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CTF: The Fundamentals

J.N. Tullberg, CTF Solutions and University of Queensland, Gatton

INTRODUCTION

The starting point for controlled traffic farming is blindingly obvious. 'Plants grow better in soft soil, but wheels work better on roads'. Research in the USA and Europe demonstrated the problems of random field traffic over 50 years ago, but large-scale adoption of controlled traffic by 1st world farmers has occurred only in Australia, and then only since the mid-1990s. Controlled traffic systems of one sort and another are believed to be in place on about 2Mha in Australia now.

Controlled traffic research was originally stimulated by the problems of soil compaction. Keeping all heavy wheels on permanent traffic lanes is essential, but it is only the first step in a much more profound system change, which goes well beyond dealing with soil compaction. Controlling traffic provides the improvements in efficiency, timeliness and soil structure necessary to reduce the waste of inputs and natural resource degradation inherent in conventional farming.

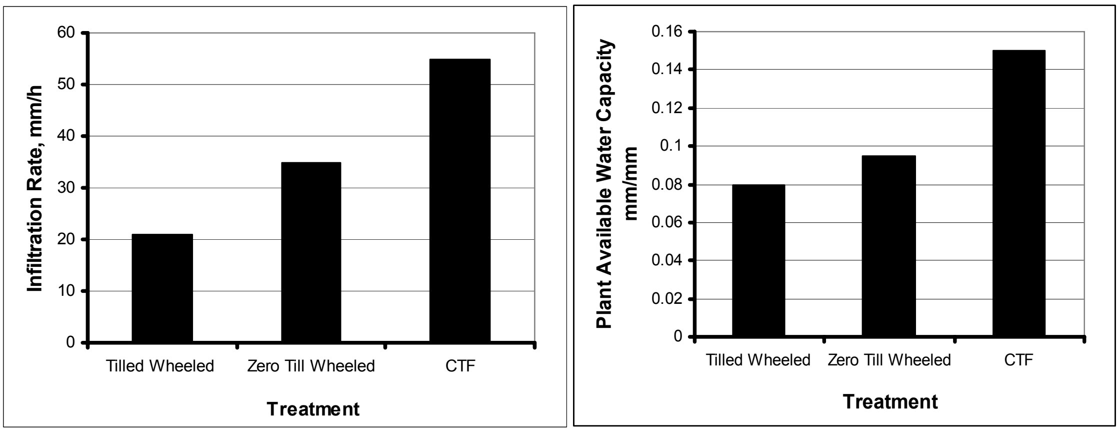
Controlled traffic farming-- CTF -- is a system to achieve greater productivity and sustainability from crop production in soil uncompromised by wheel traffic. Improvements in soil structure, field efficiency, or fuel use might still be an important motivator for adoption, but the outcome can be a truly revolutionary change in farming systems, providing major benefits to the economics of farming and to the broader environment.

The object of this paper is to summarise what we know to be important in terms of the science and practice of controlled traffic farming, and suggest future directions. It is important to note that most of the hard evidence to date is largely concerned with what we know already: uncontrolled wheel traffic causes major soil damage. What we know about practice generally coincides with that science, but all farms and farming systems are different. This conference is an opportunity to learn more about the technology, benefits and issues of CTF in different farming systems.

THE SCIENCE

Soil in optimum condition for plant growth is relatively weak and permeable. When a wheel or track rolls over that soil, it must compress or compact it until the soil is strong enough to carry this load. The processes of transmitting surface loads to lower layers of the soil are not straightforward, but it is generally accepted that tyre pressure is the most important factor in surface soil damage, but total axle load is a more important influence on subsurface damage, and the depth to which damage penetrates.

In most soils, natural processes of wetting, drying and biological activity will eventually repair that damage. This repair can be rapid at the surface, but it is much slower further down the profile. At a depth of 20cm, for instance the time the scale of repair is in years, even on 'self-ameliorating' soils. These natural processes, or tillage, can hide the surface damage quite quickly, but the subsurface damage persists. One of the major effects of this damage is on soil moisture. Tillage reduces infiltration of rainfall by destroying the surface's residue protection. Wheel traffic reduces infiltration by reducing the rate at which water can move down into the profile. Both these mechanisms increase runoff and soil erosion, particularly in high-intensity rainfall events, while reducing the total water getting into the soil. Wheeled soil has a larger proportion of small pores and holds on to moisture more tightly than non-wheeled soil, so a smaller proportion of this moisture is available to plant roots.



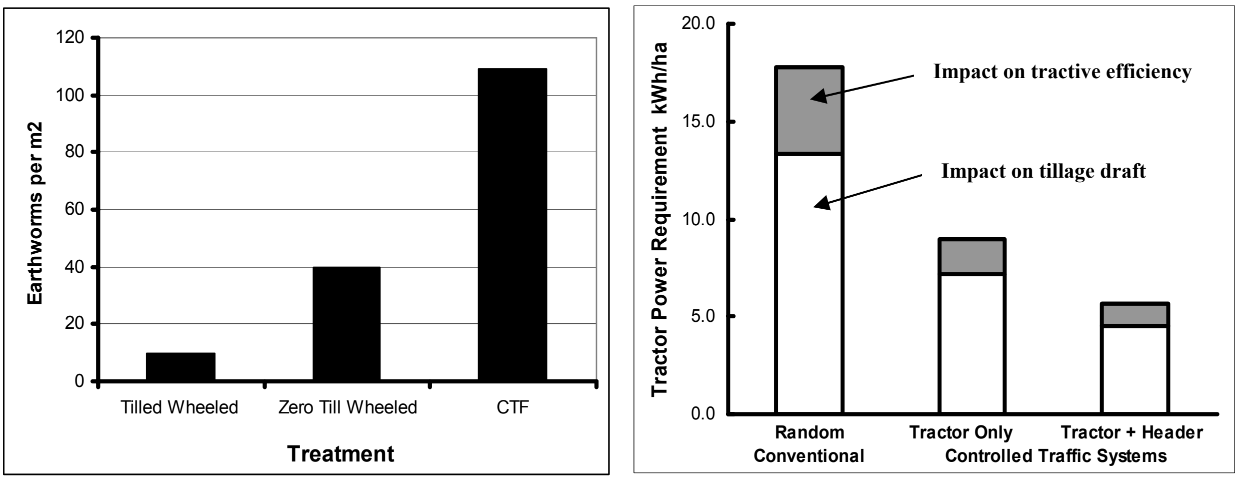
a) Iinfiltration rate during 80 mm/hour rainfall event

b) Plant available water capacity (0 - 30 cm after two years CTF.)

Figure 1. The impact of tillage and wheeling on infiltration rate and plant available water capacity.

The impact of tillage and wheeling (1pass/year by 2t tractor wheel) on infiltration rate and plant available water is illustrated in Figure 1, where conventionally farm soil (tilled and wheeled) is compared with zero tillage and random traffic and also with CTF (neither tilled nor wheeled). This data comes from Queensland's black vertisols, but broadly similar outcomes have been found in totally different soils in Victoria, in Western Australia, and other parts of the world. For all practical purposes, wheeled soil absorbs less rainfall and produces more runoff. It is more likely to get waterlogged, but capable of storing less moisture in plant-available form.

Most soil organisms do not enjoyed being dug up or squashed. Biological activity of all sorts -- from earthworms down to bacteria and fungi -- is much more plentiful in soil which has not been tilled or wheeled. The effect of one annual 2t tractor wheeling on earthworm numbers (mean, monthly samplings of top 15cm over two years) is illustrated in Figure 2a.



a) