extra spray nozzles on SP sprayer target weeds on wheeltracks.

Wheeltrack treatment	Pros	Cons
Unsown	• Tracks can be maintained for optimal machinery speed and traction. • Easy to find and follow permanent wheeltracks when autosteer goes down. • More even crop maturity with no green crop along the wheeltracks at harvest. • Higher yielding edge rows often compensate for potential loss. • No crop damage during in-crop operations. • Keeping tracks narrow is a good compromise, as is increasing the seeding rate of the edge rows.	• More light can get into the canopy and encourage weed growth on and along the edges of the wheeltracks. • Loss of sown area. • Increased erosion risk. • No incorporation of pre-emergent herbicide may allow weeds to establish, particularly on sandy soils.
Chaff layer (Chaff deck)	• Weed seed (often herbicide resistant) is concentrated in a small, identifiable area of the paddock where it may decompose. • Any weeds that germinate can be treated with another weed control tactic (e.g. early knock-down herbicide using a shielded sprayer). • Low erosion risk.	• More light can get into the canopy and encourage weed growth on and along the edges of the wheeltracks. • Loss of sown area. • No incorporation of pre-emergent herbicide may allow weeds to establish, particularly on sandy soils.
Sown	• Maximise sown area. • Provide competition for weeds. • Better soil cover and reduced erosion risk. • Incorporation of pre-emergent (residual) herbicide. • Can help even out the tracks in the initial years and help establish firm wheeltracks.	• Potential for uneven crop maturity, with stunted crop and low-quality grain. • Soil disturbance at planting can compromise the trafficability of the wheeltrack.
Broadcast seeding	• Maximise sown area. • Provide competition for weeds. • Better soil cover and reduced erosion risk.	• Potential crop damage due to ineffective incorporation of pre-emergent herbicide. • Potential for uneven crop maturity, with green crop along the wheeltracks at harvest. • Poor germination in dry years.

Chaff-decking is a harvest weed seed control (HWSC) method that delivers the weed-laden chaff fraction onto one or both of the wheeltracks. Some growers sow through the chaff layer on the wheeltracks, but most leave the chaff undisturbed to create a hostile growing environment for the weeds. Chaff-decking can assist with erosion control and reduces the amount of dust when spraying.

Other HWSC methods, such as chaff-lining, chaff carts and impact mills, are compatible with CTF and may suit growers who prefer to keep wheeltracks bare.

Additional yield produced in the crop zone will usually more than compensate for any loss from unsown wheeltracks, particularly when wheeltrack edge rows can access moisture from the tracks. This edge-row compensation effect sometimes produces uneven ripening, which can also occur with sown (or broadcast seeded) wheeltracks. Plants growing in the wheeltracks can sometimes be stunted and produce poor quality grain.

These effects are all likely to occur in non-CTF systems too, but are more visually obvious in a CTF system.

To sow the wheeltracks some growers use a shorter point or a disc on the wheeltrack row. Disc units retain more firmness in the wheeltrack than using tynes. Some growers find that sowing the wheeltracks in the first few seasons after implementing permanent tracks is beneficial for weed control until the tracks harden and become a very hostile environment for weed or crop growth. It is then easy to change to unsown wheeltracks for future crops.

Broadcast seeded wheeltracks are sown by dropping seed and fertiliser on the soil surface along the track and using the planter presswheel to achieve seed-soil contact. Using lugged tyres can assist with this method of planting.

JUMP TO
Yield penalty study

Permanent wheeltracks may be sown or left bare.

Paul Adam,
Tottenham, NSW

I leave the wheeltracks un-sown, and about 480mm wide. The good ground cover between the tracks and the reduction in run-off achieved through better infiltration has resulted in less erosion along tracks.

Mark Kentish,
Piangil, Vic

Sandhill erosion remains one of my biggest challenges in CTF, due to the deep wheeltracks, and blowouts along the wheeltracks. A chaff deck might provide extra cover to avoid this erosion, but at present I need to manually renovate the damaged wheeltracks.

Linc Lehmann,
Birchip/Kinnabulla, Vic

There is a lot less dust from the wheeltracks, which is excellent for summer spraying in terms of herbicide efficacy, particularly near wheeltracks. A spray contractor working on our farm commented that there was considerably more dust when he turned at the end of the paddock compared to spraying along the tracks.

HOW TO CTF – FIELD OPERATIONS

In low rainfall zones the 'system' benefits of CTF – improved paddock trafficability, accessibility and more uniform crops – are less obvious than in the high rainfall zone. They are nevertheless real and provide opportunities to improve crop management and overall efficiency, and boost the business' bottom line.

The ability to complete an operation sooner after rain might occur only occasionally, but can have a major impact on production and profitability in these years.

Establishing permanent wheeltracks improves the trafficability of the paddock – allowing machinery to operate more efficiently, enabling more timely operations such as spraying herbicides and fungicides sooner after rainfall and with less dust in dry conditions, enabling more area to be covered during optimal hours of application.

Small rainfall events do not impede sowing operations and can contribute to better crop establishment.

Likewise, at harvest and when spraying, controlled traffic allows the grower access to paddocks that would otherwise be untrafficable. This means crop protection products can be applied at the optimal time, such as herbicides being applied to small, rapidly growing and unstressed weeds.

Without exceeding optimal ground speeds, spray rigs operating in a CTF paddock can cover more ground within the safe spray application daytime hours, reducing the pressure to continue spraying during times of higher spray drift risk.

A change to CTF is an opportunity to study the current time and motion efficiencies of each paddock and the overall farm operation. Take time to quantify the inefficiencies that might currently exist during key operations such as planting, harvesting and spraying. Determine what is causing the downtime or extra travel time and look for ways to reduce these problems. It may be planter type, refill time, location of water or storage facilities or a multitude of other variables. Making a change to CTF is an opportunity to 'fix' things that might have caused frustrations and delays for many years.

Operating in straight lines is easier and faster than curves and eliminates double worked corners. Seeding and tillage equipment also works better and wears more evenly when operated in straight lines and crop protection sprays are applied more evenly, avoiding low dose applications that can elevate resistance risks, and avoiding costly overlaps.

Another benefit of implementing CTF is the ability to effectively use precision planting and variable rate technologies.

Addressing problems that may have limited cropping options in the past, such as wet areas within paddocks, or using variable rate technology to fix soil constraints such as pH, can open up the possibility of more diversity in the cropping program. This in turn can have significant impacts on farm profitability and on the efficacy of weed, pest and disease management.

Some changes to layout and equipment may take several seasons to fully implement. To design the most efficient layout consider:

- length of run
- shape of the paddock
- access roads
- wheeltrack orientation and sun angle for weed control
- erosive wind direction

RESEARCH PROJECT INSIGHT

Agricultural machinery operating in a CTF system were observed to use 26 per cent less draft to pull a seeder tyne through soil in the crop zone, and 25 per cent less motion resistance had to be overcome when the wheels operated on firm, permanent wheeltracks.

Energy study

Linc Lehmann, *Birchip/Kinnabulla, Vic*

One of the main benefits of CTF to the farming system is having more traction when it is wet, allowing access to paddocks a little earlier than previously. This is a fine balance though because going on too early can do a lot of damage to permanent wheeltracks.

Alistair Murdoch, *Kooloonong, Vic*

The change to CTF has resulted in a 15 per cent improvement in spraying efficiency. The boomsprayer works a lot harder when I am contract spraying off-farm.

- surface water control
- typical crop lodging direction
- integration with tree and forage planting.

Placement of access tracks at right-angles to the row direction, or possibly sowing long narrow paddocks at right-angles to the long side, can reduce the number of empty runs. Both options give greater flexibility for exiting the paddock in a timely way to unload or refill, while also taking advantage of long runs. The topography of the farm and the direction of sand hills will strongly influence the layout of the CTF plan.

The general recommendation from experienced operators is to look for ways to increase capacity without increasing width. For example, choice of row spacing and opener type can impact on planting speed and a larger capacity air cart and faster loading system increase the area that can be sown in a day. It is better to look for increased efficiency here than to move to a wider seeder than does not fit well with the CTF layout. Researchers have demonstrated that increasing ground speed and seeding capacity of a 12m seeder can make it equal to an 18m seeding operation without the expense.

Another option is to run two seeders with smaller tractors to also reduce capital depreciation and improve flexibility of tractor use, while increasing seeding capacity. The additional labour costs and logistics of running two machines are important considerations.

Getting the layout right on paper is very important as any serious oversight could be very damaging and expensive to fix. Ask lots of questions of experienced operators in the area and/or engage a consultant with CTF experience to assist with an overall plan.

JUMP TO

How to – Energy saving
How to – Seeding efficiency
How to – Erosion control

Chris Leed,
Pyramid Hill, Vic

Fuel savings are unlikely to be the greatest benefit from converting to CTF. We find that we can generally get on the paddocks slightly sooner after a rain event than growers who are not on CTF.

David Greig,
Tottenham, NSW

I can now drive onto paddocks to spray much sooner after rain than previously, without damaging the wheeltracks. During harvest, wheeltracks are much less likely to get bogged in wet conditions, however issues still remain when turning in the headlands, once the harvester is off the permanent wheeltracks.

Paul Adam,
Tottenham, NSW

The ease of management in CTF, combined with the self-propelled sprayer has significantly improved our weed management. This particularly relates to timeliness of weed control, with weeds controlled earlier in the growing season for both winter and summer growing weeds.

HOW TO CTF – HARVEST EFFICIENCY

Grain harvesters are usually the heaviest machines used in a cropping system, and can cause deep compaction damage. Even when the surface soil is dry, moist layers can sometimes persist at depth and 20t harvester axles can produce compaction effects more than 0.5m into the profile. Compaction at this depth is expensive to repair.

Harvesters are also often the most expensive machine to replace, and their configuration can be out of the grower's control when contractors are used. This leads many growers to take the existing harvester as the base machine for wheeltrack gauge and operating width ratio, modifying other machines to suit.

When thinking about harvesting, also consider the chaser bin. Many growers accept that the chaser bin must move off the wheeltracks when the harvester is unloading. In the longer term most move to auger extensions or chaser bin receival platforms to keep all units on permanent wheeltracks. Some growers use machine synchronisation technology to control the chaser tractor's forward speed and keep the auger well-aligned with the chaser bin.

Full implementation of a CTF system can take five years or more, so it is important to consider what the business will require in the future. If the harvester will be the base unit for the system's operating width, it will usually be cheaper to replace a cutting front early, if it will ensure the right capacity for the future.

A careful tape-measure check of machine dimensions can determine the exact cut width, and whether harvester fronts are properly centred on the harvester.

It is also important to consider factors such as run length in relation to harvester and chaser bin capacity, and chaser bin paddock exit. Greater run lengths usually improve field efficiency with seeding and spraying, but internal cross tracks (sited also to avoid undesirable channelling of wind or run-off), can increase harvest efficiency by reducing chaser bin travel.

RESEARCH PROJECT INSIGHT

The difference between motion resistance driving on cropped area compared to on permanent wheeltracks is just over 2 per cent of the tractor weight.

Energy study

Machinery used at harvest can have a large impact on the soil, particularly in moist conditions.

In addition to causing less compaction, harvesters, chaser bins (and all other units) will operate more efficiently when they are running on firm wheeltracks. With less power being drawn for traction, more power is available to increase capacity while maintaining efficient threshing and separating.

Having the harvester running on the same wheeltracks also allows the adoption of a variety of harvest weed seed control options that are compatible with CTF, such as chaff-decks, and chaff-lining.

Wade Nicholls, *Pinnaroo, SA*

At harvest, we have to drive off the permanent wheeltracks when loading the chaser bin, but we don't feel as safe using an extended auger on the harvester. We are reluctant to go to an 18m harvester, as this would be less efficient for reaping lentils in our undulating paddocks.

JUMP TO

Critical components of CTF

CTF Calculator

Harvest weed seed control tactics such as chaff-lining are compatible with CTF.

Front tracks on header.

Adjusted rear wheels on header.

Extended header auger.

HOW TO CTF – SOIL HEALTH

Crop productivity can be lifted through correction of chemical, physical or biological soil constraints in the topsoil and or the subsoil in the crop zone. Addressing soil compaction, and preventing its reoccurrence, is one of the main driving forces behind the adoption of CTF on many farms.

Before undertaking expensive soil amelioration work on a paddock, it pays to identify and understand the soil constraints that are limiting yield. Simply removing heavy machinery traffic from the crop zone can maximise the benefits of other farming methods, such as minimum tillage and stubble retention, and start the natural process of improving soil structure.

The term 'biological ripping' describes the use of deep-rooted species, such as lucerne and tillage radish, to help break up layers of dense soil structure. In low rainfall zones, and particularly on sandier soils, lower biomass production can mean that biological methods take longer to improve soil structure compared to what might be possible in higher rainfall environments.

In some situations it may pay to invest in deep ripping to break deep compaction layers and 're-set' the system. Keep in mind that there is limited information about the effect of deep ripping of soils found in the LRZ. This limited information suggests that deep ripping has only shown consistent benefits on sands deeper than 25cm.

If deep ripping is done to break compacted zones it also provides an opportunity to incorporate ameliorants such as lime, gypsum, organic matter or fertiliser. The benefits of these interventions are best preserved through the adoption or re-adoption of controlled traffic following the amelioration activity. By adopting CTF, machinery traffic is confined to as little as 15 per cent of the paddock, avoiding re-compaction of ameliorated soils in the crop zone. Soil amelioration techniques may be costly but are often economical in the long-term.

If a CTF system is in place, deep ripping and some cultivation options can still be used, but it is advisable not to disturb the permanent wheeltracks, unless changes are needed in the system layout or equipment working width or track gauge. Keeping the wheeltracks in good condition can significantly reduce the cost of soil amelioration work.

To identify compacted layers in the soil profile, use a penetrometer or push rod (preferably when soil moisture is close to field capacity), to compare areas of suspected compaction with un-compacted soil (e.g. field v fenceline). Digging a small soil pit with a spade can also help confirm the rooting patterns and depth of compacted layers.

Collecting soil samples at a number of depths through the root zone and having them analysed will provide insights into the chemical nature of the soil. This will identify whether applications of lime or gypsum would be beneficial and whether there are any risks in disturbing the subsoil (e.g. boron toxicity).

To be effective the deep ripper tynes must be run at a depth that is below the compaction layer. If the tynes simply skid along the top of the compaction zone the operation will be not break the compacted layer and if the subsoil is moist, can cause a smearing effect on top of the compacted layer, further impeding water infiltration and root growth.

Once a compaction layer has been broken, adopting CTF and restricting all traffic to permanent wheeltracks will preserve the benefits of the investment in deep ripping and any other soil ameliorants.

Robert Pocock, *Lameroo, SA*

I could see the value in minimising soil compaction to improve crop water use efficiency and have been able to achieve this without slowing our program down.

RESEARCH PROJECT INSIGHT

Not all soils respond positively to deep ripping. Understanding the characteristics of the topsoil and subsoil is essential.

Deep ripping study

Bulla Burra, *Loxton, SA*

Our main reason for implementing CTF was to alleviate compaction, particularly on sands, giving crops better access to soil moisture, resulting in increased yields.

RESEARCH PROJECT INSIGHT

Push rods and penetrometers help land managers to get a base feel as to the level of soil resistance at a point in time at a location and can be used to identify the depth of compaction.

Penetrometer study

RESEARCH PROJECT INSIGHT

The degree of soil damage caused by trafficking depends on the equipment axle load, the soil water content during trafficking, and the number of passes. When soil is already severely compacted however, the effects of any additional traffic might be small and can be difficult to detect.

Research results

Re-compacting soil after ripping can result in the soil being more compacted than it was before ripping.

Amelioration of sandy soils in WA has been shown to have large financial benefits, particularly if CTF is adopted to prevent re-compaction. The amelioration package for these, usually acidic, soils usually involves the application of lime followed by a cultivation. This cultivation, using a mouldboard plough, spader, delver or Plozza plough, and sometimes a deep ripper, mixes applied lime and the nutrients and organic matter that tend to accumulate at the soil surface in an otherwise no-till farming system.

Identifying the soil limitations to root growth, and targeting specific constraints with appropriate amelioration techniques is critical. It is often worth doing a few strip trials to observe any changes in soil condition or crop productivity before substantial investment in soil amelioration activities. In low rainfall zones the cost of some soil amelioration activities may be harder to justify.

Agronomic improvements also come through:

- better stubble handling,
- inter-row sowing,
- edge or or on-row sowing for improved weed control in non-wetting sands,
- accurate placement of fertiliser for maximum benefit, and
- either banding pre-emergent herbicides post-planting or using an inter-row shielded sprayer.

JUMP TO

How to – A word on compaction

RESEARCH PROJECT INSIGHT

Deep ripping of responsive soils in WA and SA comes with an expectation that the yield benefits can be prolonged from three to possibly ten years under a CTF regime in light soil types.

Deep ripping study

RESEARCH PROJECT INSIGHT

Trafficking Mallee sands reduces arbuscular mycorrhizal fungi (AMF) colonisation, which means plants are less efficient in their uptake of phosphorus from the soil.

Microbiology study

David Greig,
Tottenham, NSW

Our soils have become much softer, to the degree that what we once described as 'hard-setting red soils' are no longer hard-setting at all. Another example is a recently-purchased paddock that was quite gravely and very hard, that is developing cracks like self- mulching soil and is now very friable.

Jock McNeil,
Paruna, SA

After monitoring root growth in soil pits, and trialling deep ripping, it was evident there were compacted soil layers at depth. After commencing a deep ripping program, it was a natural progression to move to CTF to preserve the benefits for as long as possible.

A large proportion of the farm is made up of sandy soils that have proved to be very responsive to deep ripping, with 30 to 40 per cent yield improvement and sometimes up to 100 per cent.

Mark Kentish,
Piangil, Vic

I could see compaction issues across the farm, particularly heavy machinery tracks persisting after paddocks were trafficked in wet soil conditions. There was potential to reduce compaction by reducing the machinery footprint from over 40 per cent, to less than 20 per cent, of the cropped area.

HOW TO CTF – EROSION CONTROL

Many landscapes in the LRZ are prone to wind and water erosion. However, grower experience suggests that erosion is no worse in CTF than non-CTF systems, it just needs to be managed.

Soil type, landform and ground cover are all important factors that influence the erosion risk. Steps taken to reduce water and wind erosion will also reduce nutrient loss from the paddock.

To prevent soil erosion, it is necessary to plan a paddock layout and farming system that will reduce wind and surface water flow velocity and maximise:

- ground cover (both standing stubble and surface cover),
- aggregate strength (the ability of the soil to form small clods),
- water infiltration.

Stubble retention and minimum tillage are valuable soil-saving practices fully compatible with CTF. With these practices in place to protect the crop area, the wheeltracks can present the greatest risk for erosion damage.

Even when wheeltracks are seeded, they are still more exposed to erosive forces than the rest of the paddock. This occurs particularly when the plants in the wheeltracks are damaged as a result of multiple wheel passes. 'Rotating' the set of wheeltracks used by the boomspray can reduce this effect. Using a chaff-deck to deposit a layer of chaff on the wheeltracks every year provides excellent ground cover, along with the weed control advantages. In cases of extreme risk, such as the tops of sand hills or dunes, adding a layer of gravel or clay to the exposed wheeltracks could provide the cover needed to avoid expensive repair work.

One key long-term benefit of CTF is the opportunity to improve water infiltration. Many growers find that areas that previously experienced minor water erosion have reduced runoff when CTF is in place, as a result of improved water penetration and infiltration across the non-trafficked area of the paddock.

Layout considerations

Soil type and landform are key factors in determining erosion risk. When planning a controlled traffic layout, take into account local evidence and experience of water flow and run-off patterns and prevailing wind directions around the farm. Combine this knowledge with accurate elevation data as the basis of the controlled traffic plan.

Protecting the wheeltracks from wind erosion is all about ground cover and wind direction, particularly on hill-tops and ridge lines. If the wind erosion risk is high, consider angling the wheeltracks perpendicular to the prevailing wind direction. When controlled traffic is combined with zero-tillage practices, the wind erosion risk is reduced. If cultivation, such as deep ripping or wheeltrack renovation, is required, avoid leaving the soil disturbed and bare during windy periods of the year. The amount of stubble cover, type of crop and crop density will have a direct impact on the erodibility of the soil in windy conditions. Standing crops and anchored stubble provide the best protection for the soil surface.

Although water erosion is lower risk in the LRZ than other regions of Australia, any intense rainfall can result in erosion and it is worthwhile to take this into account when planning a CTF layout, particularly on sloping paddocks. Even in the LRZ, water erosion can account for up to 3t/ha soil loss per year if measures are not taken to protect vulnerable soils.

Hayden Wass, *Nyngan, NSW*

There has been a considerable reduction in water run-off and an increase in infiltration since we adopted CTF, no-till and stubble retention.

Alistair Murdoch, *Kooloonong, Vic*

Wheeltrack erosion in sandy soils remains an ongoing issue. To counter this, I alternate between wheeltracks each time I spray, reducing the annual passes from nine to three, especially for pulse crops that require spraying for control of summer weeds and in-crop management of grass weeds, insects and disease.

Where water erosion might be an issue, good system layout can ensure that runoff remains distributed across paddocks. Erosion is usually an issue only where water concentrates, causing it to flow at erosive speeds, so access tracks can be a particular problem if their siting allows them to harvest and concentrate run-off from a large area.

Factors to consider include:

1. Reduce run-on water – small interceptor or diversion banks on the upslope boundaries of the paddock can divert water away from the cropped area and safely into a stable waterway.
2. Row slope and run length – the safe row slope and run length depends on the soil type. If steep slopes are unavoidable, then runs must be short and water diverted to prevent it concentrating and gaining velocity (e.g. using farm-over contour banks).
3. Maximise in-field infiltration – identify and fix surface and sub-surface soil constraints to improve infiltration. Initial deep ripping (and possibly clay incorporation to address non-wetting sands) to break subsoil compaction is a common first step when implementing CTF and will have long-lasting benefits for water infiltration and reducing erosion.
4. Maximise anchored ground cover – on elevated and sloping land, the intact root system underneath standing stubble increases the erosive resistance of the soil surface to overland flow.

A CTF layout may take several seasons to fully implement but it makes sense to have a well-planned layout that allows for a staged implementation. Ask a CTF consultant for advice if there are paddocks that present complex landforms or variation in soil type. RTK guidance systems collect high accuracy elevation data that can be very useful to help plan layouts to reduce the risk of waterlogging and erosion and the damage to wheeltracks.

A well-designed and maintained layout will maximise efficiency, protect the soil resource and preserve the wheeltracks. A full layout involving earthworks for surface water control requires complex calculations and professional surveying and construction. Poorly designed or built earthworks can cause more damage than leaving the water to flow naturally.

Using the same principle as a corrugated tin roof, the aim of working up and down the slope is to contain the water – ideally within each crop row. This will ensure the slope drains uniformly and water is prevented from concentrating from more than one machine width. Thoughtful planning is required to prevent erosion, waterlogging and flooding. Be sure to deliver water onto safe areas where it can disperse – using waterways and banks if necessary and ensuring that access tracks are also well-drained.

If the layout requires cross-slope or contour working, be aware of the risk of machinery and implement 'creep' downslope and operator safety. Remember also that cross-slope wheeltracks will concentrate run-off, and have been associated with significant erosion.

Broad grade banks, with channels 4 to 5m wide, located at the top of the slope and at strategic intervals down the slope can assist with slowing water down during high intensity rainfall events. These banks can be used on slopes of 2 to 6 per cent and are generally designed to be driven over at 90 degrees or on an angle of more than 45 degrees.

JUMP TO
How to – In-crop wheeltracks
How to – Wheeltrack renovation

Bulla Burra, *Loxton, SA*

There have been ongoing wind erosion issues on the wheeltracks over the sandy rises. We hire a grader board as soon as wheeltrack erosion begins to appear. If the erosion is not fixed quickly, the problem can escalate into larger blowouts and further problems in following years. Switching run lines for the sprayer may help reduce this problem to some extent.

Jock McNeil, *Paruna, SA*

Wheel ruts are becoming deeper with wind erosion from the many passes on the spraying wheeltracks being a major issue in the deep sandy soil types. Rotation of the wheeltracks used for spraying will reduce this issue.

Robert Pocock, *Lameroo, SA*

We are considering using chaff decks to drop chaff on wheeltracks to stop erosion on the sand, with additional wheeltrack spray jets to control any extra weed pressure created. In the interim, we are using chaff-lining to move away from narrow windrow burning, which wastes valuable organic matter and concentrates burnt stubble on the same row each year.

HOW TO CTF – WHEELTRACK REPAIR

In a CTF system, the concentration of traffic on permanent wheeltracks comes with some potential problems. Even when every effort is made through good layout and design, damage will be inevitable on some wheeltracks in some years. Damage is minimised in layouts that provide even and effective wheeltrack drainage, with no low spots to pond water.

Smooth wheeltracks will improve the efficacy of spray operations, enable optimal operating speeds and reduce stress on the machinery and operators. Periodically it may be necessary to renovate wheeltracks, particularly if wet weather traffic (or wind erosion) has caused deep ruts or pushed up banks of soil on each side of the wheeltrack.

Prevention is better than cure and early intervention is important. Careful consideration of the risks to wheeltracks needs to be given in the early planning phases to minimise the need for frequent renovation and maintenance work.

Good drainage is an essential component of an effective CTF system and managing how water moves across paddocks must be a priority during the planning phase. Good paddock layout and keeping crop or residue cover in the tracks can reduce damage to the wheeltracks, as can attention to tyre and track size and type.

While wider tyres might sometimes mean wheeltracks need less renovation, they increase the trafficked area of the paddock.

Once tracks become deep, or rutted, enough to hold water in puddles, rather than flowing evenly down the track, the risk of them being damaged further increases, particularly on higher clay soil types.

The sprayer is the machine most likely to damage the tracks as it is used the most often, sometimes during moist conditions, and often has narrower tyres than other machines or equipment. Alternating between sets of wheeltracks when spraying (or spreading) is one of the best ways to reduce the risk of damage to the wheeltracks. This rotation is also useful for reducing wind erosion on sandy soils. If wheeltracks are sown, rotation of sprayer tracks reduces the crop damage that occurs if the same track is always used. The plants growing in the wheeltrack reduce wind erosion, and slow water movement.

Wheeltrack renovator.

David Greig, *Tottenham, NSW*

The wheeltracks will need renovating periodically, probably every 10 years. I'll use the opportunity to level paddocks that need it, apply lime if necessary and implement control strategies on problem weeds such as windmill grass. In paddocks that are in otherwise good condition I will consider using wheeltrack renovators.

The use of chaff-decks to direct all chaff into CTF wheeltracks is an increasingly common weed control tactic that can also help reduce wind and water erosion and the need for renovation of wheeltracks.

During normal cropping operations care needs to be taken to avoid entering the paddock when there is potential for machinery to get bogged. While firm CTF wheeltracks allow paddock access well before the same paddock would have been dry enough to drive on under conventional farming, the wheeltracks still need to be dry enough!

Under wet conditions it is even more important than ever to stay on the wheeltracks.

Renovation operations may be best done after a break crop when there is less stubble on the paddock. Incorporating stubble onto the tracks can make them spongy in some situations, such as on clay soils.

A range of implements, from discs to scrapers and custom-built machines, are available to repair or renovate wheeltracks. Renovation work must be undertaken in dry conditions. In a run of wet years it may be very difficult to renovate and pack down the wheeltracks without doing more damage. Take care not to leave sandy soils loose and bare over summer.

If the damage is extensive, it may be necessary to deep rip the whole area and re-establish the wheeltracks, which will remain soft for several months. Alternatively, gravel can be used in the most severely eroded sections of the wheeltracks or those parts of the tracks that are prone to repeated damage or erosion.

It is rare for wheeltrack damage to become so bad that modern track renovators cannot rectify the issue.

JUMP TO

How to – Erosion control

How to – In-crop wheeltracks

How to – Field efficiency

HOW TO CTF – LIVESTOCK

If a farm is a mixed cropping and livestock enterprise, there is no inherent reason why it can't transition to CTF. CTF and livestock can co-exist.

Research conducted in the low rainfall environment of Condobolin, NSW, from 2009 to 2013 found that sheep grazing on stubbles did not reduce crop yields, provided summer weeds were controlled with herbicides and at least 70 per cent stubble cover (2 to 3t/ha cereal stubble) was maintained on the soil surface.

Sheep grazing stubble in summer or vegetative crops in winter did have an impact on soil strength (surface compaction) and water infiltration but this was rarely detrimental to productivity of the grain crop. The excessive removal of cover was determined to have a greater impact on infiltration rates than compaction.

Grazing increased the availability of soil mineral N to subsequent crops, which increased grain yield and protein in some seasons.

Therefore, CTF is fully compatible with fodder production, grazing juvenile crops, stubble grazing and pasture rotations. How the livestock are managed within the system will vary from farm to farm, but some infrastructure changes will be needed to meet the needs of both the cropping and livestock enterprises.

Since the main purpose of CTF is to ameliorate compaction, some growers are concerned about the trampling effect of livestock. This effect is most likely to affect the surface condition of the soil and will never cause the subsoil compaction that develops as a result of heavy machinery in un-controlled traffic farming.

The impact of sheep and cattle hooves can reduce the water infiltration rate of the soil. Managing stock numbers and the length of time stock are permitted to graze in the paddock will reduce this risk. The aim should always be to preserve sufficient anchored stubble to protect the soil from wind and water erosion. Managing stock density according to the soil moisture content is one strategy to limit the effect of trampling on water infiltration. To avoid damage to heavier soils, remove livestock from the paddock when the soil is wet.

Generally, the trampling damage that livestock may cause to the cropped area will be remediated during the sowing operation.

Livestock will often walk along and camp on wheeltracks, potentially making some wheeltracks more prone to erosion if the grazing pressure is too high for too long.

Significant productivity gains, such as improved weight gains and better lambing percentages, have been measured where sheep graze chaff directed onto the wheeltracks, dumped from a chaff cart or even left in a chaff line directly behind the harvester. Sheep can spread chaff as they graze, but weed seeds that are eaten are usually rendered unviable once they pass through the sheep's digestive tract. More weed seed remains viable when cattle are used to graze stubble.

Paddock size should be a consideration when planning the CTF and farm layout to ensure the management needs of livestock are taken into account. This may be less important if wethers are mostly used for grazing the cropping paddocks, but smaller paddocks are generally recommended for mothering lambs.

Robert Pocock, *Lameroo, SA*

There are times and situations where compromises need to be made, such as to accommodate livestock or hay.

Alistair Murdoch, *Kooloonong, Vic*

When bringing sheep back into the farming system I wanted to ensure they did not negatively impact on the cropping program. So far, I haven't noticed any increase in grass germination due to weed seed being trampled into the soil. I use a carefully stacked rotation strategy to achieve up to three years grass control if required.

There are ways to achieve both the efficiencies of larger paddocks with less headlands for cropping and also confining grazing stock to portions of the paddock to maximise productivity, such as weaning percentages. Containment paddocks, electric fencing, mobile watering points and even electronic (virtual) fencing can be used to manage flock density and grazing patterns.

Growers who produce hay can have difficulties integrating hay-making equipment into a CTF system. Hay production is possible in CTF and although many growers make some compromises there are some who have modified their hay-making equipment to operate within their CTF system.

CTF is compatible with mixed farming operations.

Haymaking represents some challenges in a CTF system but it can be fully integrated or certain compromises can be made to minimise potential compaction.

Chris Leed,
Pyramid Hill, Vic

Making hay within a CTF system is challenging because not all hay machinery will fit the wheeltracks used in grain production. The more farmers and contractors there are making hay, the easier it will be to do CTF hay.

Linc Lehmann,
Birchip/Kinnabulla, Vic

We have not kept livestock for 10 years, but we do agist sheep to graze stubbles over summer. We find that livestock do have a fit within CTF systems if they are managed well and infrastructure is up-to-standard.

Wade Nicholls,
Pinnaroo, SA

Our hay mower is only 4.5m wide, so it only aligns with CTF wheeltracks 20 per cent of the time. The baler wheels are on 2m spacings, which is not ideal, but is a compromise we are willing to make at the present time.

Grower: Darrell Boxall
Location: Woomelang, Victoria
Soil types: Heavy Mallee soil to sand
Average annual rainfall: 325mm
Growing season rainfall: 217mm

Darrell Boxall

Darrell Boxall's farming system at Woomelang has been 100 per cent cropping until a small number of sheep were brought in 2018 to clean-up failed crops. The cropped area is 2630ha with a rotation of two cereals and then a legume, either lentils, lupins or vetch. Oaten and vetch hay is made opportunistically.

Motivations for adopting CTF

Darrell commenced and completed the conversion to CTF in 2009. He was keen to try CTF after observing a crop response to some deep ripping, with a significant difference being seen in this crop compared to crop on compacted soil. After further research into CTF he decided it could be a good fit for their farm.

Issues encountered in the conversion to CTF

No major issues were encountered during the conversion, and Darrell kept costs to a minimum through the purchase of second-hand equipment and making alterations himself as required.

There are 900mm wide tyres on the header, which is not ideal for CTF, but thinner tyres would not be suitable for driving over the sandy hills.

Changes to the farming system since converting to CTF

Hay making does not fit with the Boxall's CTF system. Darrell has not yet seen the full benefits from CTF, and so is not willing to take hay out of the farming system just because it does not fit with CTF.

Having a small flock of sheep on the farm has only damaged the top few centimetres of soil and the seeder will easily go through this at sowing time. The only problem Darrell can envisage is the possible spread of weed seeds through sheep faeces.

Darrell has some areas of herbicide resistant brome grass, and in more recent years ryegrass is starting to appear and become a problem. He is planning to experiment with narrow windrow burning to control brome.

Current machinery set up and modifications made to convert to CTF

The header and seeder are 12m wide, the sprayer is 36m wide and the spreader is 24m wide. The cost of converting the machinery to CTF in 2009 was roughly $4000 and Darrell spent approximately 10 days in the workshop making alterations. All wheeltracks are 3m apart and all machinery is on 2cm GPS autosteer. Dual wheels are necessary on machinery working in some sandy soils.

Since 2009 Darrell has upgraded his header twice, which has made it necessary to adjust other equipment to match the width of the header front. Darrell started on a 9m system before changing to a 10m system four years later and again changing in the 2018 season to a 12m system.

Wheat growing on wheeltrack.

Changes in fuel and work rates due to CTF

Darrell has measured a reduction in fuel usage. More significantly he has found that the header is much less likely to get bogged during harvest when operating on permanent wheeltracks. It is also easier to see the tracks and where to go when turning at the ends of rows, which makes driving equipment more straight forward for everyone.

Impact of CTF on crop yield

Darrell's crops are yielding higher but this is not a direct result of CTF alone. Other important factors are improved farming practices, better variety choice and or improved soil nutrition.

Learnings from the transition to CTF

Darrell is not yet observing benefits, but still strongly believes in the theory of CTF and is planning to continue with the system into the future.

The biggest drawback has been the limitation it puts on second-hand machinery replacement options, which results in having to travel further afield for machinery or having to make modifications himself.

Darrell plans to deep rip some paddocks because the soils are not self-repairing soils, unlike some soils in other areas, such as the Victorian Wimmera region.

Further into the future Darrell hopes smaller, lighter automated machinery will be operating in CTF systems, having multiple machines operating rather than one large heavy machine.

Deep ripper used in on-farm trial.

Grower: Chris Leed
Location: Pyramid Hill, Victoria
Soil types: Clay
Average annual rainfall: 375mm
Growing season rainfall: 236mm

Chris Leed started farming in 2000 while studying agricultural science at Dookie Agricultural College, and was farming full-time by 2002. He farms 1740ha with his father, with both owning their own land and running separate businesses at Pyramid Hill, Victoria.

The farm was de-stocked in 2008 and they now follow a crop rotation of two or three barley crops with a canola break, on both irrigated and dryland areas. They have also trialled irrigated faba beans and dryland field peas.

Motivations for adopting CTF

Chris believed that CTF was the right thing to do for the farm but he needed to work hard to convince his father of the potential benefits.

GPS-guidance equipment was purchased in 2008 and the transition to CTF occurred in 2010, with most changes implemented in the first year.

A John Deere centre-mounted header front was purchased two years later. GPS-guidance was a $5/ha investment and immediately saved the Leeds $5/ha on inputs.

After two years they could see the difference in the crops on and off the wheeltracks.

Issues encountered in the conversion to CTF

Chris originally used 10.5m centres but after doing a contract sowing job he converted to 10.36m to have true 10.67m (35ft) centres. To do this, he put extensions on the axles. Chris does most of the machinery modifications himself.

On the 24m Commander boomsprayer, the brace underneath the axle required rebuilding after it fell apart. In 2015 the Leeds bought a second-hand boomspray that required modification because the standard axle would not go to 3m.

Chris found that Swan Hill Engineering were able to build an exact replica for $4000 less than the manufacturer's version. Chris put new middle sections of boom in at $2000 each and took some off the ends to make the boom 32m wide. This took two to three weeks to complete, but it was done correctly and now works very well.

Changes to the farming system since converting to CTF

Hay is opportunistic and an effective weed control option, so it is generally always part of the Leeds' system. They use their own equipment and make 21.3m (70ft) windrows. They have changed from round bales to square bales to improve storage and logistic options.

Chris also windrows straw and bales it as a valuable additional income source. Making hay within a CTF system is challenging because not all hay machinery will fit the wheeltracks used in grain production. Chris is willing to make the necessary compromises, knowing that hay is still a profitable option. The more farmers and contractors there are making hay, the easier it will be to do CTF hay.

Current machinery set up and modifications made to convert to CTF

When converting to CTF Chris was advised to use narrow tyres but he believes wider tyres float better and do less soil damage. Chris uses 620 tyres on the tractor and 540 tyres on the boom. Another tractor (from the cotton industry) has 420 tyres on the front and 480 tyres on the back, a combination that has done a lot of damage to wheeltracks in the three years he has used the tractor.

When the clay soils get wet, the wheeltracks stay firm but the area just off the tracks is wetter, which can make it difficult to keep machinery on track, especially when spraying and spreading.

Chris has tried a blower chaff cart but has stopped using it because it takes six hours to put it on or take it off the harvester. He plans to try a conveyer chaff cart when the season is conducive, and he has time to make it.

Changes in fuel and work rates due to CTF

The Leeds have not seen significant differences in fuel usage per hectare. Chris suggests that fuel savings are unlikely to be the greatest benefit from converting to CTF. He does find that they can generally get on the paddocks slightly sooner after a rain event than growers who are not on CTF.

The Leeds' biggest savings came when they shifted from 25 to 38cm (10 to 15in) row spacings at the same time as converting to CTF). Widening the row spacing has resulted in sowing being completed 30 per cent quicker.

Impacts of CTF on soil characteristics

Because their soils are shallow, generally 25 to 55cm rooting depth, Chris does not expect to gain the same benefits of CTF as expected in the Wimmera (Victoria) or Liverpool Plains (NSW).

He has seen better infiltration rates as a result of CTF, stubble retention and de-stocking, which has been the greatest benefit to his farming system. There are some very salty areas on the Leeds' farms and being able to retain cover on these areas, get a crop established and keep the soil capillaries open, is critical.

Impact of CTF on crop yield

Chris has found that CTF does not always come out as the winner in yield. For example, one year a paddock was levelled (smudged) then sown to canola, yielding 2.5t/ha. In a similar paddock, following CTF practices the canola yielded 1.3t/ha. The other factors that influenced this result were that the smudged paddock had more mineralised nitrogen, warmer soil and no habitat for mice or insects. Chris finds that warmer soil temperatures are the key to higher yields, particularly in irrigated paddocks.

Chris is starting to collect some good data from trial plots within paddocks but he wants to improve on the set-up. He would like to do some trials with variable rate nutrient applications but the cost of approximately $30,000 plus $20,000 for a liquid kit is prohibitive at the moment. His priority is getting the crops in the ground on time and established as well as possible.

Learnings from the transition to CTF

A lot of people advise beginning the conversion to CTF with the header, but Chris believes that the greatest benefit comes from aligning the sprayer and spreader first, as they are the machines that drive over wet country the most. He thinks that having a CTF cart is essential, but it is not as critical for the bar to be CTF-aligned, unless you have a good opener to work a greater depth of soil (e.g. Boss parallelogram).

Chris recommends that growers first look for productivity gains through no-till farming and effective weed control and then consider CTF if they need to improve water infiltration into their soils. Chris also emphasises that CTF will not overcome losses that result from poor timeliness. He suggests that there are times when CTF may need to be compromised when there is pressure to get a job done in time.

Chris has found it difficult to convince and educate other people about CTF. For example, truck drivers often come in and drive all over the paddocks even though crossing the wheeltracks rattles their trucks.

Tractor front wheel.

Tractor rear wheel.

Chris uses CTF as a tool in his farming operation.

If a situation arises where a paddock needs to be managed in a way that is not compatible with CTF, he is willing to make compromises to get the job done.

Grower: Linc Lehmann

Location: Birchip/Kinnabulla, Victoria

Soil types: Mostly heavy clay to red loam to clay loam with 5 to 10% sand

Average annual rainfall: 350mm

Growing season rainfall: 220mm

Linc Lehmann

Linc Lehmann farms 2400ha at Birchip with his father on a flexible rotation of wheat, lentils, barley, canola and brown manure. They have not kept livestock for 10 years, but do agist sheep to graze stubbles over summer. They find that livestock do have a fit within CTF systems if they are managed well and infrastructure is up to standard.

Motivations for adopting CTF

Linc introduced no-till practices in 2007 but was dissatisfied with the effect of random boomspray wheeltracks on seed placement, germination and knocking over standing stubble (due to the tynes bouncing over wheeltracks). Consequently, he introduced CTF in 2010 on 3m wheel spacings to establish a more suitable way of cropping with bare wheeltracks to keep crop trampling to a minimum.

Issues encountered in the conversion to CTF

The transition was mostly seamless as it worked in with planned machinery change-overs. Paddocks did not need altering specifically for CTF, and although old channels were filled in, this would have happened regardless of converting to CTF.

Changes to the farming system since converting to CTF

One of the main benefits of CTF to the farming system is having more traction when it is wet, allowing access to paddocks a little earlier than previously. This is a fine balance though because going on too early can do a lot of damage to permanent wheeltracks.

There is a lot less dust from the wheeltracks, which is excellent for summer spraying in terms of herbicide efficacy, particularly near wheeltracks. A spray contractor working on Linc's farm commented that there was considerably more dust when he turned at the end of the paddock compared to spraying along the tracks.

Linc is also able to easily do his own on-farm trials as all wheeltracks are lined up. He is also planning to begin chaff tramlining.

Current machinery set up and modifications made to convert to CTF

Linc has kept costs to a minimum by buying CTF equipment when machinery is due for turnover or upgrade, and not looking for the biggest or flashiest machinery. Linc started with an autosteer upgrade and modifications to the tractor and boomspray wheel axles (spending $2500 on wheel spacers for tractors and $3000 on a boomspray axle).

In the process of these modifications, Linc took nozzles off a 28.7m (94ft) sprayer, shifted tyres and took wing extensions off the 10.7m (35ft) seeder, and shifted tynes around to suit the CTF system.

The transition occurred over several years, beginning with a 9.1m (30ft) seeder and header and a 27.4m (90ft) sprayer. After two years the family agreed that a 12.2m (40ft) header front and seeder width would be better as they were buying more land. Linc switched the airseeder to 12.2m (40ft) and the sprayer to 36.6m (120ft) and stuck with the 9.1m (30ft) header until it was time to upgrade. He believes that upgrading over five years is not unrealistic, and that growers should take as long as they need to get their gear lined up.

The 12.2m (40ft) system is working well but when it comes time to replace the header, Linc plans to buy one with a longer arm and auger so the chaser bin does not have one wheel running off the permanent wheeltracks. He is also considering widening the 48 to 51cm (19–20in) wheeltracks to further reduce damage to the neighbouring crop rows.

The seeder previously had evenly spaced rows at 38cm (15in) but Linc modified it so that there is a 33cm (13in) space either side of the wheeltracks, and the permanent tracks themselves are bare.

He is also considering purchasing a 48.8m (160ft) boomspray when the time comes.

A brome grass issue prompted Linc to build an inter-row 12.2m (40ft) shielded sprayer for late season weed management, and it works very well. Starting with a small prototype that was towed behind a motorbike, the results exceeded Linc's expectations, causing much less crop damage than expected. The shielded sprayer has cost $10,000 to build whereas a similar commercial machine that uses cameras for guidance costs in excess of $100,000.

Changes in fuel and work rates due to CTF

Linc has not measured changes in fuel usage but he notices that the seeder is much easier to pull through the soil.

Impacts of CTF on soil characteristics

It is hard to separate changes in soil as a result of implementing no-till in 2007 and CTF in 2010, but water is not running off the paddocks into crab holes like it used to.

Wheeltrack erosion is not a big problem, but Linc has built a wheeltrack renovator and plans to start renovating some tracks in summer to remove any dips. He plans to do a couple of paddocks each year.

Impact of CTF on crop yield

The combined effect of no-till and CTF has generated an increase in lentil yields as the lentils stand up and trellis better on crop stubbles. Lentils are now grown on paddocks where they never would have been considered five to 10 years ago. Soil moisture probes confirm that crops are now accessing water from deeper in the profile. It is difficult to determine a percentage increase in yield as varieties are also improving significantly and many things, including CTF, have helped to improve crop yields.

Learnings from the transition to CTF

The greatest benefits include all machinery lining up, resulting in less crop trampling, more standing stubble, the ability to own and use smaller tractors that are more versatile as machinery is easier to pull and there is no need for dual wheels. There have not been any major drawbacks as far as Linc in concerned, just some learning opportunities.

In hindsight, it would have been better for Linc to have started on 12.2m (40ft) width instead of 9.1m (30ft). He suggests doing the necessary research, and not trying to rewrite the CTF 'rule book', but sticking to known and common widths, as it makes machinery decisions easier.

Soil moisture probes confirm that crops are accessing moisture from deeper in the profile.

Grower: Paul Adam
Location: Tottenham, NSW
Soil types: Red-brown earth
Average annual rainfall: 425mm
Growing season rainfall: 200mm

Paul Adam

Paul Adam farms at Tottenham, NSW, where approximately 90 per cent of his farming system centres on growing wheat, canola and a grain legume break crop. Paul also runs livestock on his lease country.

Motivations for adopting CTF

Paul commenced CTF in 2009 with total conversion of all cropping land occurring in that year.

The conversion to CTF allowed for consolidation of machinery assets with four items of machinery that were either due for replacement or surplus to requirements being sold and replaced by two new machines. This reduced depreciation and maintenance costs.

Analysis of past research and experiences of other farmers also indicated that CTF would be a good fit for the soil type, climate and cropping systems being run at that time.

Issues encountered in the conversion to CTF

Some trees had to be cleared but these were generally old and were suffering from die-back.

Prior to converting to CTF, there were areas of gilgai country that had not been farmed. These areas were levelled and have been part of the cropping program since 2009.

Initially there were patches of soft ground where the gilgais were filled and in the very wet 2016 season tracking was an issue in the gilgai country.

Changes to the farming system since converting to CTF

Prior to implementing CTF, Paul's cropping program included only wheat and barley in rotation with a lucerne phase of varying intervals, incorporated to provide a disease break and to build soil nitrogen.

Since adopting CTF, Paul has removed barley and lucerne from the cropping rotation and incorporated canola and grain legumes. Paul feels that this rotation is a better fit in his soils and climate, and gives improved options for weed and disease control.

The mix of crops also gives a better economic risk profile than the previous system.

Current machinery set up and modifications made to convert to CTF

The seeder is 12m wide. When it was converted for use in the CTF system, four discs were removed. The tractor required wheel spacing conversion at a cost of around $3000 and Paul operates on 3m centres.

The spreader is 36m wide, as is the self-propelled sprayer that was purchased when the decision to convert to CTF was made. The SP sprayer is also used for the application of nitrogen fertiliser (UAN).

A new 12m header front was purchased when converting to CTF. The cost of the sprayer and header conversion was covered by the sale of surplus machinery when converting to CTF. All machinery operates on a 2cm GPS autosteer.

Changes in fuel and work rates due to CTF

Paul estimates the conversion to CTF has resulted in a 30 per cent reduction in fuel costs, which he attributes to the tracks being harder, providing better traction.

He has been able to increase the speed at sowing from 10 to 14km/hr, but estimates actual sowing time has not changed significantly as the bin size has remained the same and therefore fill-up time has increased slightly.

He hasn't seen any change in work rate at harvest. The wheeltracks have significantly improved access in wet conditions, which has enabled better timeliness with cropping operations.

Impacts of CTF on soil characteristics

There has been a considerable improvement in water infiltration and moisture storage in recent years, though Paul does not attribute this to CTF alone. He believes that the combination of better summer weed fallow management has also contributed significantly to improved moisture storage.

The use of a self-propelled sprayer, combined with the ease of CTF operations, has improved timeliness of weed control practices, which has contributed to better infiltration and soil moisture storage.

Paul has not reported any issue with erosion along wheeltracks. The wheeltracks are left un-sown, and are about 480mm wide. He believes the good ground cover between the tracks and the reduction in run-off achieved through better infiltration has resulted in less erosion along tracks.

Overall, Paul believes more time is needed to evaluate the effect CTF alone has had on soil characteristics on his farm.

Learnings from the transition to CTF

Paul believes the ease of management in CTF, combined with the self-propelled sprayer has significantly improved their weed management. This particularly relates to timeliness of weed control, with weeds controlled earlier in the growing season for both winter and summer growing weeds.

Herbicide use has increased by about 30 per cent since adoption of zero-till and CTF. Paul said the main reason for the increase in use of herbicides is due to increased ability to control weeds in a timely manner with the self-propelled sprayer on permanent wheeltracks.

Grower: Matt Burkitt, Northparkes Mine

Location: Parkes, NSW

Soil types: Red-brown earth and grey clays

Average annual rainfall: 525mm

Growing season rainfall: 230mm


Matt Burkitt

Northparkes Mine operates a 2500ha cropping property near Parkes, NSW, growing equal areas of canola, wheat, barley and pulses. Matt Burkitt is the farm manager.

Motivations for adopting CTF

CTF commenced in 2001 and the transition, in conjunction with adoption of minimal tillage and stubble retention, was completed by 2003.

The decision to convert to CTF was made on the basis of research showing increased production, improved efficiency and less input waste. Matt says that the increases in water infiltration and water storage in the soil profile have had a large impact on soil health and property's capacity to grow crops.

Issues encountered in the conversion to CTF

It was necessary to remove some trees to accommodate the CTF layout, and the mine is compensating for this through an extensive tree re-planting program. Over time, all internal fences have been removed to make management easier. Particular attention has been paid to the management of waterways.

Changes to the farming system since converting to CTF

A major advantage of CTF combined with minimum tillage and stubble retention has been an overall improvement in soil conditions, which has greatly increased the ability to grow good crops across the Northparkes properties.

Matt uses inter-row sowing with three rows per metre, which enables the retention of very heavy stubbles that would otherwise have been burnt. The ability to access paddocks under wet conditions has been a significant advantage in improving timeliness of operations compared to conventional systems.


Chaff-lining for weed control is compatible with CTF.

Current machinery set up and modifications made to convert to CTF

All cropping operations are undertaken by contractors. The CTF system is based on 3m wide wheeltracks and the autosteer accuracy is 2cm.

The seeder is 12m wide, the sprayer is 36m wide and granulated fertiliser products are spread on 36m widths while some compost and manure alternatives are spread on 12m widths.

Changes in fuel and work rates due to CTF

Matt describes a major advantage of CTF as being the ability to access paddocks and carry out operations in a timely manner. This is particularly useful in winter where the permanent wheeltracks allow spraying and other operations to be undertaken without damaging the paddocks.

Impacts of CTF on soil characteristics

Stubble retention and minimal tillage in combination with CTF has led to better water infiltration, reduced run-off and reduced erosion across the majority of the paddocks.

Sinking on wheeltracks at harvest has been an issue in some years such as 2016, a very wet year, where there were significant issues with sinking and slippage along wheeltracks. Matt is unsure how this problem will be rectified in the long-term, but it is a considerable issue.

Matt estimates that crop yields are 20 to 30 per cent higher under the CTF, minimum tillage, stubble retention system at Northparkes Mine, compared to the district average for conventional farming.

Grower: David Greig
Location: Tottenham, NSW
Soil types: Red, clay loam
Average annual rainfall: 450mm
Growing season rainfall: 250mm


David Greig

David Greig's enterprise at Tottenham, NSW, consists of 40 per cent winter cropping and 60 per cent sheep. Wheat and canola are grown as cash crops and oats and lupins are grown for grazing and fodder.

Motivations for adopting CTF

The Greigs commenced CTF in 2008, having used minimum till practices since 2001. The decision was made after coming out of two particularly dry years, and David had noticed at several field days that CTF crops with good fallows were performing better than traditionally-farmed crops.

As they were looking to expand their farmed area they decided to try CTF as a means of gaining better efficiency. Since their airseeder was already CTF-compatible the only purchase necessary to get started was a new tractor.

Issues encountered in the conversion to CTF

There were no glaring issues to converting to CTF, though David was conscious of not spending too much on machinery, choosing suitable second-hand machinery where available. He found that the biggest obstacle was 'in his head' and the challenge of changing his mindset.

Although starting CTF was easier than he thought, an early hurdle David encountered was teaching staff and contractors to stay on the wheeltracks. He finds that other people often do not understand what he is trying to achieve. An example being a windrowing contractor with less accurate GPS, who often strays off the wheeltracks unless constantly monitored.

Changes to the farming system since converting to CTF

David recently changed from a tyne to disc seeder to allow better stubble handling. The change came after heavy stubble loads in 2011 created trash clearance problems with his tyned seeder, forcing him to burn large areas of stubble.

It was very noticeable in following crops how uneven the yields had become due to additional water run-off. This effect was observed for some years after burning and reinforced David's experience of retained stubble reducing run-off and providing better water infiltration.

David's cropping rotations are fairly fluid, depending on gross margins for any enterprise. Before converting to CTF his rotations generally were wheat/wheat/chickpeas or lupins but he no longer grows wheat-on-wheat and has added canola to the rotation. A typical rotation is now wheat/canola/wheat / lupins. He has found lupins as a break crop produces the best wheat crop the following year.

Current machinery set up and modifications made to convert to CTF

David's machinery operates on 3m centres. His seeder is 12m wide while the spray rig (a re-purposed cotton picker) is 36m wide and his two headers have 12m fronts. His GPS is accurate to 2cm.

Changes in fuel and work rates due to CTF

The biggest change for David was changing from a tyned to disc airseeder, this alone halved his fuel usage during sowing. He believes CTF is also providing further savings in fuel with firm tracks reducing the rolling resistance of the tractor. David finds that if his spray rig drops off the wheeltracks the speed will reduce by 1 km/hr.

David is now able to drive onto paddocks to spray much sooner after rain than he could previously, without damaging the wheeltracks. During harvest, headers are much less likely to get bogged in wet conditions, however issues still remain when turning in the headlands, once the header is off the permanent wheeltracks.

Impacts of CTF on soil characteristics

David is finding that his soils have become much softer, to the degree that what he once described as 'hard-setting red soils' are no longer hard-setting at all. Another example is a recently-purchased paddock that was quite gravelly and very hard, that is developing cracks like self-mulching soil and is now very friable.

Water infiltration has been much improved, resulting in much more even crops. David is aware that the wheeltracks will need renovating periodically, probably every 10 years. David will use the opportunity to level paddocks that need it, apply lime if necessary and implement control strategies on problem weeds such as windmill grass. In paddocks that are in otherwise good condition David will consider using wheeltrack renovators.

Interestingly David has noticed that wheeltracks in paddocks that were no-till farmed before CTF are in better condition than wheeltracks in newer paddocks. He is unsure whether the wheeltracks in new paddocks have sunk or if the soil has fluffed up between them.

Impact of CTF on crop yield

Although some above average seasons have seen a general increase in yield across the district, David has noticed much more consistency across all soil types and crop types since switching to CTF. He is now much more confident in predicting crop yields based on available stored moisture and also more confident with new crop varieties.

One example is a paddock that slopes upwards to a hill where, in the past, the hill area would consistently yield 1t/ha less than the lower section of the paddock. Since switching to CTF nine years ago in that particular paddock the yield difference is now only 0.2 to 0.3t/ha.

A contract sprayer who also worked on a neighbour's property commented on how little dust was raised on David's CTF paddock compared to spraying in conventional paddocks. Less dust means better weed control in the wheeltracks than was possible before CTF was implemented. Timeliness of spraying is also improved as David can get onto paddocks much sooner after rain.

Fleabane has become an increasing issue but David feels this is more related to no-till practices than CTF.

Learnings from the transition to CTF

David has found that the biggest hurdle to overcome is to change your mindset. He advises other growers to decide on the width to work at and target machinery based on that when upgrading equipment.

Do not try to do it all in one year. It is better to focus on getting the basics right and allow four or five years to make the transition. The soils start to respond quite quickly and that provides the confidence required to progress further with each new crop.

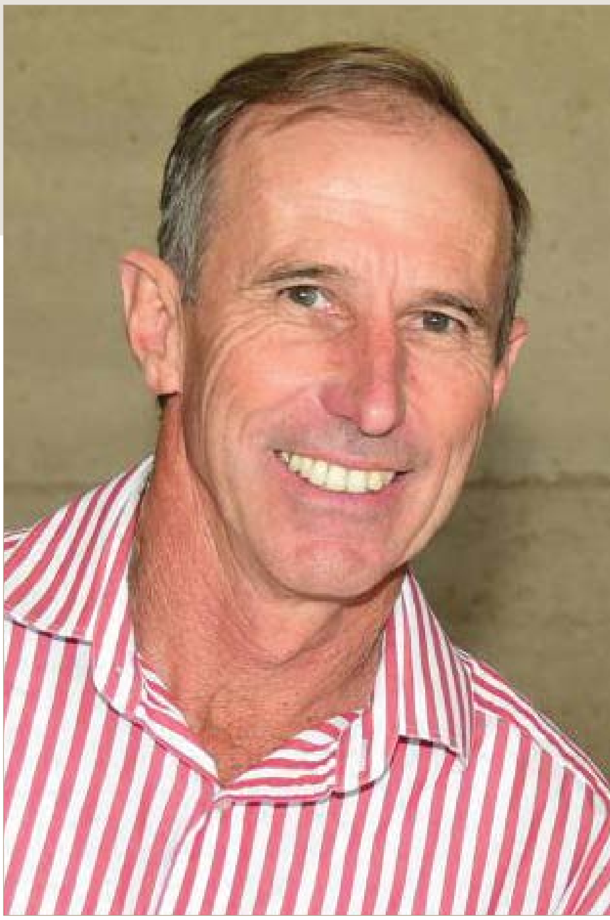
Grower: Hayden Wass

Location: Nyngan, NSW

Soil types: Red sandy loam (80%), Gilgai country (20%)

Average annual rainfall: 450mm

Growing season rainfall: 170mm



Hayden Wass

Hayden Wass runs a 100 per cent cropping business at Nyngan, NSW. The total cropped area is 4500ha and usually consists of equal areas of wheat, canola and either chickpea or lupins.

Motivations for adopting CTF

Hayden commenced CTF in 2001, with the whole cropping area converted to CTF by 2003. Soils across the farm were run-down and larger tractors were required to drag implements through the soil.

At the same time as adopting CTF, Hayden also moved fully to no-till and full stubble retention. The decision to convert to CTF and no-till was made to ameliorate soil issues, reduce costs (particularly in the size of tractors required and fuel used for cultivation), enable greater precision (less overlap and gaps) and because high precision GPS units were becoming more affordable.

Issues encountered in the conversion to CTF

Implementing CTF involved gaining approval to remove isolated trees. At the time, the total cropping area was much larger (in a family partnership) and an application to allow tree removal in this situation was the first of its kind to be approved.

Changes to the farming system since converting to CTF

Hayden adopted CTF, no-till and stubble retention simultaneously, so changes in the farming system have been a combined effect of all of these factors. Improved water infiltration and moisture retention have been significant benefits of the overall change in farming practice.

Hayden grows canola following a 12-month fallow and as a result moisture conditions at sowing are generally very good. Retaining stubble has increased frost risk.

However, prudent variety selection for sowing dates has assisted in alleviating this problem and the benefits of increased moisture retention outweigh the increase in frost risk.

Current machinery set up and modifications made to convert to CTF

A major part of the change to CTF was the reduction in size of tractors required, enabling Hayden to sell 300 and 400 horsepower tractors and replace them with 250 horsepower tractors. This meant there was very little actual cost in terms of machinery for the change to CTF. All wheeltracks are on 3m spacings, the seeder is 12m wide and the sprayer and spreader work a 36m widths. The autosteer GPS has 2cm accuracy.

Changes in fuel and work rates due to CTF

There has definitely been a reduction in fuel costs associated with change to CTF, although the actual reduction has not been calculated. Certainly the reduced tractor size and the switch to no-till has meant less fuel is required for sowing operations and the compacted wheeltracks reduce the rolling resistance for all operations, resulting in less fuel usage.

Impacts of CTF on soil characteristics

There has been a considerable reduction in water run-off and an increase in infiltration since Hayden adopted CTF, no-till and stubble retention.

Gypsum has also been applied on heavy country to improve soil structure, with deep ripping on 660mm spacings between the wheeltracks undertaken 15 years ago, which has greatly improved soil health and productivity. Hayden's country is relatively flat and there have been no issues with erosion along wheeltracks, even under very wet conditions in 2016.

Impact of CTF on crop yield

Hayden believes that the combined benefit of CTF, no-till and stubble retention are most apparent in drier-than-average years where the benefit of increased moisture retention is more fully expressed compared to a conventional farming system. In wet years, he feels there is probably little difference in yield between the two systems.

One major advantage of CTF is the ability to be timely in cropping practices. Under conventional farming systems, rainfall events of less than 5mm are enough to prevent sowing due to the ground becoming non-trafficable. With CTF, sowing can continue under these conditions.

Similarly, spraying can occur under conditions where soil moisture conditions may prevent access to paddocks. This means weeds can be targeted at their ideal growth stage rather than waiting for soil conditions to allow access to the paddock. There is also less likelihood of harvest needing to be stopped due to paddocks being non-trafficable in wet weather.

Hayden has seen a change in the weed spectrum since converting to no-till, with windmill grass and fleabane now more common. He has not had any problem with weeds in the wheeltracks, which he attributes to the zero soil throw of the disc seeder. With very little soil throw onto the wheeltracks there are very few 'micro seedbeds' to allow weeds to germinate in the wheeltracks.

Learnings from the transition to CTF

If Hayden was converting to CTF now he would consider establishing 4m wheeltracks to accommodate the larger machinery now available. He would also look at a 15m planter and 45m sprayers. He is concerned by the increase in proprietary GPS systems with in-built firewalls, which he thinks will raise issues for growers when changing machinery plant brands.

CTF, no-till and stubble retention have combined to improve crop reliability, particularly in dry seasons.

Grower: Trevor Cliff

Location: Kimba, SA

Soil types: Deep white sand to heavy clay – with everything in between (sand has been clay spread)

Average annual rainfall: 340mm

Growing season rainfall: 249mm

Trevor Cliff

Trevor Cliff grows wheat, barley, lupins, peas and occasionally canola at Kimba, SA.

Motivations for adopting CTF

Trevor has been looking at CTF for around 18 years and has seen the negative impacts of compaction on their soils. He has invested in ripping and spading, and knows that implementing CTF would help him gain the full benefits of this investment.

Issues anticipated for the conversion to CTF

Trevor is concerned about the cost of changing over to CTF as he will need to change header and buy a more sophisticated GPS system. Wind erosion on wheeltracks in sandy soils is an issue so he sows these tracks to reduce the impact of erosion. Trevor has seen the benefit of using a chaff deck to help protect wheeltracks from wind erosion.

Expected changes to the farming system since converting to CTF

Trevor does not envisage any vast changes to his farming system if he were to adopt CTF as he generally follows the same wheeltracks now. He is concerned about the trend toward bigger and heavier machinery. He is keen to see new technologies such as drones and smaller, lighter, mobile units following set tracks.

Expected machinery modifications required to convert to CTF

Trevor's header is too small for a front that would be suitable for CTF. He would also need to update their present GPS technology to the current industry benchmark of 2cm accuracy to more easily implement half-boom runs.

Expected changes in fuel and work rates due to CTF

Ripping and spading causes fuel costs to go up and reduces work rates.

Expected impacts of CTF on soil characteristics

Trevor does not expect that he would see much change in his soils if he implemented CTF. He has been continuous cropping paddocks for 30 years and the soil remains loose and friable.

Expected impact of CTF on crop yield

Trevor believes that the combination of CTF with ripping and spading, could improve yields dramatically, but is unsure whether the return on investment would pay for the change.

Barriers to adoption of CTF

Trevor is finding out more about the cost of converting to CTF and the likely income return. He is also looking at the returns from ripping and spading. He is concerned about the risks of leaving wheeltracks unsown on their light soils.

Trevor estimates that soil amelioration has probably improved their yields by 0.4t/ha on that soil type. Paddocks that were cropped once every five years can now be cropped three or four years in every five, on what was the worst of their country. The best land can be cropped continuously.

Trevor has seen barley grass become a problem in unsown CTF wheeltracks but he thinks this could be overcome with chaff tramlining.

Grower: Ben Pope

Location: Warramboo, SA

Soil types: Dune swale and some grey calcareous soil

Average annual rainfall: 300mm

Growing season rainfall: 230mm

The Popes are considering adopting CTF in their farming enterprise at Warramboo, SA, which is comprised of barley (45 per cent), wheat (40 per cent) and legumes/peas/lentils (15 per cent).

Motivations for adopting CTF

Compaction on certain soil types is the main reason why the Popes are considering CTF. The current compaction issue is restricting root growth and limiting crop access to moisture and nutrients, leading to yield loss.

Issues anticipated for the conversion to CTF

The Popes anticipate some issues in conversion to CTF, such as matching wheel tracks while keeping the more efficient, wider machinery. They expect that it may take some time to train staff to always use the permanent tracks.

Expected changes to the farming system when converting to CTF

The Popes are not sure that they will ever implement CTF on all of their cropping area, but they will try where it fits, to limit compaction and crop damage.

Expected machinery modifications required to convert to CTF

Most of their current equipment (tractor, sprayer, spreader and chaser bin), except the seeder, is on 3m centres. The working widths do not fit any suitable ratio for CTF.

Expected changes in fuel and work rates due to CTF

The Popes expect to see negligible fuel benefits for their operation. They anticipate that downsizing some equipment to fit a CTF ratio could be less fuel or time efficient. For example, changing from a 45m boom down to 41m to match the ratio that fits with the 13.6m harvester.

Expected impacts of CTF on soil characteristics

The Popes expect CTF to reduce the compaction on the inverted clay over sand hills. They are concerned about the potential for large wheel ruts to develop through the year.

Expected impact of CTF on crop yield

With CTF, the Popes expect that crop yield on their sand over clay soils will stabilise, rather than declining over time like they do with their current non-CTF system.

Barriers to adoption of CTF

The Popes are not convinced that CTF will deliver enough benefit over all their soil types and that efficiency may be reduced. Their farming land is spread over 30km, meaning that implementing RTK will be expensive.

On large farms on the upper Eyre Peninsula, most growers choose wider machinery and there is a perception that wider machinery is incompatible with CTF. There are also difficulties in getting all farm machines to fit the CTF wheeltracks.

If the Popes adopt CTF they expect that it will take about two years to see results on their inverted clay over sand hills. They do not see livestock as an impediment to adopting CTF.

Grower: Robin Schaefer and John Gladigau, Bulla Burra
Location: Loxton, SA
Soil types: Sandy rises, loams, heavy constrained flats and small areas shallow stone
Average annual rainfall: 275mm
Growing season rainfall: 175mm

Robin Schaefer

Bulla Burra is a 6000ha cropping enterprise of wheat, barley, canola, lentils, chickpeas, peas, lupins and vetch, in a no-till, variable rate, continuous cropping system at Loxton SA.

Motivations for adopting CTF

Bulla Burra commenced CTF in 2012, aligning machine wheeltracks and purchasing a tractor with track tyres. The main reason for implementing CTF was to alleviate compaction, particularly on sands, giving crops better access to soil moisture, resulting in increased yields.

Issues encountered in the conversion to CTF

Managing the logistics and efficiencies was difficult as machinery was gradually upgraded to suit CTF. Initially, the cost of accurate guidance was an issue as an RTK base station network was not available. Now, the new John Deere receivers and differential correctors mean Bulla Burra does not need repeaters and there is 3cm accuracy guidance on all properties.

There have been ongoing wind erosion issues on the wheeltracks over the sandy rises. These are repaired by hiring a grader board as soon as wheeltrack erosion begins to appear. If the erosion is not fixed quickly, the problem can escalate into larger blowouts and further problems in following years. Switching run lines for the sprayer may help reduce this problem to some extent.

Changes to the farming system since converting to CTF

Bulla Burra has been growing more pulses such as lentils and chickpeas in recent years. In 2012 the operation was about 80 per cent cereals, but this has reduced to about 55–65 per cent, depending on the seasonal risks, opportunities and commodity prices.

Deep ripping at Bulla Burra used to create issues with machinery sinking into the very soft sand. Now that the permanent CTF wheeltracks are not ripped, trafficability is greatly improved in the deep ripped areas.

CTF has improved the consistency of inter-row sowing at Bulla Burra. Paddocks are sown west or north on even run lines and east or south on odd run lines. This means the seeder can be nudged and more easily follow through the previous stubble lines, compensating for the slight machine row variances and the tendency to crab on hillsides. Since the tynes on a seeder are never symmetrical, if you sow in the opposite direction between years the rows will never line up properly. Similarly, they now roll and reap the pulse paddocks in the same direction as sowing, which makes harvesting far easier.

Extension adaption for 3m wide tracked tractor.

Current machinery set up and modifications made to convert to CTF

Bulla Burra uses a 1:2:3 CTF ratio, with 12.2m wide seeders, harvesters and roller, 24.4m wide sprayer and spreaders either 24.4m or 36.6m wide. All equipment is set on 3m wheeltracks. Robin estimates that the machinery footprint sits at about 12 per cent for most operations. The seeder bar tyres are slightly wider than the other machines, but there is less weight in the seeder. The headers require dual wheels, which takes the footprint out to about 24 per cent, but this extra trafficking is generally done when the soil is dry and less susceptible to compaction.

Changes in fuel and work rates due to CTF

Changes in fuel use and work rates have not really been measured, but Robin believes that CTF has helped increase the efficiencies within their machinery and workforce operations. Their soil types are generally not hard to get back onto after rainfall so there has been no noticeable change in timeliness of operations since implementing CTF.

Seeder bar wheels are slightly wider than on other machinery.

Impacts of CTF on soil characteristics

Robin notices a big difference in the friability of the soil. This is particularly noticeable in paddocks where run lines have been turned by 90 degrees and there is poorer crop growth along the previous compacted tramlines. In seasons with a dry finish, the plants growing on wheeltracks die off very quickly, which is a good indication that minimising machinery compaction on the rest of the paddock is beneficial.

Impact of CTF on crop yield

CTF is one part of a whole system working together to benefit crop root growth, improve crop access to water and nutrition and, ultimately, improve yields.

Learnings from the transition to CTF

Have your goal firmly in mind when you replace machinery so that the change fits with your CTF system. It may take 10 years, but you will get there.

When Bulla Burra purchased its first WEEDit boomspray for summer weed control, the width did not exactly fit the CTF system. It was later replaced with a 36.6m WEEDit boom on 3m wheel spacings.

Chaser bin on 3m wheeltracks.

SP boomspray on 3m wheeltracks.

WEEDIT OPTICAL SENSOR BOOMSPRAY

The WEEDit uses near-infrared sensors to identify the chlorophyll in living plants in a paddock and trigger spray nozzles to apply herbicide directly to these living plants only.

Bulla Burra has many hard-to-kill summer weeds and cannot afford to have any suggestion of spray drift emanating from their properties onto adjacent horticultural and urbanised areas. Using the WEEDit sensor means these weeds can be spot-sprayed with higher chemical and water rates for more effective control at a fraction of the cost, and minimal risk of spray drift. This replaces blanket sprays of very expensive chemistry with low volatility to try and control these weeds.

For most summer sprays the WEEDit is using less than 10 per cent of the chemical that would have been used in a blanket spray, with the added bonus of not having to refill tanks as often. It is less effective on grass weeds than on broadleaf weeds, and is best used in low weed density situations of less than 30 per cent weed coverage.

For the scale of the Bulla Burra spraying program, the WEEDit has proved to be a very cost-effective and practical weed management tool.

WEEDit boomspray – note near-by vneyards.

Grower: Mark Kentish, Gala-Manor

Location: Piangil, Victoria

Soil types: Deep sands, sandy loams, limey heavy flats, sheet limestone

Average annual rainfall: 330mm

Growing season rainfall: 200mm

Mark Kentish

Mark Kentish farms 4900ha at Piangil, Victoria, growing wheat and barley (60 per cent), canola (about 15 per cent) and the remaining 25 per cent is made up of chickpeas, lentils, faba beans, lupins and brown manure. He sows all crops with a no-till NDF single disc seeder on 38cm (15in) rows.

Motivations for adopting CTF

After talking with other farmers who were into CTF, particularly those from the Wimmera, Mark purchased his disc seeder and started CTF in 2016. Even though some of the issues on Wimmera self-cracking clays were different to his soils, Mark had seen compaction issues across his farm, particularly heavy machinery tracks persisting after paddocks were trafficked in wet soil conditions. He could see that there was potential to reduce compaction by reducing his machinery footprint from over 40 per cent, to less than 20 per cent, of the cropped area.

Issues encountered in the conversion to CTF

While the transition to CTF is not yet complete, Mark believes one of the biggest difficulties is to 'get your head around it' and change your farming mindset. For example, it was hard for him to consider going back to a 12.2m (40ft) seeder, down from a 16.5m (54ft), but this was compensated for by increasing seeding speed on cereals from 11 to 13km/hr when converting to a disc machine.

Sandhill erosion remains one of Mark's biggest challenges in CTF, due to the deep wheeltracks, and blowouts along the wheeltracks. Mark hopes to use a chaff deck to provide extra cover to avoid this erosion, but at present needs to manually renovate the damaged wheeltracks.

Changes to the farming system since converting to CTF

When Mark started CTF he also made a change to a disc seeder and a stripper front header. Using a disc seeder meant that he can no longer use trifluralin, as the disc seeder does not throw soil (and chemical) out of the row. To compensate, Mark is using chaff-lining and rotations (up to 3-years of grass control when necessary, with brown manure/canola/Clearfield cereal) to keep grass weeds under control.

Current machinery set up and modifications made to convert to CTF

Mark has established a CTF system using a 12.2m (40ft) seeder and headers, a 24.4m (80ft) spreader and 36.6m (120ft) boomspray. The spreader and chaser bin tractor are still on dual wheels to cope with his farm's sandhills when fully loaded, but Mark intends to move to track tyres in his next tractor upgrade.

In the meantime, he reduces the tyre pressure on the outside tyres to ensure the main compression and traction remains on the tyres running on the permanent wheeltracks.

Mark is looking to change from chaff-lining to a chaff deck, which places the chaff on each wheeltrack, to reduce the erosion on wheeltracks on the sandy paddocks, while concentrating any grass weed seeds passing through the header into these narrow, mulched rows.

He is planning to set up to apply post-emergent herbicides with larger nozzle size and shields, or possibly use a more expensive pre-emergent herbicide specifically along these chaff lines.

Mark's 38cm (15in) row spacings is matched by 38cm nozzle spacings on his boomspray. He is considering reducing row spacing to 25cm (10in) in the future to increase plant coverage and weed competition, particularly if chemical options become fewer.

Changes in fuel and work rates due to CTF

Mark estimates the change to CTF has achieved about a 15 per cent increase in fuel efficiency. In his self-propelled sprayer this equates to covering an additional 100ha per tank of fuel.

Impacts of CTF on soil characteristics

Mark finds it hard to identify clear soil benefits without any side-by-side comparisons of CTF and non-CTF paddocks. The combined effect of the disc seeeder and CTF is achieving good, even germination right across all soil types. Mark is also noticing that there is less root disease, and that crops appear to be extracting more moisture from the soil.

Impact of CTF on crop yield

While Mark believes that his farming system has improved, he has not quantified any increase in yields over the last three seasons.

Learnings from the transition to CTF

Mark did a considerable amount of 'homework' before making any changes to his farming system and believes this has helped him to make the right decisions. This included being willing to sacrifice some machinery width to achieve gains in other areas.

There is much to be gained by overcoming the old mindset of how things used to be done when embracing the challenges of new technologies.

120ft (36.6m) SP sprayer.

Tracked tractor and aligned 40ft (12.2m) NDF disc seeder.

USING A STRIPPER FRONT HEADER

Soil cover and residue management is a key driver of Mark's farming system. The stripper front header leaves more standing straw in the paddock, increasing cover levels while making it easier for the disc seeder to pass through, with less hair-pinning of flattened straw.

The stripper front has led to improved harvesting efficiency, particularly in barley, and with larger crops. In the wet harvest of 2016 with high levels of lodging, the stripper front was able to reap at 50t/hr compared to the conventional header at 25t/hr.

The stripper front works well within Mark's CTF system, allowing him to better achieve his goals of soil improvements through residue management and reducing compaction.

Shelbourne Reynolds stripper front comb.

Grower: Jock McNeil, SMIMAC Farming

Location: Paruna, SA

Soil types: Deep sands, loam, clay flats, stone

Average annual rainfall: 280mm

Growing season rainfall: 190mm

Jock McNeil

The McNeils have a 16,000ha mixed farming operation at Paruna, SA, growing 30 per cent barley, 20 per cent wheat, 10 per cent cereal rye, 30 per cent pulses (chickpeas, lentils, lupins, peas) or canola, and 10 per cent vetch for grazing. The entire farm is operating under a no-till system and generally on a cereal/cereal/break crop rotation.

Motivations for adopting CTF

In 2017 they began CTF, setting up permanent wheeltracks at harvest and placing chaff lines. All operations since the 2017 harvest have used these wheeltracks. Jock was concerned about soil compaction preventing the crops' access to valuable soil water in such a low rainfall environment.

After monitoring root growth in soil pits, and trialling deep ripping, it was evident there were compacted soil layers at depth. After commencing a deep ripping program, it was a natural progression to move to CTF to preserve the benefits for as long as possible. Jock could also see the benefits of chaff-lining to help control grass weeds.

Issues encountered in the conversion to CTF

While it is still early days, it has taken a few years of machinery replacement to get everything lined up. Wheel ruts are becoming deeper with wind erosion from the many passes on the spraying wheeltracks being a major issues in the deep sandy soil types. Rotation of the wheeltracks used for spraying will reduce this issue.

There were some adjustments required to make up for the discrepancies between John Deere and Trimble guidance lines, where the same coordinates do not line up. Jock has had to offset some coordinates to make consistent lines on the ground.

Changes to the farming system since converting to CTF

Random trafficking is now avoided in all field operations, with chaser bin U-turns being the only exception. Trying to stick to a simple CTF system, Jock has removed many fences across the numerous properties, which makes it easier for everyone to operate on about three AB lines, consistently running either north/south or east/west.

Extra spray nozzles on SP sprayer target weeds on wheeltracks.

Current machinery set up and modifications made to convert to CTF

The McNeils use a 1:2:3:4 ratio for their CTF on 3m wheeltracks, including 12m headers and deep ripper, a 24m wide seeder, a 36m WEEDit optical sprayer for targeting summer weeds and a 48m SP sprayer. One header is on tracks, while the others are on dual tyres and the plan is to eventually have all the headers on tracks.

They modified their Seedhawk seeder to metric row spacing and their SP sprayer was extended from 46.5m to 48m. Machine working widths were the highest priority to start off the CTF system. They still have dual tyres on the air-cart and headers, which makes their machinery footprint an estimated 22 per cent of the paddock. With little investment made on axle centres to date the plan is to reduce this footprint either through modification or machine replacement as time goes on.

Jock aims to put splitter boots on his 375mm row spaced tynes to bring the gaps back to 300mm. He is also looking to fit chaff decks to his headers to place chaff onto wheeltracks to help reduce the erosion on sands.

Changes in fuel and work rates due to CTF

It is too early to assess any specific changes in fuel use or work rates. The hard wheeltracks are much easier to use than travelling over rip lines, as occurred with more random trafficking of the paddocks.

Impacts of CTF on soil characteristics

The CTF program has only just commenced in full in 2018, so it is too early to assess soil impacts.

A large proportion of the McNeils' farm is made up of sandy soils that have proved to be very responsive to deep ripping, with 30 to 40 per cent yield improvement and sometimes up to 100 per cent. They have already ripped about 5000ha, and are still working out how far the benefits may continue down the slopes and into the loamy ground. The economic benefits could be very significant, particularly if re-compaction can be minimised over time, ideally through the implementation of CTF practices.

Impact of CTF on crop yield

It is too early to know whether the CTF has improved crop yields on the McNeils' farms.

Learnings from the transition to CTF

Jock strongly recommends doing thorough research well ahead of implementing any CTF practices and making machinery purchases or modifications. Looking back, he is happy with the progress they have made so far through effective planning and he will continue making improvements to the system.

Extended header auger.


Front tracks on header.

Adjusted rear wheels on header.

DEEP RIPPING SANDS

Jock has a 12m wide Agrowplow ripper with 52cm tyne spacings. The front tynes have 45cm shanks, in line with the deeper working rear shanks at 60cm. Currently they rip to about 40cm depth with a breakout pressure of 4000lb.

A roller trails the ripper to help flatten the ridges and fill the gullies to improve flotation of the seeder bar and allow even seed placement depth at sowing. They are experimenting with inclusion plates to help move more organic matter down the soil profile.

Evidence from Western Australia suggest that CTF can improve the longevity of deep ripping impacts from about 3 to 10 years, or more. CTF is therefore an absolutely vital element to ensure the McNeils' farming enterprise remains both profitable and sustainable in this very challenging environment.


Deep ripper with light roller to smooth surface for seeding.

Grower: Alistair Murdoch, Carinya Ag Enterprises
Location: Kooloonong, Victoria
Soil types: Deep sands, sandy loams, heavy clay flats in mainly a dune/swale landscape
Average annual rainfall: 330mm
Growing season rainfall: 200mm

Alistair Murdoch

Alistair Murdoch farms 6000ha at Kooloonong, with a rotation of wheat and barley (60 per cent), pulses (25 per cent, with up to 5 per cent brown manured), canola (10 per cent) and oaten hay (5 per cent). Alistair also trades approximately 1300 cross-bred lambs or merino wethers grazing over summer and finished in an on-farm feedlot.

Motivations for adopting CTF

Alistair began CTF in 2010 when he purchased a new header that enabled him to begin lining up all his machinery on a 12.2m (40ft) system, with his airseeder, boomspray and spreader only requiring relatively minor adjustments. Initially, not all tracks lined up perfectly and his articulated tractor still used dual wheels, but it was a good start.

Alistair implemented CTF to improve the resilience of his no-till farming system and increase its water use efficiency through reduced compaction and better root penetration, particularly in drier seasons. He had noticed that wheeltrack compaction was particularly evident in pulse crops.

Issues encountered in the conversion to CTF

Wheeltrack erosion in sandy soils remains an ongoing issue. To counter this, Alistair alternates between wheeltracks each time he sprays, reducing the annual passes from nine to three, especially for pulse crops that require spraying for control of summer weeds and in-crop management of grass weeds, insects and disease.

Lining up the various GPS tracking systems has been frustrating, with differences between companies and even with different models within the same brand.

The move to the wider harvester has made it difficult to spread straw across the full operating width.

When the chaser bin is loading, it needs to run with one side on the wheeltracks and the other on the crop area, before moving back onto the wheeltracks once fully loaded.

Alistair needs to use dual wheels on the header to harvest over sandhills as the cost of converting to tracks is considered too high for the potential rewards. As a compromise he runs the outer tyres at 10psi less than the inner tyres to reduce their compaction impacts.


Track adjustment made to tractor.

Changes to the farming system since converting to CTF

CTF has allowed Alistair to implement chaff-lining as a harvest weed seed control tactic. The single chaff line concentrates weed seeds into a mulch strip 20 to 30cm wide between the wheeltracks.

This results in less weed germination due to poor soil-seed contact and any weeds that do germinate are subject to strong competition from the crop sown either side or through the row.

Alistair is considering changing to a chaff deck system that will direct the chaff onto each wheeltrack, providing better ground cover to protect the wheeltracks from erosion on the sand.

Current machinery set up and modifications made to convert to CTF
Alistair uses a 3:1 ratio on 3m wheeltracks. His airseeder, harvester and roller are 12.2m (40ft) wide, and the boomspray and main spreader operate on a width of 36.6m (120ft). Some spreading is also done with a smaller, 24.4m (80ft) wide machine.

Alistair uses a Primary Sales Nichols Bar for sowing cereals, and an NDF single disc seeder for sowing chickpeas, lentils and brown manure crops. He estimates that he has reduced the machinery footprint from over 50 per cent of the cropping area to about 15 per cent.

Changes in fuel and work rates due to CTF
Alistair estimates that the change to CTF has resulted in a 15 per cent improvement in spraying efficiency. He notices that the boomsprayer works a lot harder when he is contract spraying off-farm.

Impacts of CTF on soil characteristics
Alistair is able to enter paddocks much sooner after rain than he could before changing to CTF, and he finds it is much safer when working through seep-affected areas. Soil surveys with penetrometers do not show any specific improvements in soil strength as a result of CTF and, as there is no long-term trial work, it is hard to quantify benefits in Mallee soils.

Impact of CTF on crop yield
This has been hard to accurately assess, but Alistair has noted a very large visual difference between the wheeltracks and the untrafficked zones.

Learnings from the transition to CTF
In hindsight, Alistair would have tried to align all his machinery onto the same width wheeltracks to achieve the 15 per cent machinery footprint sooner – but it all costs money.

Airseeder cart needed minimal adjustment for CTF.

Chaser bin needs to run on the crop area when filling.

REINTRODUCING LIVESTOCK

Alistair reintroduced sheep to his farming system to build more resilience into his business and manage risk, while making better use of available resources and increasing his return on capital. For the same land and machinery, and a relatively small investment in building the feedlot, he now runs 1300 cross-bred lambs and merino wethers.

The sheep graze on crop stubble over summer, then Alistair brings them into the feedlot in March–April, before selling them in June–July when there is strong demand. The sheep also graze the early growth in the paddocks sown for brown manure and Alistair value-adds to his seconds grain through the feedlot.

When bringing sheep back into the farming system Alistair wanted to ensure they did not negatively impact on his cropping program. So far, he has not noticed any increase in grass germination due to weed seed being trampled into the soil. Alistair uses a carefully stacked rotation strategy to achieve up to three years grass control if required.

The sheep have not caused any major problems in dispersing the chaff lines to date. Alistair is careful to maintain sufficient residue cover, so the sheep are moved into the feedlot before they remove too much of the residue.

Chaff-lining for harvest weed seed control.

Grower: Wade Nicholls, Nicholls Partners
Location: Pinnaroo, SA
Soil types: Heavy flats, loams and non-wetting white sands
Average annual rainfall: 330mm
Growing season rainfall: 250mm


Wade Nicholls

The Nicholls family farms 5500ha at Pinnaroo, SA, comprised of wheat and barley (50 per cent), break crops, including canola, lentils, lupins or vetch (40 per cent) and hay (usually 10 per cent, depending on frost).

Motivations for adopting CTF

In 2013 the Nicholls gradually started implementing CTF with a spray unit, spreader and tractor all on 3m wheel spacing. The main motivation was to avoid running over too much crop, reduce paddock compaction and have better traction on the clay soils when wet.

Issues encountered in the conversion to CTF

To have made all the necessary changes at one time was considered far too expensive, particularly where chassis needed to be redesigned, so the Nicholls have chosen a strategy of lining things up every time they buy new machinery. There are some items that still need to be replaced.

Wheel ruts from the sprayer tracks causing erosion on sand has been of major concern. At harvest, they have to drive off the permanent wheeltracks when loading the chaser bin, but feel this is a fair compromise, as they would not feel as safe using an extended auger on the header.

Changes to the farming system since converting to CTF

The Nicholls have made recent farming systems changes, in addition to moving to CTF, such as growing more lentils.

They are also now using a Protrakker to improve stubble handling and to better place the seed near the previous year's stubble row, which improves crop establishment on non-wetting sands.

They have a splitter on the seeding boot, and expect to see an improvement in crop establishment with the Protrakker.

The Nicholls have an integrated weed destructor unit attached to their header to help manage annual ryegrass pressure.

They are building a 6m wide deep ripper, and expect that the benefits of ripping their deep sands will last considerably longer under CTF.


Spreader adjusted to 3m wheel spacing.

Current machinery set up and modifications made to convert to CTF

The Nicholls use a 3:1.5:1 ratio CTF system, consisting of a 36m self-propelled sprayer, WEEDit and spreader, an 18m no-till seeder and a 12m harvester and roller. While this is not perfect, they are reluctant to go to an 18m harvester, as this would be less efficient for reaping lentils in their undulating paddocks.

The Nicholls used cotton reels on their tractor to take the wheel spacings out to 3m. They bought a new axle for their chaser bin and also adjusted the spreader to the same axle width. Their harvester is currently on slightly wider tracks. They have used JD RTK for 12 years to 2.5cm accuracy, working off a single base station. Wade finds that hydraulic steering is much better than steering wheel adapters.


36m SP sprayer is on 3m wheel spacing.

Changes in fuel and work rates due to CTF

The Nicholls have not noticed any obvious fuel savings since going CTF, but they have not really been looking at it closely.

Impacts of CTF on soil characteristics

By taking sheep out of the system and implementing CTF, the soils tend to wet up a lot easier and Wade feels that their crops now get more benefit from available soil moisture. They are able to get on with both sowing and spraying much quicker after rainfall events, particularly on the heavier soils.

Impact of CTF on crop yield

A number of contributing factors such as CTF, early sowing, new varieties and the removal of sheep from the system that have all helped to move production in the right direction.

Learnings from the transition to CTF

Wade suggests that other growers interested in CTF should ‘do what you can, when you can’, while maintaining maximum efficiency in the farming operations.

Integrated weed destructor on header.

HAY IN A CTF SYSTEM

The Nicholls have increased their hay production for both local and export markets to help manage frost risk in the Pinnaroo district. It also provides another excellent tool for ryegrass control, which is a major impediment to their cereal crops. The 10 per cent of area sown to hay each year usually generates 20 per cent of their income.

The Nicholls have a weather station located within their crop to get a more localised and accurate assessment of frost events. This helps to inform their decisions on whether they need to act quickly to cut crops down for hay to improve bulk and forage quality, or to leave the crops for grain harvesting.

To improve grass control, the Nicholls have built a boomspray with nozzles to spray glyphosate beneath the windrow of their hay-cutter. This stops any regrowth through the windrows, which is important as regrowth attracts dew, slows drying and impedes the turning or baling of the hay, particularly after any rain delays – costing time and quality. They also apply paraquat after the hay has left the paddock to make sure there are no escapes.

The Nicholls’ hay mower is only 4.5m wide, so it only aligns with CTF wheeltracks 20 per cent of the time. The baler wheels are on 2m spacings, which is not ideal, but is a compromise they are willing to make at the present time.

Wade finds that deep ripping sand after hay is a good strategy as there is more moisture in the subsoil, and this extra moisture is better preserved under CTF.

Hay is a profitable enterprise and a useful weed control tool – but not fully compatible with CTF.

Grower: Robert Pocock, Lampata

Location: Lameroo, SA

Soil types: Deep sands, sandy loams, loamy clay flats with subsoil constraints

Average annual rainfall: 345mm

Growing season rainfall: 250mm

Robert Pocock

Robert Pocock farms 3000ha with his wife Courtney and parents Bruce and Gaye, at Lameroo, SA. They sow 2000ha to wheat, barley, lupins, vetch and cereal hay, as well as contract seeding and harvesting within the district. The family also run a poll merino stud of 2050 self-replacing breeding ewes.

Motivations for adopting CTF

Robert started CTF in 2015 using RTK and implement guidance, mainly to keep standing stubble integrity, help trash flow and enable edge-row sowing. He also saw the value in minimising soil compaction to improve crop water use efficiency and was able to achieve this without slowing their program down for the scale of their business. Robert has found upgrading to CTF achievable at little extra cost when purchasing new equipment.

Issues encountered in the conversion to CTF

Initially there were staff training issues with changing guidance lines starting points and planting patterns, resulting in calls at all hours of the morning. Robert supplied a page of instructions for each tractor, with accurate maps and clearly named guidance lines.

Rob has achieved CTF alignment as he has upgraded machinery. However, there remains a major concern with erosion of wheeltracks over sand, particularly following legumes in the rotation. Some cultivation is required to smooth out resultant ruts and lumps.

Changes to the farming system since converting to CTF

A Protrakker implement steering system has been fitted to help Robert achieve edge-row seeding. He also now has a triple bin airseeder cart and trailing fluid tank to improve his nutrient management and strategic placement for crops. Robert is also considering reducing the area sown to cereals, as profits in stock pastures and other break crops are competing heavily for their place in the rotation.

Current machinery set up and modifications made to convert to CTF

Rob uses a 1:3 CTF ratio, with a 12m seeder and header, and a 36m boomspray and spreader. Due to his deep sandy rises, Robert still uses dual wheels on his seeding tractor, and his hay system does not operate on the

Seeding system with trailing fluid cart.

wheeltracks, but these are compromises he currently must make. His chaser bin also has to move off the wheeltracks to load.

Cotton reels were used to space the wheels to 3m on some tractors, along with axle modifications to various implements.

Robert is considering using chaff decks to drop chaff on wheeltracks to stop erosion on the sand, with additional wheeltrack spray jets to control any extra weed pressure created. In the interim, he is using chaff-lining to move away from narrow windrow burning, which wastes valuable organic matter and concentrates burnt stubble on the same row each year.

Changes in fuel and work rates due to CTF

Robert has not noticed or specifically measured any changes, but they may have occurred. It is hard to measure as none of the seasons have been the same yet, but he expects that fuel and draft requirements will decrease.

Impacts of CTF on soil characteristics

The topsoil between wheeltracks appears softer, more friable and the loams seem to wet-up better. The sand is also generally softer and quite fragile when residue levels are low.

Impact of CTF on crop yield

Robert believes that his crops are hanging on a bit better through the spring, but the yield benefit is hard to measure as it depends on the season, and there have been other agronomic improvements made to crop nutrition as well.

Learnings from the transition to CTF

Robert has learned not to worry about achieving full CTF at once. He recommends seeking advice from other farmers doing similar things in the same environment and doing what works for you at the time. There are times and situations where compromises need to be made, such as to accommodate livestock or hay.

Front axle cotton reels on spray tractor.

Rear axle adjustment on spray tractor.

PROTRAKKER GUIDANCE SYSTEM

Mallee Sustainable Farming (MSF) research has shown clear benefits of edge-row sowing on non-wetting sands. The previous season's stubble and crowns allow rainfall to flow into the zone immediately beneath the row, and the increased nutrition and microbial activity provides a far better environment for even crop establishment than the inter-row zone. Robert also thought this technology could be used to improve the latticing legumes such as peas on high cut cereals to aid with disease control, harvesting and increase ground cover post-harvest.

The Protrakker guidance system uses a steerable drawbar and customised seed boot to precisely place the seed in the moisture zone alongside the previous year's stubble row, while minimising stubble disturbance or blockage, thereby minimising soil erosion. The technology is a significant improvement on guidance technologies that only steer the tractor.

The Protrakker guidance system accuracy to 2cm aligns well with CTF. Leaving more standing stubble with a smaller machinery footprint helps to maximise the benefits of the edge-row seeding.

Protrakker implement guidance on the seeder.

Edge-row sowing between wheeltracks.

Moisture penetration on-row in non-wetting sand.

RESEARCH RESULTS FROM FOUR LRZ SITES

Key message

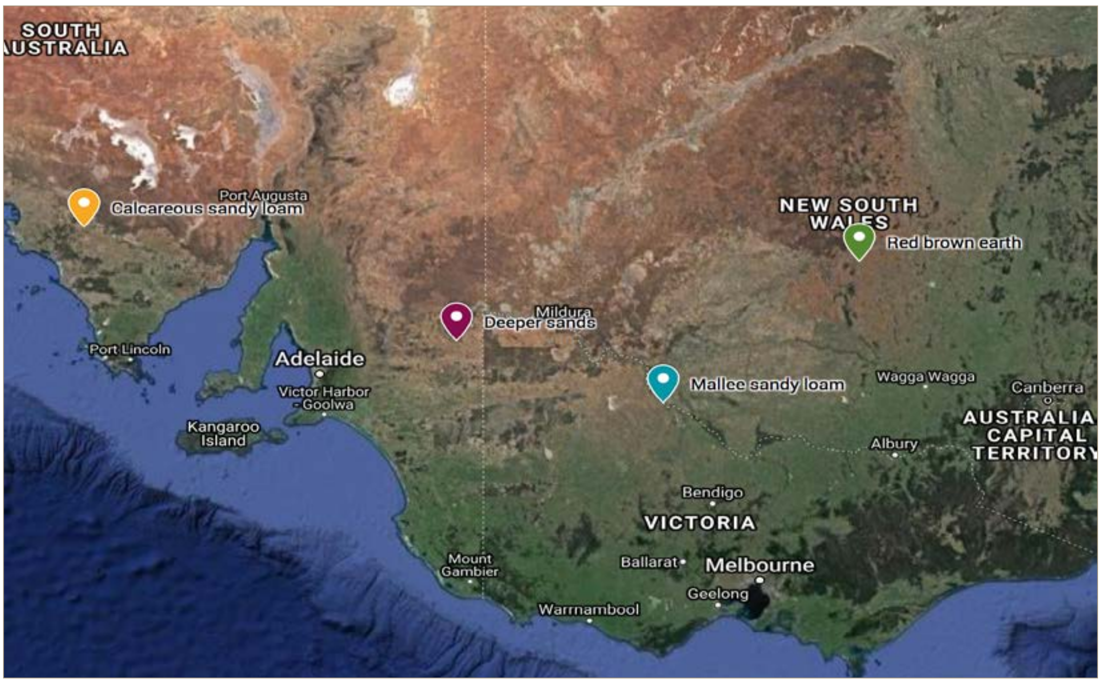
The results from this CTF project and previous studies, plus the theoretical understanding of soil-crop processes, has led to the development of the following five general conclusions about the application of CFT in the LRZ of south-eastern Australia:

- The degree of soil damage caused by trafficking depends on the equipment axle load, the soil water content during trafficking, the number of passes, soil type, and the degree of existing soil compaction.
- Low severity trafficking, such as a single pass under dry conditions, will not, in most cases, affect crop yield.
- Intensive trafficking by standard farm machinery, such as three passes under wet conditions, can result in significant and persistent yield penalties on sandy soils in the LRZ.
- Trafficking can show contradictory results when other factors, such as Rhizoctonia, impact yield.
- Crops grown on higher clay content soils in the LRZ can expect a greater yield penalty than lower clay content soil immediately following intermediate (1-pass wet) and high (3-pass wet) intensity trafficking in moist conditions.

The 5 to 10 per cent adoption of controlled traffic farming (CTF) in the LRZ of south-eastern Australia is well below the national average of around 30 per cent of the cropping area. In other zones, increased yields and cost savings have accompanied adoption of CTF, raising the question 'can these benefits be captured in low rainfall zones?'

To investigate, GRDC initiated a project that evaluated the potential benefits of implementing CTF on four sites (at Lake Cargelligo, Loxton, Swan Hill and Minnipa), representing important soil types in the LRZ of south-eastern Australia.

Although all sites had been in long-term controlled traffic crop production, some historical compaction, of the subsoil particularly, was expected as a result of previous management systems.



Research trial sites at Lake Cargelligo, Loxton, Swan Hill and Minnipa.

The aim of these four trials was to impose three trafficking treatments at each site, and to monitor crop performance and soil condition for four seasons (2015 to 2018) to determine if CTF could effectively increase productivity of these four representative LRZ environments.

The sites varied in clay content from a sand to a sandy-clay-loam in the 0 to 10cm depth and from a loamy-sand to a clay in the 30 to 50cm depth. Many LRZ soils are coarse textured, easily erodible and have constraining subsoils, with no mechanisms for natural self-repair.

Long-term growing season rainfall varies across sites from 196 to 274mm and long-term annual rainfall varies from 270 to 424 mm.

The trafficking treatments were imposed under either 'wet' or 'dry' soil conditions at each site to compare the effects of this trafficking with the CTF system already in place on the rest of the paddock. The maximum axle weight used to traffic the plots at each site ranged from 8 to 24t, each traffic plot was at least 3m wide by 40m long and each treatment replicated four times in a randomised complete block design.

The compaction treatments imposed on the traffic plots were (see diagram below):

- CTF-control,
- Low (1-pass dry): one pass (overlapping) in dry conditions,
- Medium (1-pass wet): one pass (overlapping) in moist conditions,
- High (3-pass wet): three passes (overlapping) in moist conditions.

The moist treatments were imposed after approximately 15 to 20mm of rainfall in the previous 2 to 3 days.

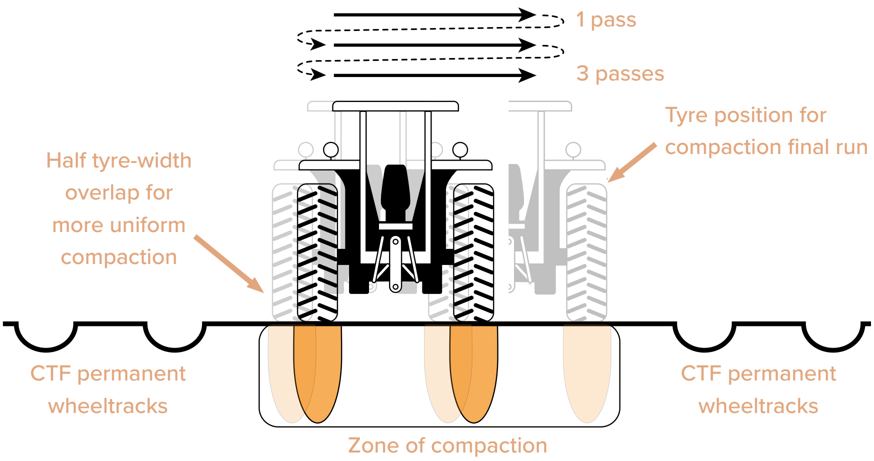
In addition, a ripping treatment was also included at most sites to represent a soil compaction amelioration process. The farmer at each site carried out all in-season field operations across the plots identically to the remainder of the paddock.

Causes of variation in yield benefits can be attributed to a complex mix of:

- initial soil moisture conditions,
- soil and crop type,
- soil water content when trafficking occurred, and
- the frequency, axle load, and tyre pressure of the trafficking vehicles.




Machinery used to implement the compaction treatments at the various trial sites.



Design of trafficking treatments using a 50 per cent overlap of the load bearing wheels to ensure a more uniform distribution of compaction.

LRZ SOIL TYPES

Minnipa – Calcareous sandy loam

Loxton – Deep sand

Swan Hill – Mallee sandy loam

Lake Cargelligo – Red brown earth

MINNIPA SITE

Minnipa is on the Upper Eyre Peninsula of South Australia. The area has an annual rainfall of 311mm and an average growing season rainfall (April to November) of 248mm. The farm chosen for the trafficking trial had been in controlled traffic farming for three years prior to 2015.

The soil texture at the Minnipa site is sandy loam throughout the profile. Most notably there was an extremely high level of carbonate, reaching over 30 per cent of the soil mass at a depth of 40cm, and toxic levels of salinity and boron also starting to occur at this depth.

There was no apparent cultivation pan at the Minnipa site, with a uniform bulk density to depth, which was not likely to be restrictive to root growth. The uniform soil profile was also reflected in uniform plant-available water-holding capacity to depth.

The soil amelioration 'ripping' treatment was very effective, further reducing the bulk density to a depth of 25cm. The mean crop yields were -24 per cent (620kg/ha), +23 per cent (600kg/ha), +4 per cent (10kg/ha) and -8 per cent (-180kg/ha) for the 2015 wheat, 2016 wheat, 2017 vetch, and 2018 wheat, respectively. Only the 2015 and 2016 results were statistically significant (5% LSD) compared to the CTF-control.

The low yield in 2015 was attributed to an uneven seedbed and deep sowing depth as a result of the ripping. The positive response to ripping in 2016 was not expected since the bulk density measurements in the CTF-control were less than what would be expected to limit root growth.

The trafficking treatments were imposed using the grower's CAT Challenger 35 tractor (11.1t) on 40cm wide tracks and a 22t Vennings chaser bin weighing 19t on 77.5cm wide aircraft tyres with a low pressure of 20 psi. This combination was expected to apply less stress to the soil than the similar weight applied at the Loxton site.

In the lead up to the trial, a total of 15.6mm fell between 1 and 10 January. The dry trafficking treatment was imposed on 9 April 2015, with no rain having fallen since 10 January 2015.

From 10 to 17 April a further 29.2mm fell (21mm on 17 April) and the wet trafficking treatments were imposed on the 20 April 2015.

The dry trafficking treatment did not impact on the soil bulk density or soil water retention functions. The dry trafficking treatment did not affect yield except for an unexpected 23 per cent yield increase in 2016.

The soil profile was quite dry when the wet trafficking treatments were applied but despite the low water content and low tyre pressure, there was a marked increase in bulk density as a result of the two wet treatments in the 10 to 20cm depth range. The higher bulk density is still apparent, to a lesser amount, in 2016 but appears to have disappeared by the 2018 measurement.

This apparent self-amelioration after four crops is surprising for this soil type but could explain the low and uniform bulk density found at the start of the experiment. The maximum bulk density caused by the trafficking treatments was expected to have only minor impact on root growth. The two wet treatments did not decrease the plant-available water-holding capacity of the soil.

The changes in soil properties were below the critical thresholds expected to affect roots and yields in the 3-pass wet trafficking treatment were never worse than the control. However, for some of the trafficking treatments there were unexplained yield increases, such as the 3-pass wet treatment resulted in yield increase of over 30 per cent in the 2016 wheat (1 t/ha).

In 2016, the site was affected by Rhizoctonia and as might be expected, the ripping treatment had a lower (n.s.) incidence of Rhizoctonia compared to the CTF-control. However, although the two wet trafficking treatments had the lowest levels of observed Rhizoctonia, possibly explaining the yield increases, the single pass dry trafficking treatment had the highest observed incidence but also had a statistically significant +26 per cent (680kg/ha) increase in yield compared to the CTF-control. This combination of results suggests that there was another factor affecting yield other than Rhizoctonia in 2016.

Yield response to trafficking and deep ripping at the Minnipa site

Year/crop	CTF-control	Deep ripping	Dry traffic	1-pass wet traffic	3-pass wet traffic
2015/wheat	2.5t/ha	-24%	n.s	n.s	n.s
2016/barley	2.6t/ha	+23%	+26%	+26%	+38%
2017/vetch	0.35t/ha	n.s	n.s	n.s	n.s
2018/wheat	2.4t/ha	n.s	n.s	n.s	n.s

n.s yield response is not significantly different to the CTF-control yield (5% LSD)

LOXTON SITE

The Loxton site in the Northern Mallee region of South Australia has a sand topsoil progressing to a sandy loam at 40cm depth. The area has a long-term average rainfall of 270mm and a growing season rainfall of 196mm.

There was a pre-existing cultivation pan at 15cm and a high soil strength zone from 18 to 25cm depth. Root growth, and possibly crop productivity, are likely to be constrained by the physical properties of the soil in these zones.

The cultivation pan resulted in a slight decrease in plant-available water-holding capacity, further restricting the ability of this sandy soil to store moisture. Surprisingly, the ripping treatment did not appear to change any of the soil physical measurements and the treatment only increased mean crop yield compared to the CTF-control for 2018 barley (+360kg/ha or 23%).

The trafficking treatments were imposed using the grower's John Deere 8335 RT tractor (17.7t) on tracks and a Grain King 25T chaser bin weighing 24t.

In the lead up to the trial, a total of 27mm fell between 1 and 13 January. The dry trafficking treatment was imposed on 1 April 2015, with no rain having fallen since 13 January 2015.

Between 1 and 17 April a further 37.6mm fell (22mm on 17 April) and the wet trafficking treatments were imposed prior to sowing on 28 May 2015.

The high axle load, small footprint tyres, and high tyre pressure (60 psi) was predicted to cause high and deep soil stress at the sites. The dry trafficking treatment appears to have made no effect on the soil bulk density, however, below 30cm there appeared to be greater resistance compared to the CTF-control.

The soil profile was still quite dry when the wet treatments were imposed but was still expected to cause some changes to soil physical properties. Soil measurements confirmed that the wet treatments resulted in an increased bulk density down to 35cm with the cultivation pan being further compressed in both wet treatments compared to the CTF-control. The deep compaction at Loxton is attributable to the much heavier axle load used at this site.

This constricted zone was likely to be very restrictive to root growth and was still apparent, if slightly reduced, in measurements taken in 2018 after four cropping seasons. This suggests that the soil did not self-repair and that long-term damage can occur when heavy trafficking axle loads cause deep compaction.

Following a 44C79 canola crop in 2014, Kord CL Plus wheat was sown into low soil moisture on 28 May 2015 using John Deere 1870 Conserva Pak seeder with individual depth control capability, and there was small variation in sowing depth at the site, despite the high axle load used during the trafficking treatments.

In 2016, the grower changed seeders and sowed the following crops using an airseeder with knife points and press wheels.

The 3-pass wet trafficking treatment had a persistent effect on yields, reducing the mean crop yield by 31 per cent (240kg/ha), 20 per cent (380kg/ha), 63 per cent (212kg/ha) and 56 per cent (870kg/ha) compared to the CTF-control in the 2015 wheat, 2016 wheat, 2017 peas, and 2018 barley, respectively.

Although the 1-pass wet trafficking treatment resulted in almost identical effects on soil physical properties as the 3-pass wet treatment, the reduction in crop yield was not as severe as in the 3-pass wet treatment, only the 32 per cent (400kg/ha) yield loss in 2018 was less than the control.

Yield response to trafficking and deep ripping at the Loxton site

Year/crop	CTF-control	Deep ripping	Dry traffic	1-pass wet traffic	3-pass wet traffic
2015/wheat	0.8t/ha	n.s	n.s	n.s	-31%
2016/wheat	1.9t/ha	n.s	n.s	n.s	-20%
2017/peas	0.3t/ha	n.s	n.s	n.s	-63%
2018/barley	1.5t/ha	+23%	n.s	-32%	-56%

n.s yield response is not significantly different to the CTF-control yield (5% LSD)

Soil cores provided vital information about the characteristics of the soil at each site.

SWAN HILL SITE

The site at Swan Hill in the Victorian Mallee has an annual rainfall of 342mm and an average growing season rainfall of 250mm. The sandy loam paddock had been in CTF for seven years.

The soil texture at the Swan Hill is sandy clay loam throughout the profile, with 20 per cent clay at the surface and up to 40 per cent clay at a depth of one metre. The soil also has high levels of carbonate, reaching 20 per cent of the soil mass at 40cm depth and high levels of salinity and boron at 85cm depth.

There were indications of a slight cultivation pan at a depth of 15cm, where the bulk density is higher than desirable, but not likely to be very restrictive to root growth.

The soil amelioration 'ripping' treatment applied in 2015 was very shallow and had no effect on soil properties, nor the 2015 crop yield. The ripping treatment was repeated to a greater depth in 2016 and was effective in breaking the compaction layer and loosening the soil down to 35cm. However, the ripping treatment reduced the 2016 wheat yield by 32 per cent (800kg/ha).

The trafficking treatments were imposed using the grower's John Deere 8130 tractor (11.5t) and a Goldacres 6500 L chaser bin weighing 10t. The wet trafficking treatments were imposed on the 19 April 2015, immediately after 16.6mm of rain fell over two days, making a total of 38.8mm since the 1 January 2015.

All the trafficking treatments increased the surface bulk density above the pre-existing cultivation pan. The surface bulk density for the two wet treatments was high enough to expect restrictions to root growth. The increase in bulk density made little difference to the total plant-available water-holding capacity.

Following a brown manure vetch crop in 2014, Kord wheat was sown on 6 May, 2105, into low stored moisture using a no-till single disc NDF seeder.

The wet trafficking treatments resulted in 28 per cent (230kg/ha) decrease in the 2015 wheat mean yield, for the 3-pass wet trafficking treatment.

In 2016, Kord CL wheat was sown on 7 May using the same NDF seeder. The yields were similar in all treatments.

The trial was discontinued after the 2016 season due to a change in property ownership.

Yield response to trafficking and deep ripping at the Swan Hill site

Year/crop	CTF-control	Deep ripping*	Dry traffic	1-pass wet traffic	3-pass wet traffic
2015/wheat	0.8t/ha	n.s	n.s	n.s	-28%
2016/wheat	2.5t/ha	-32%	n.s	n.s	n.s
2017					
2018					

n.s yield response is not significantly different to the CTF-control yield (5% LSD)
* the deep ripping method was ineffective in 2015 and was re-applied in 2016

LAKE CARGELLIGO SITE

The Lake Cargelligo site in Central NSW had been in CTF for 11 years prior to 2015. The red brown earth site has a sandy clay loam topsoil progressing to a clay at 40cm depth. The site has an average annual rainfall of 424mm and an average growing season rainfall of 274mm.

The three crops grown prior to the trial were wheat (2012), wheat (2013) and lupins (2014).

There was no evidence of a cultivation pan in the soil profile, however, the density of the soil increased down the profile, becoming root restricting at a depth of about 15cm. The better structure in the topsoil supported a high level of plant-available water-holding capacity.

The trafficking treatments were imposed using the grower's John Deere 8430 tractor (13t) on R46 tyres and a Stolls spray rig S8 weighing 8t. The deep ripping treatment was not implemented at this site.

In the lead up to the trial, a total of 104mm fell between 1 January and 7 April 2015. The dry trafficking treatment was imposed on 16 April, with the most recent rain being 8mm on 7 April. An additional 23mm fell between 16 and 18 April and the wet trafficking treatments were imposed on the 19 April 2015.

None of the trafficking treatments increased compaction at depth, however, all the trafficking treatments compacted the topsoil (0 to 10cm depth). The dry and 1-pass wet treatments caused a similar level of damage and the 3-pass wet treatment caused highly root restricting damage. By the following year, the surface bulk density was similar across all three trafficking treatments.

The 3-pass wet trafficking treatment was repeated on fresh plots under wetter conditions in 2018. This resulted in identical results to the 2015 treatment. The increased bulk density decreased the volume of large pores but made little difference to the total plant-available water-holding capacity of the topsoil.

In the 2015 wheat crop, the 3-pass trafficking treatment resulted in a 41 per cent (1030kg/ha) yield decrease.

All trafficking treatments in 2016 had wheat yields no lower than the CTF-control. Yields were higher than the control for dry and 1-pass wet trafficking.

No yield was achieved from the 2017 peas, but mid-season dry matter cuts showed no effect of the trafficking treatments.

In the 2018 wheat, only the dry and 3-pass wet traffic treatments reduced yields, by 30 per cent and 74 per cent respectively, confirming the 2015 result.

Yield response to trafficking and deep ripping at the Lake Cargelligo site

Year/crop	CTF-control	Deep ripping*	Dry traffic	1-pass wet traffic	3-pass wet traffic	3-pass wet traffic†
2015/wheat	2.5t/ha		n.s	n.s	-41%	
2016/wheat	3.35t/ha		+23%	+23%	+23%	
2017/peas	0t/ha (grazed)					
2018/wheat	0.5t/ha		-30%	n.s	n.s	-74%

n.s yield response is not significantly different to the CTF-control yield (5% LSD)
* not implemented at this site
† newly applied treatment for 2018 season

CONCLUDING COMMENTS

Low axle weights and using tyres with low pressure and large contact area can reduce soil stress, particularly when the soil is trafficked when it is as dry as possible. However, this research has also shown that many soil types in the LRZ are susceptible to compaction as a result of machinery trafficking.

In sandy conditions, high axle load and tyre pressure, especially if combined with multiple passes can produce persistent yield declines for many years after the trafficking.

In soils with higher clay content, compaction seems to be limited to the surface and yield penalties are limited to the year of trafficking, with some self-repair occuring, if the soil water content is not too high.

In extremely wet conditions, which only occur episodically in the LRZ, trafficking these clay soils is likely to cause far more severe damage.

Establishing permanent wheeltracks on LRZ soil types confines the compaction effect to the small portion of the paddock and protects the majority of the paddock from damage.

Above – Uneven maturity in wheat at Lake Cargelligo CTF site sown in intensively compacted (3-pass wet) plot.

Below – Wheat crop at Lake Cargelligo CTF site sown in non-compacted plot.

DEEP RIPPING ON LRZ SOILS

Key points

- Not all soils respond positively to deep ripping. Understanding the characteristics of the topsoil and subsoil is essential.
- Deep ripping can bring hostile subsoil into the crop root zone, potentially causing negative effects on crop growth and yield. The amount of material that different tyne designs move from depth toward the top of the profile varies markedly.
- For maximum impact, aim to shatter the full depth of the compacted layer.
- Deep ripping responsive soils, such as deep sands, can generate a wheat yield increase of 0.3 to 1t/ha.
- Inclusion plates can further increase yields (but the effect was not consistent).

In some regions in WA and SA, deep ripping of sandy soils has been widely adopted by growers, and yield gains have been consistently demonstrated. The expectation is that these yield benefits can be prolonged from three to possibly ten years under a CTF regime in light soil types.

A pilot study in the Mallee (Loxton, SA) during 2017 demonstrated a significant yield increase in field peas as a result of deep ripping. To further assess the potential of this tactic, five trials were established in 2018 at sites across in the Victorian and South Australian Mallee. The on-farm trials tested the effect of deep ripping and topsoil slotting on wheat yields. These sites were located on CTF growers' properties at Kinnabulla, Woomelang and Kooloonong in Victoria, and Loxton and Paruna in SA, covering a range of soil types from duplex soils to deep sands.

The Department of Agriculture and Food in WA has estimated the cost of deep ripping to range from $50 to $90/ha, depending on ripping depth, machinery and soil conditions, which corresponds to ripping costs estimated by growers in south-eastern Australia. It pays to consider the likely returns as a result of deep ripping and to preserve the benefit for as long as possible through CTF to minimise re-compaction of the crop zone.

Yield benefits of deep ripping and topsoil slotting

The highest yield improvements across the five trials were observed on deep sands at Loxton, where grain yields increased on the dune by 1.1t/ha in the year of ripping, compared to the control (Table 1). Deep sandy soils also responded positively at Kooloonong and on the swale at Paruna with an additional grain yield of 0.5 and 0.3t/ha respectively. Deep ripping of the duplex soil types (at Kinnabulla and Woomelang) did not increase grain yield.

Topsoil slotting involves attaching inclusion plates to the back of the deep ripping tynes to funnel topsoil and surface-applied ameliorants into the ripper furrow. This technique has been used to good effect on sandy soils in WA, but produced only minimal additional yield (0.3t/ha) at one of the sites (dune at Paruna SA), possibly due to the low nutritional status of the topsoil at these sites.

Summary of deep ripping sites established in 2018 and the yield responses to deep ripping (+/- inclusion plates) compared to the control.

Location	Kinnabulla (VIC)	Woomelang (VIC)	Kooloonong (VIC)	Loxton (SA)	Paruna (SA)
Soil Type	Sandy loam & sandy clay loam over medium-heavy clay	Sand over sandy loam (dune) & sandy loam over clay loam (swale)	Deep sand to loamy sand	Deep sand	Deep sand
2018 GSR	120mm	125mm	65mm	81mm	106mm
Av. GSR	220mm	217mm	200mm	151mm	173mm
Ripping depth	40–50cm	16–23cm (dune & swale)	40–42cm	45–50cm	35–40cm (swale) 45–50cm (dune)**
Crop type	Wheat (cv. Scepter)	Wheat (cv. Scout)	Wheat (cv. Scepter)	Wheat (cv. Cutlass)	Wheat (cv. Cutlass)
Yield response (- plates)	-0.3t/ha to Nil*	Nil	+0.5t/ha	+0.5t/ha (swale)* +1.1t/ha (dune)*	- 0.6t/ha (dune)* +0.3t/ha (swale)*
Yield response (+ plates)	N/A	Nil	+0.4t/ha	+0.3t/ha (swale)* +1.0t/ha (dune)*	+0.3t/ha (swale)* + 1.4t/ha (dune)*
Why?	Subsoil constraints	Ripping depth	Soil type	Soil type	Ripping depth

* Non-replicated demonstration site

** Penetrometer data indicates ripping depth not achieved

IS DEEP RIPPING FOR ME?

Soil type, timing and the depth of the compaction layer are key considerations in the decision to deep rip or not. If the decision is to go ahead with deep ripping, consider when in the crop rotation to deep rip, machinery set-up and costs to achieve optimal production results and financial returns from this practice.

The research trial data suggests that unless soil strength measured near field capacity with a penetrometer exceeds 1.5 to 2.0MPa, yields are probably not being limited.

Soil type

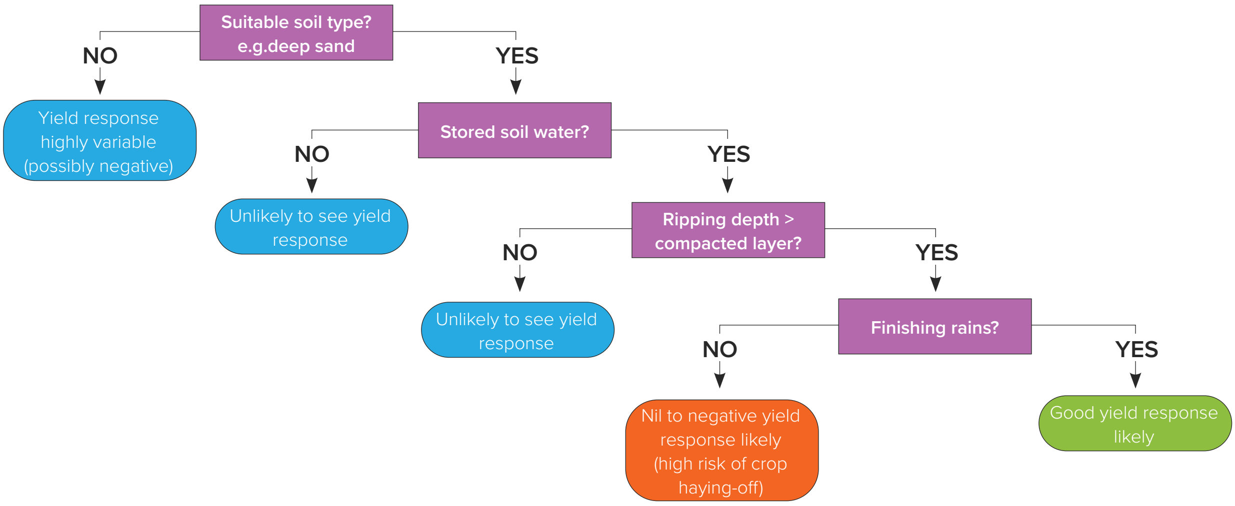
Use a penetrometer or push rod to identify whether compaction is an issue and if so, where is the compacted layer and how deep is it?

Sandy soils typically have the greatest response whereas red loams and black vertosols show very few positive responses to deep ripping. Generally, sand over clay soils will not respond to ripping unless the clay is deeper than 25cm (Jarvis et al. 2000).

It is advisable to undertake soil tests to depth prior to deep ripping. The soils most responsive to deep ripping are deep sands (at least 25cm deep) with a non-hostile subsoil. Mallee subsoils can be highly alkaline and sodic, with high levels of chloride and/or boron, which can inhibit root growth and access to soil water. It is suspected that crop roots were exposed to a hostile subsoil at the Kinnabulla trial site, which contributed to the negative to nil response observed (Table 1).

Even on deep sands, other factors (outlined below) can influence the grain yield response.

Soil profile with crop growing at deep ripping trial site.



Timing of operation

For maximum benefit, deep ripping should be applied when soils are moist but not saturated. Ideally, deep ripping would occur following substantial summer rainfall events or after the autumn break before sowing. If soils are too dry, draft and fuel consumption are increased significantly, and often results in large soil clods being brought to the surface. Optimal timing also helps with soil preparation before seeding and therefore better crop establishment.

Ripping depth

Identifying the presence of the compacted layer and its depth is very important to ensure the ripper tynes penetrate deep enough the shatter the compacted layer. Ideally, the ripping depth should be around 1.5 times the depth of the lower extent of the compacted layer. Typically, in the Mallee compacted layers are found between 30 to 70cm, which would ideally require ripping to a depth of 105cm. Ripping below 60cm is likely to be costly, so a test strip is recommended.

Given the importance of this information to the overall success of the operation, it is well worth making the effort to accurately assess the location and extent of the compacted zone in a few representative places within a paddock. The depth of the compacted layer is likely to be variable depending on the paddock history and soil type. If the available equipment is not able to rip deep enough, it is unlikely that the operation will achieve any measurable yield response.

Other considerations – crop rotation, machinery requirements and costs

Anecdotal reports suggest that deep ripping prior to growing wheat or lentils will give more reliable results than planting canola after deep ripping. The difference in results is believed to be associated with crop establishment issues with canola in freshly-ripped soil.

If the ripper leaves the surface too cloddy and rough, consider using a crumble roller, or other means of remediating the surface, after ripping. The first year yield response can be reduced if the surface condition adversely affects crop establishment.

Deep ripping requires significant horsepower to break a compacted layer deep in the soil profile. First determine how deep and how thick the compacted layer is, then ensure that the implement used can effectively shatter the compacted layer and that the tractor has sufficient power for the task.

The addition of shallow lead-in tynes on the deep ripper may help to achieve the desired depth of disturbance, reduce the draft force and help keep running costs down.

ENERGY SAVINGS IN CTF ON LRZ SOILS

Key points

- Agricultural machinery operating in a CTF system were observed to use about 25 per cent less draft to pull a seeder through the soil in the crop zone and about 25 per cent less motion resistance had to be overcome when the wheels operated on firm, permanent wheeltracks.
- These results are consistent with LRZ farmer reports of about 15 per cent fuel saving from CTF, due to a range of other factors that influence fuel use on-farm.
- Less motion resistance means that energy otherwise used to compact the soil is conserved (saving fuel). It also allows better paddock access and improved timeliness of operations.
- Less draft requirements potentially means lower horsepower machinery could be used (lowering machinery ownership and running costs) to do the same job, or the same machinery could possibly work faster.

In 2106, two PhD students from the University of Southern Queensland visited the LRZ to collect data, bringing with them a purpose-built three-point linkage unit for measuring seeder point or tillage tyne draught (simultaneous measurements, in and out of the tractor wheeltracks), and a pullmeter for motion resistance assessments. Soil physical parameters (bulk density, moisture content, penetration resistance) were also assessed.

Due to an extended wet winter period in 2016 it was not possible to collect data from all six intended sites. Consequently, the following useable data sets were collected:

- draught results for seeder opener (Loxton and Swan Hill)
- motion resistance results for wheeled tractors (Hopetoun and Swan Hill), and rubber-track tractors (Loxton and Swan Hill).

Considerable confidence can be placed in individual sets of results from this work (3 reps of >200m runs logging mean values at 0.5s intervals), but the low number of sites tested means any generalisations must be treated with caution.

Draft energy effect

Draught effects of previous traffic were assessed with chisels, sweeps and seeder openers at three depths. The draft results were similar, regardless of the implement tested. This trial showed that a tractor wheel in front of a narrow tyne opener increases the power required to move the tyne through the soil at 8km/hr by 26 per cent in representative southern LRZ soil types, compared to a tyne not following a tractor wheel.

In practice, the reduction in power required for the CTF seeding operation is likely to be less than 26 per cent. This is because the effect only applies to the change in wheeled area between conventional and CTF wheeltrack patterns. Also, the motion resistance of the air cart is likely to be less in CTF while the motion resistance of the depth and press wheels working in the softer crop zone is likely to be greater in CTF.

From this trial, and the experience of CTF growers in the LRZ, it is clear that CTF will reduce the seeding power requirement, but this reduction is probably closer to the 15 per cent that growers frequently quote.

Motion resistance effects

Although wheel slip is often a point of discussion, motion resistance is responsible for a much greater waste of tractor power (and fuel). More importantly, motion resistance is also the major contributor to soil compaction.

Motion resistance occurs largely because soil deflects downwards (i.e. compacts) under a vehicle's weight, so wheels or tracks are effectively always climbing a 'hill' of their own making. Soil also deflects backwards under the thrust of tyres or tracks, and this is wheel slip.

In this study, motion resistance was assessed by towing tractors on:

1. CTF beds,
2. CTF wheeltracks, and
3. 'roads', or the best readily-available hard surface.

Towing the tractors on 'roads' provided the best estimate of the motion resistance within the powertrain and the tyres or tracks themselves. Subtracting towing force on roads from towing force on beds or wheeltracks should give an estimate of motion resistance, or energy wasted in soil compaction on those two surfaces. In this case, the average difference between the motion resistance on crop beds and traffic lanes was 2.3 per cent of tractor weight. The average total motion resistance on non-wheeled soil was 9.1 per cent of tractor weight.

It is important to point out that the individual tests indicated that rubber-track tractors wasted more power in soil compaction than wheeled tractors, which conflicts both theory and practical experience. The problem was probably caused by the reverse weight transfer effect when towing rubber-track tractors. This would put excessive weight on the relatively small front sprocket, rather than having it evenly distributed along the length of the tracks.

The results were nevertheless consistent in demonstrating the CTF effect, and indicate that CTF should reduce motion resistance by about 25 per cent. To put this in practical terms, CTF would reduce power requirement by 11kW (15HP), and fuel use by about 4L/h diesel for a 15t tractor. This probably accounts for a large proportion of the 15 per cent fuel savings that several LRZ CTF growers have observed. The effect would be much greater on soil that had been recently deep ripped.

NITROGEN LOSS FROM LRZ SOILS

Key points

- Greenhouse gas (GHG) emissions and nitrogen losses from wheeled soil are between 2 and 4 times greater than those from non-wheeled soil.
- Single pass or random wheeltracks often lose more nitrogen to the air than do CTF permanent wheeltracks.
- The net effect of a change from a typical non-CTF (≈50% wheeled soil) system to CTF (12% wheeled soil) can reduce GHG emissions by about 70kg of carbon dioxide equivalent per hectare per year.
- Such a change to CTF would save about 11kgN/ha, valued at $9.20/ha (at $400/t for urea on farm).

The results discussed in this report come from measuring nitrous oxide N_2O emissions from wheeltracks and untrafficked soil. It is impracticable to measure the N_2 directly, because it is already at 70 per cent of the atmosphere, whereas there is no N_2O except from the denitrification process.

From a series of 15 trials at six CTF sites (SW Vic, Wimmera, Darling Downs, SW of WA and Vic Mallee) over three years, it was clearly shown that the soil in both permanent CTF wheeltracks and non-CTF single wheel passes, always loses much more nitrogen (N) to the atmosphere as N_2O and N_2 than soil that has no wheel traffic. This difference in emissions was consistent across all the sites, regardless of factors such as soil moisture, organic matter or fertiliser application.

We cannot be sure whether these losses are from applied fertiliser, or from other soil N sources or from both, but it is all N that might otherwise be available to crop plants. In our trials both permanent wheeltracks and single passes at seeding emitted, on average, 2 to 4 times as much N_2O gas as untrafficked soil near the wheeltracks. Random single passes usually emitted more than permanent wheeltracks.

These higher losses of N from wheeltracks have been shown to occur in all environments. The actual loss is likely to be lower in the LRZ because of generally lower soil moisture throughout the growing season, but the effect of the loss may be magnified due to the generally lower lower levels of nitrogen present, and applied, in LRZ soils compared to standard practice in higher rainfall zones.

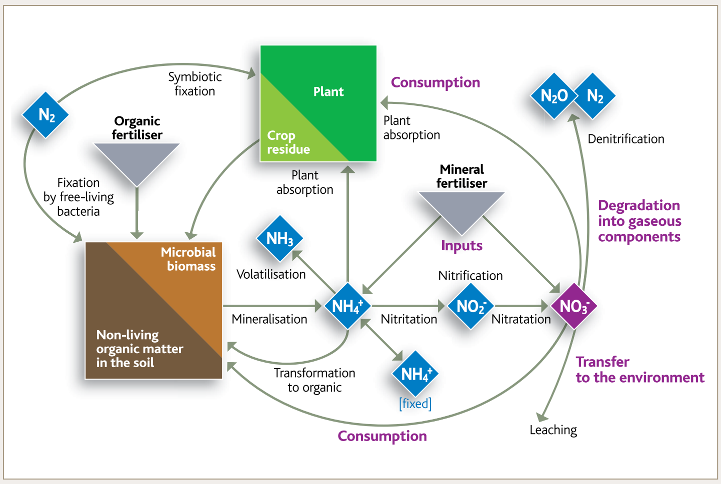
The amount of N applied is an important factor, but the highest levels of denitrification occur when the soil is very wet or waterlogged, with the air in the soil pores replaced with water. In compacted wheel tracks, even single pass ones, these conditions occur more frequently than in well-structured untrafficked soil.

Laughing gas emissions are no laughing matter

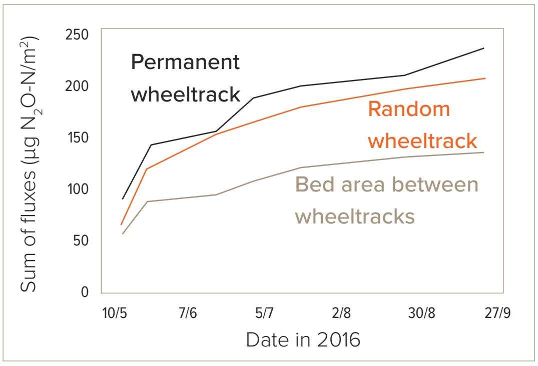
Nitrous oxide (N_2O) (sometimes called ‘laughing gas’) is a potent GHG with a global warming potential of 296 relative to carbon dioxide (CO_2).

Soil compaction reduces aeration and water infiltration and increases the risk of very wet or waterlogged soil. Compacted soils emit more N_2O than non-compacted soil because the anaerobic conditions that often develop in these soils favour microbes that can thrive in oxygen-depleted environments.

Under compacted conditions, if free oxygen levels drop below a critical level, these microbes obtain the oxygen they need by taking the oxygen atoms off molecules of nitrate (NO^{3-}) in the soil that would otherwise be available for plants to use. The resultant nitrogenous gases such as N_2 and N_20 are lost to the atmosphere, in a process called denitrification.



The graph shows the summed N_2O emissions from sampling at an LRZ site at Swan Hill in the very wet year of 2016. While in this case the permanent wheeltracks and the single non-CTF wheel pass lost about the same amount of N_2O, the random wheeltrack emission of 230µg of nitrous oxide is 72 per cent higher than the 134µg lost from beds. That difference between emissions from CTF beds and random wheeltracks was relatively small. In many of the other 14 trials the difference was more than double.



Sum of N_2O.
Swan Hill, Victoria. Lat. -35.4 Long. 143.6 2016 Growing Season Rainfall 197mm. Barley yield 4.5t/ha

Reduced greenhouse emissions

Emissions are highly variable due to differences in N availability and fertiliser rate, timing and product used, but at the Swan Hill site CTF beds emitted 0.42kg/ha N_2O. In terms of greenhouse gas equivalents, if the paddock was 100 per cent un-wheeled this equates to releasing 125kg/ha of CO_2 into the atmosphere. Permanent CTF traffic lanes emitted 0.97kg/ha N_2O, or 289kg CO_2/ha if the paddock was 100 per cent trafficked, while random passes emitted 1.25kg/ha of N_2O, or 372kg of CO_2/ha.

CTF systems often have wheeltracks on only 12 per cent of the paddock area, with 88 per cent always untrafficked. Using the calculation (125 x 0.88) + (289 x 0.12) = 110 + 34.68 such a paddock emits the equivalent of 144kgCO_2/ha. In contrast, a non-CTF paddock that is 50 per cent wheeled emits the equivalent of 211.5kgCO_2/ha. [(125 x 0.5) + (289 x 0.5) = 62.5 + 149].

The difference between the CTF and non-CTF systems is 67.5kgCO_2/ha in wet situations. The adoption of CTF on 68ha is equivalent to taking a typical passenger vehicle off the road for a year. [https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle]

Cost of nitrogen losses

These results make it possible to do some 'educated estimations' of the extent and costs of denitrification in compacted soil.

The N_2O component of the total N loss is small but it is easier to measure than nitrogen gas (N_2), because the air is already comprised of 70 per cent N_2. During denitrification, there is 10 to 70 times more N_2 lost than is lost as nitrous oxide (N_2O). To make some general calculations we will use a factor of x30 and the average increases of N loss from compacted soil compared to non-compacted, measured across all 15 trials.

In the trials, CTF beds emitted 0.42kg/ha of N_2O. If this amount is multiplied by 30, we get an estimated loss of 12.6kg/ha of nitrogen. Using the same method we can calculate the losses from permanent wheeltracks and random passes. Permanent CTF wheeltracks emitted 0.97kg/ha of N_2O, indicating an estimated loss of 29.1kg/ha of nitrogen and random passes emitted 1.25kg/ha of N_2O, a loss of 37.5kg/ha of nitrogen.

Using the results above on a CTF system with 12 per cent wheeled area, the average amount of nitrogen lost from the paddock would be 14kg/ha. However, if 50 per cent of the paddock is subjected to wheeled traffic, as is common in non-CTF systems, the nitrogen lost rises to 25kgN/ha, and if 100 per cent of the paddock is wheeled, the loss is between 29 and 37kgN/ha.

The conclusion is that, in the conditions experienced over the 15 trials and on average across the range of environments, adopting CTF and reducing the wheeled area from 50 per cent of the paddock to 12 per cent could save 10.6kg/ha of N per growing season, and changing from 100 per cent wheeled to 12 per cent saves 23.0kg/ha of N.

If urea (46 per cent N) costs $400/t on-farm then 1kg of fertiliser nitrogen costs $0.87. A change from a non-CTF (50 per cent wheeled) system to CTF (12 per cent wheeled) will save $9.20/ha. If the non-CTF system is 100 per cent wheeled, the saving as a result of implementing CTF will be $20/ha. Repeating these calculations using a urea cost of $500/t on-farm, means the value of implementing CTF ranges from $11.55 (50 per cent wheeled) to $25/ha (100 per cent wheeled).

USING PENETROMETERS TO MEASURE COMPACTION IN LRZ SOILS

Key points

- Soil resistance is a key factor in limiting plant performance. Zones of high soil resistance in the profile are often layers of soil compacted by heavy machinery traffic.
- Land managers can use push rods and penetrometers to compare soil resistance throughout the crop root zone at a point in time and can be used to identify the depth of compaction.
- Measurements taken when the profile is near field capacity soil moisture provide the best indication of whether soil resistance is likely to restrict crop root elongation and potentially reduce yield.
- Farmer groups can use a penetrometer across many sites to expand their understanding of soil resistance in known trafficked and untrafficked areas and the effect of amelioration works on local soil types.

Penetrometers and push rods are valuable tools to demonstrate differences in soil structure and strength under different machinery traffic regimes such as on and off wheeltracks in CTF systems, different soil types across a conventionally farmed paddock and between ripped and non-ripped soils.

Push rods are the most rudimentary tool available to 'measure' soil resistance in the soil profile. The push rod (e.g. a pointed metal rod of a recommended diameter with a T-handle welded to the top) is simply pushed into the soil until it becomes hard to push, indicating is that it is also hard for roots to grow in that zone of the profile. By applying more pressure it is sometimes possible to push through the compacted layer to estimate the thickness of the layer.

A more scientific version of the push rod is a cone penetrometer, which has a pressure gauge mounted on it and markings on the side to show how far into the soil the rod has travelled. As with the push rod, the operator applies an even downward force to push the penetrometer into the ground while noting the changes in pressure required to move the rod through the soil profile.

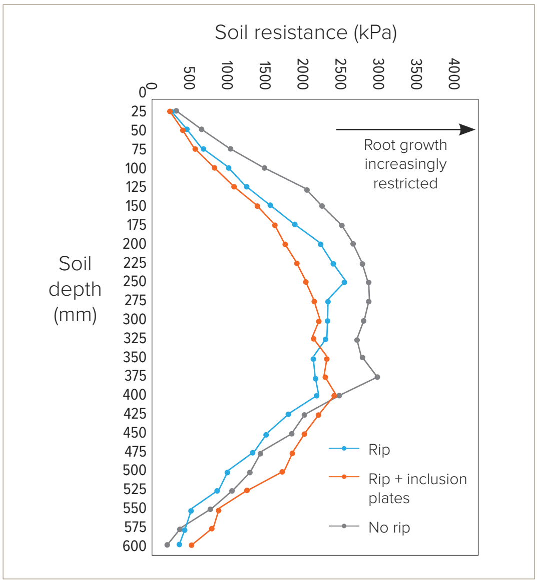
Modern penetrometers have digital capability to record soil resistance at regular intervals as the shaft is pushed into the soil. The addition of Bluetooth technology to the penetrometer allows data to be more easily downloaded and some penetrometers have screens that allow the data to be viewed while it is being collected.

The data collected can be used to generate graphs, making it easy to compare treatments or areas within a paddock.

In 2009 researchers Whitmore and Whalley showed that plant root elongation is unimpeded when the soil strength is below 2000kPa. Finding the depth at which resistance exceeds 2500kPa can indicate the presence of a compacted layer that would be expected to restrict plant root growth.

While the critical pressure varies between species, plant roots become unable to extend into a soil when the resistance is in excess of 3000kPa.

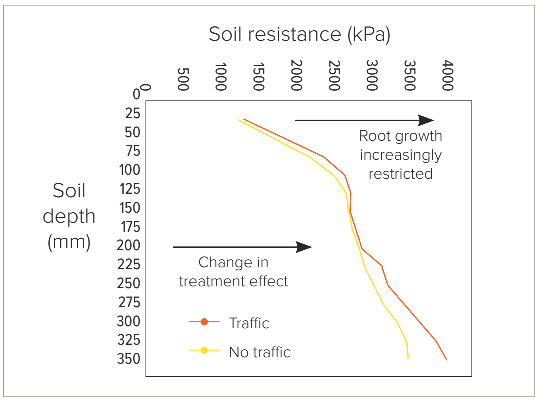
Soil moisture can strongly influence resistance, so penetrometer measurements are best taken when the soil is at field capacity (i.e. after heavy rainfall when the profile is full).



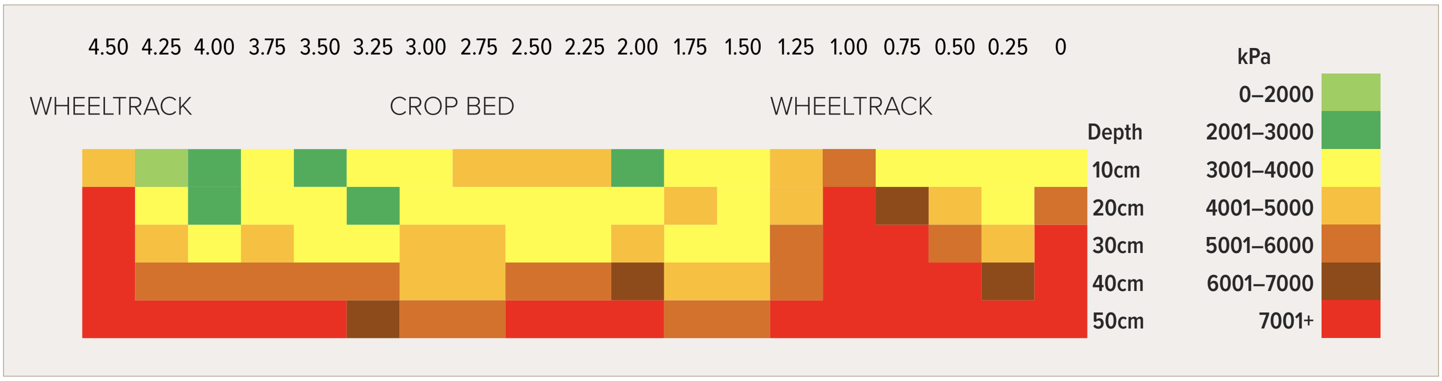
Graph showing deep ripping treatment (Rip), deep ripping with inclusion plate (Rip +) and the unripped control (No Rip), in a deep ripping trial at Paruna, SA.

The digital penetrometer identified the point where the effect of trafficking treatments became apparent, which occurred in this example at a depth of 200mm (see graph).

In a CTF paddock, the variation in soil strength as measured along a transect using a penetrometer can be shown visually, with the areas in red being extremely restrictive (see diagram). The red zones toward the top of the profile correspond with known wheeltracks within the site.



Compaction depth noted at 20cm as this is the depth at which the treatments, traffic and no traffic begin to differ in resistance.



Manipulated data showing soil resistance readings taken along a transect every 25cm.

SOIL STRENGTH v BULK DENSITY

Bulk density (BD) is the weight of the soil in a given volume.

The most common method of measuring soil BD is to press a metal ring into the soil to extract an 'intact core', and determine the weight after drying (McKenzie et al., 2004).

Because the soil is dried to measure BD, soil moisture at the time of sampling does not affect the result.

Plant roots are restricted in soils with high BD, which may be linked to soil compaction.

Soil strength or resistance is a measure of how hard soil is to break apart or push through.

It is most commonly measured using a penetrometer and readings are affected by the soil moisture at the time of sampling.

Soil with high bulk density will have low soil strength when the soil is saturated. A soil with high bulk density will have higher soil strength than a low BD soil at the same moisture level.

Comparisons can therefore be made between treatments at the same site (and soil type) where measurements are taken within a short time frame to ensure similar soil moisture levels across treatments.

YIELD DIFFERENCE ON AND OFF THE WHEELTRACKS IN LRZ SOILS

Key points

- On average, a 14 per cent yield penalty was observed in wheat sampled on the wheeltracks compared to wheat growing in untrafficked soil, at sites across the southern LRZ with varying soil types and machinery operating.
- Calculating the change in area trafficked between a current farming system (e.g. 60% trafficked) and a proposed CTF system (e.g. 12% trafficked) and using the trafficking yield penalty for wheat, the estimated yield benefit across a farm is 7 per cent.

Previous work has detailed compaction yield penalties in trafficked soil, compared to untrafficked soil. Blackwell et al (2004) reported a 15 to 50 per cent yield penalty in compacted wheeltracks on sand, sandy loam and clay soils in Western Australia, and Tullberg et al (2007) reported a 15 per cent penalty in the black self-mulching vertosols of southern Queensland.

With little work previously undertaken to understand yield penalties in the southern LRZ, this study aimed to shed light on the effects of compaction on yield and estimate the yield gains that may be expected if a CTF system is implemented in this region.

For three years (2016 to 2018) grain samples were collected from 70 sites representing varying soil types, crops and equipment, and were assessed to answer the question: Can we understand compaction effects on yield in the southern LRZ?

Samples were collected from paired rows, taking five 1m cuts along a wheeltrack and its paired untrafficked row. These samples were then measured for grain yield and harvest biomass.

Due to low sampling numbers of barley, vetch and oats statistical analysis of the data from the 70 sites indicated that, from this data set, only samples from wheat crops could be used.

Exploration of data using the restricted maximum likelihood (ReML) model showed that soil class did not have any significant effect on yield or harvest biomass.

Results showed that there was a 14.23 per cent yield penalty when looking at wheat grown on trafficked soil compared to untrafficked soil, across all soil types, geographical areas and specific wheeltracks.

It is important to remember this study only measured wheat yield, includes data collected from four different geographical regions, covering soil types from deep sands, to duplex, to heavy clays, and can only be used as a rough guide.

Understanding current paddock trafficking is the first step in ascertaining possible yield benefits when implementing a CTF system. The CTF Calculator can be used to estimate the percentage of a paddock that is trafficked under a current farming system. The calculator can also be used to estimate the percentage of the paddock that will be trafficked under a proposed CTF system. CTF Calculator

The difference in these two percentages can be multiplied by the 14.23 per cent yield penalty to give the overall yield benfit that could be expected if the CTF system were implemented. The following table provides some example results.

Reduction in paddock trafficking when converting to a full CTF system and associated yield benefits across farm

Farming system	Trafficed % in current system	Trafficked % in a fully matched CTF system*	Reduction in trafficking (%)	Yield penalty tracked (%)	Benefit of moving to a full CTF system (% yield increase across farm)
Conventional**	60	12	48	14.23	6.83
Guidance (AB lines)	45	12	33	14.23	4.69
Compromise CTF system***	18	12	6	14.23	0.85

* 1:3 system, where the header and seeder are one-third the width of the boomspray
** no guidance, no machinery matched
*** 1:2:3 CTF system in which the header is a third of the width and the seeding bar half the width of the boomspray (Hagan, 2015)

In very general terms, using this table, we could estimate that when growing a wheat crop, moving from a conventional farming system to a full CTF farming system, in the LRZ of southern Australia, and with an estimated reduction in wheel trafficking of 48 per cent, there could be a 6.83 per cent increase in yield across the crop, due to reduced soil compaction and crushing damage of the crop in season.

More data needs to be collected to be able to understand the role soil type, wheeltrack type and geographical area might influence wheeltrack yield penalties.

TRAFFICKING EFFECTS ON SOIL MICROBIOLOGY IN LRZ SOILS

Key points

- Trafficking has a negative effect on soil microbiology and nutrient availability on coarse textured Mallee sands.
- Trafficking Mallee sands reduces Arbuscular mycorrhizal fungi (AMF) colonisation, potentially reducing the efficiency of crops in their uptake of phosphorus from the soil.
- Trafficking effects soil biology and yield more on coarse textured Mallee sands than on calcareous alkaline red sandy loams.

Soil habitat condition, i.e. pore size and pore-network structure and associated water availability, are known to influence the population and functional capacity of soil biota with subsequent implications to plant growth and productivity.

However, there is little known about the effect of CTF on soil biota (beneficial and pathogenic) or the biological processes involved in nutrient availability and uptake in an Australian grain cropping context.

During the 2018 crop season, the impact of trafficking on soil biological functional capability related to nutrient cycling and uptake, as well as root health, was investigated in ongoing field experiments at Loxton on Mallee sand and at Minnipa on a calcareous red sandy loam, in the LRZ. A functional microbial ecology approach was used to identify any changes in:

- microbial biomass and microbial catabolic diversity,
- N mineralisation and specific functional groups of soil microbiota involved in N mineralisation and P uptake,
- plant pathogens, and
- nematode fauna

between trafficked and untrafficked soil at these two sites.

Since the soil biological status that seedlings experience strongly influences the overall plant health and nutrition, the biological properties were studied close to sowing of cereal crops. These were supplemented with measurements of root health and mycorrhizal colonisation at GS31 crop growth stage.

Results from the experiments at Loxton and Minnipa indicated that surface (0 to 10cm) soils generally harboured higher total microbial biomass, total bacterial and fungal populations and populations of microbial groups involved in carbon and nutrient cycling, compared to soil at a depth of 10 to 20cm. For example, approximately 64% of microbial biomass carbon was located in the surface 10cm soil at both sites.

In this study, the effect of trafficking on N supply potential showed significant relationship (r2 = 0.89) with crop yield. The negative effects of soil compaction from the wet trafficking treatments on microbial properties, i.e. microbial biomass, bacterial and fungal populations, catabolic diversity and AMF colonisation suggests plant nutrition (N and P) related constraints, coupled with poor root health, would have played a key role in the lower crop yields, in particular in the Mallee sands.

Plant available mineral N levels in soils are modulated by the amount and turnover of microbial biomass and the activities of various N cycling functional groups of microbial communities.

Overall, the functional microbial ecology approach used in this study targeting soil biological functional capacity related to plant nutrition and health, clearly demonstrated that the effects of different trafficking treatments on soil health and cereal crop performance vary with soil type. For example, coarse textured Mallee sands are more susceptible to traffic-induced disruption to soil biological processes than the calcareous alkaline red sandy loams in the LRZ.

Mallee sand – Loxton

Trafficking effects on soil biology were most evident in the surface 0–10cm soil at Loxton. There was a significant negative effect of trafficking treatments such as 3-pass wet compaction, on microbial biomass (-26%) and N supply potential (-27%) compared to the CTF (untrafficked) control.

The 3-pass wet trafficking reduced both the microbial activity and catabolic diversity compared to the soil in the CTF Control treatment.

The 3-pass wet also reduced populations of total bacteria and fungi and microbial functional groups involved in organic N mineralisation, including nitrifying bacteria, but trafficking treatments did not influence non-symbiotic N2-fixing bacterial populations.

Trafficking treatments also reduced the arbuscular mycorrhizal fungi (AMF) inoculum levels by 23 to 49 per cent and their colonisation of wheat roots by 25 to 79 per cent.

Results observed in the Mallee sand at the Loxton experiment clearly indicated that trafficking (especially 3-pass wet), reduced the capacilty of the biological component of the soil to fulfil the necessary functions.

This resulted in a grain yield reduction under the 'wet trafficking' treatments of 26 to 56 per cent compared to the yield in the control treatment (1.55t/ha).

Calcareous red sandy loam – Minnipa

The different trafficking treatments did not cause any reduction in microbial biomass in the Minnipa experiment. However, deep ripping caused a significant reduction in the microbial activity compared to soils in the control and wet trafficking treatments.

Deep ripping and dry compaction significantly reduced the AMF inoculum by 32 and 22 per cent respectively, but there was no effect on percentage of root colonisation.

No significant effect of trafficking on wheat grain yields during the 2018 crop season at Minnipa.

Arbuscular mycorrhizal fungi (AMF) form symbiotic relationships with plants and are important in the health of many crop species, functioning in the efficient acquisition of plant nutrients such as phosphorus and zinc from the soil, especially in alkaline and calcareous soils.

Because of their extensive hyphal networks in soil, the adoption of conservation agriculture with reduced or no-till has been beneficial for AMF and their activities but different traffic systems that can modify soil physical structure could potentially affect the formation of hyphal networks and consequently nutrient (e.g. P and Zn) uptake.

GLOSSARY OF COMMON CTF TERMS

Aircart – pneumatic seeding system that holds, meters and delivers seed and fertiliser to seeder openers.

Airseeder – an aircart and 'bar', on which the seeder openers are mounted.

Autosteer – (see Precision autosteer) technology that automatically steers vehicles or implements.

Axle load – the weight supported by a single axle.

Banded spraying – spraying a narrow width to be on, or between, a crop row.

Boomspray – another term for a sprayer to apply crop inputs such as herbicides and fungicides.

Broadcast seeding wheeltrack – crop seed dropped on to the soil surface along the wheeltrack and pressed into the soil by the seeder wheel, rather than burying the seed using a seeding implement. Sometimes referred to as 'fuzzy wheeltracks'.

Bulk density – dry weight of soil for a known volume, often expressed in grams per cubic centimetre (g/cm3).

Controlled traffic farming (CTF) – a farming system where all heavy traffic is confined to permanent wheeltracks, which are either sown with crop or left bare, so the crop zone and traffic zone are permanently separated.

Crop zone (also 'bed') – the uncompacted soil between wheeltracks that is managed for optimum plant establishment and root growth.

Deep ripping – tillage that digs to depths greater than 20cm to break through a compacted hard pan or distinct constraining layer, to allow root access deeper into the soil profile and increasing plant uptake of water and nutrients.

Delving – bringing clay from the subsoil to the soil surface with specially designed tynes.

Denitrification – the reduction of nitrate (a compound) to nitrous oxide and nitrogen (gases) by soil microbes living in anaerobic soil conditions (i.e. compacted soil).

Dispersive soils – soils where the clods collapse when the soil gets wet because the clay particles disperse into solution (these soils are commonly sodic and have high amounts of exchangeable sodium on the clay).

Duplex soils – soils that have distinct layers with contrasting textures, for example sand over clay or gravel.

Electrical conductivity – ability of the soil to conduct an electrical current. Commonly used as a measure of salinity (often expressed as EC in millisiemens per metre).

Fuzzy wheeltracks – see 'Broadcast seeding wheeltrack'.

Grade bank – a form of earthworks for surface water control following a gradient.

Header – another term for a harvester.

Inter-row – zones between crop rows that are defined accurately (to a few centimetres) and can be easily used for inter-row sowing using an offset hitch, or minor adjustments to the guidance system.

Inversion ploughing/mouldboard ploughing – the top portion of the soil profile is mechanically inverted, burying the topsoil and bringing subsoil to the surface.

Normalised Difference Vegetation Index (NDVI) – a measure of plant greenness that indicates crop growth or vegetation cover using remote sensing technology. The index is calculated from the level of red light absorption and near infrared light reflection by plants.

No-tillage/minimum tillage (also zero-till, no-till, min-till) – a farming system that aims for minimal soil disturbance. Zero or minimal seedbed preparation, mechanical weed control or incorporation of stubble or soil amendments.

Permanent wheeltracks (also called traffic lanes, tramlines, trams, wheel ways) – permanent tracks that the wheels of all heavy machinery are confined to in a CTF system.

Porosity – measure of water or air-filled pores in the soil (this typically decreases with depth).

Precision autosteer – (see also 'Autosteer'), using real-time kinematic (RTK) positioning correction to provide nominal 2.5cm precision.

Seeder – implement used for sowing crops.

Self-repair – the ability of a soil to repair from physical damage through the shrinking and swelling of clay particles in response to soil moisture.

Spader – implement with rotating spade attachments to coarsely mix topsoil and subsoil.

Sprayer – see 'boomspray'.

Subsoil/subsurface – the zone in the soil profile under the topsoil and above residual bedrock, sediments and the like. The subsoil usually lacks organic matter and is often paler in colour than the topsoil.

Tramline – (see 'Permanent wheeltrack').

Tramline farming – see 'Controlled traffic farming'.

Water holding capacity – the amount of water held in the soil after drainage under gravity.

Wheeltrack centre or Gauge – the distance between the centrelines of the left and right wheels on an axle.

Wheel base – the distance from the centre of the front axle to the centre of the rear axle.

Wheeltrack – see 'Permanent wheeltrack'.

Guidance terminology

Accuracy – a statistical measurement of 'freedom from error', or how close a measurement is to the true but unknown value.

Baseline – the distance between the base station and the rover/tractor.

Cross-track error – the distance from the current wayline measured at right angles to the wayline.

GNSS – Global Navigational Satellite System (GNSS) – this is a replacement term for GPS and refers to a constellation of satellites providing signals from space to transmit positioning and timing data.

Global Positioning System (GPS) – a network of orbiting satellites that send precise radio frequency data that allows positions on earth to be calculated. These signals are obtained by GPS receivers and are used to calculate the position, speed and time at a vehicle's location.

Horizontal Dilution of Precision (HDOP) – describes how satellites are positioned around the globe (the lower the HDOP the better the position accuracy).

Implement steering – technology to steer an implement.

Marker arms – mechanic guidance that is essentially a length of steel attached to the edge of a seeder to mark the middle of the next seeding run on the ground.

Precision – how small a unit the instrument can measure.

Racetrack – working around and around.

Real Time Kinematic (RTK) – a technique used to improve the precision of position data from a satellite network (GNSS) using a known reference point or base-station to calculate the real-time position to centimetre accuracy.

Repeatability/repeatable accuracy – a statistical measurement of the accuracy with which a user can return to a previous position.

Wayline/A-B line – the line between two points that sets the initial direction of travel and subsequent path of travel parallel to this line.

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Key resources

Australian Controlled Traffic Farming Association. http://actfa.net/

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Useful links

GRDC Ground Cover 'Soil Constraints' supplement: Groundcover issue 118 Soil Constraints. https://grdc.com.au/resources-and-publications/groundcover/ground-cover-supplements/ground-cover-issue-118-soil-constraints

DAFWA 'Soil Compaction overview' hub. https://www.agric.wa.gov.au/soil-compaction/soil-compaction-overview

DAFWA 'The Science of Soil Compaction' hub. https://www.agric.wa.gov.au/soil-compaction/science-soil-compaction

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Grains

WACTFA Facebook group. https://www.facebook.com/groups/1292198200824881/

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GROWER SURVEY RESULTS

A survey of southern LRZ growers was conducted at the beginning of this project in 2014 and again in 2019. There were 101 valid responses to the survey, with 75 per cent of respondents completing both the 2014 and 2019 surveys. Almost 49 per cent of respondents to the 2019 survey were cropping over 2000ha.

Between 2014 and 2019, there was an 11 to 35 per cent increase in grower awareness of CTF across five LRZ regions and there has been a 15 to 20 per cent increase in the number of growers using CTF-related farm machinery practices.

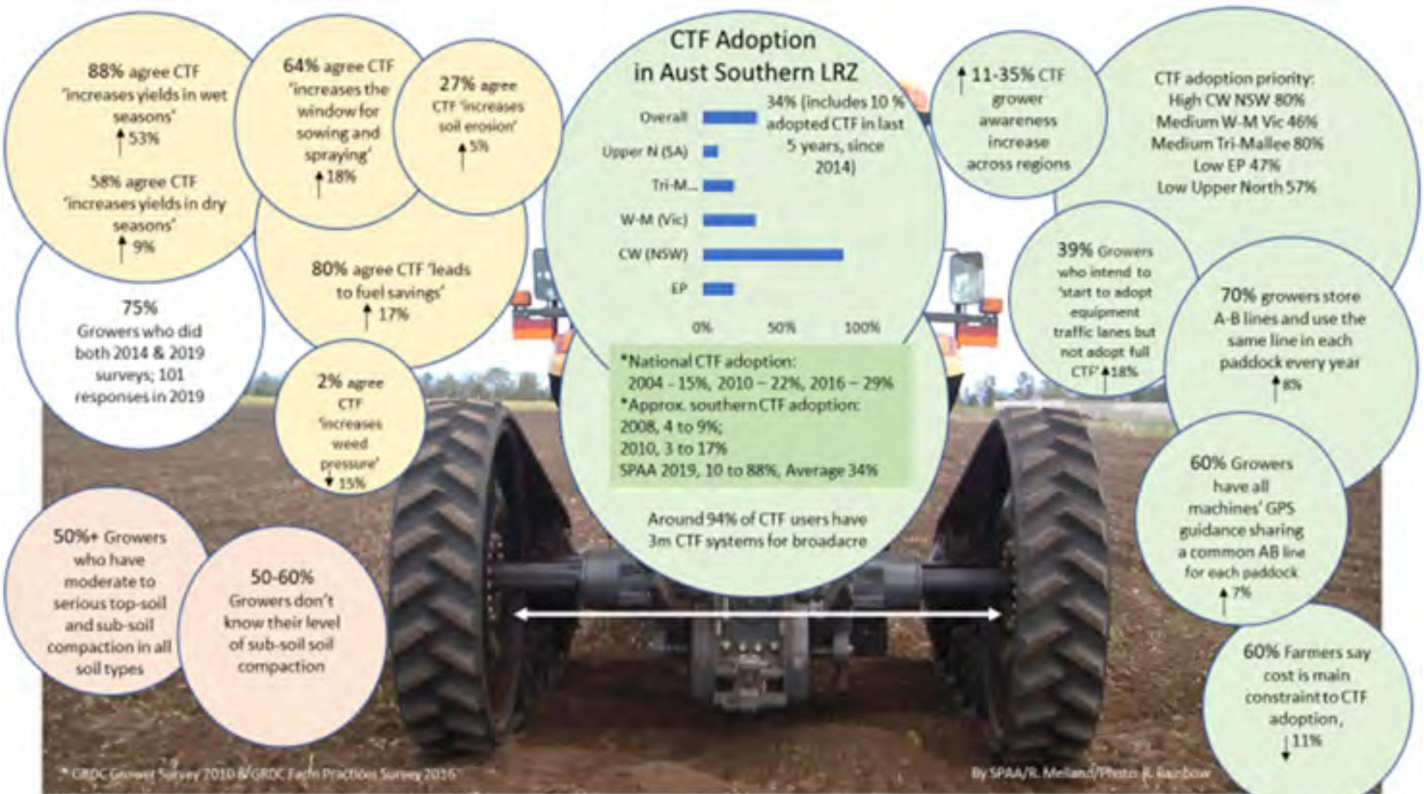
Over 50 per cent of growers have moderate to serious compaction in either the topsoil, subsoil, or both, in all soil types. CTF adoption in the southern LRZ is 34 per cent, including 10 per cent who adopted CTF over the last five years.

The largest shifts in attitude between 2014 and 2019 were:

- 35% more growers agree CTF ‘increases yields in wet seasons’
- 18% more growers agree CTF ‘increases the window for sowing and spraying’
- 15% fewer growers agree CTF ‘increases weed pressure’.

The majority of LRZ growers believe that CTF:

- cost is their main constraint to CTF adoption (66% in 2019)
- ‘leads to fuel savings’ (80% in 2019)
- ‘improves soil health’(74% in 2019)
- ‘improves infiltration and plant available water’ (73% in 2019)
- ‘increases yields in dry seasons’ (59% in 2019)
- ‘improves emergence and crop uniformity’ (58% in 2019).



Australian Controlled Traffic Farming Association Inc

AGRICULTURE VICTORIA

SARDI
Government of South Australia

SPAA
Society of Precision Agriculture Australia

GRDC
Grains Research & Development Corporation

BCG

CWFS
Central West Farming Systems Inc

SPAARF

Mallee Sustainable Farming

UNFS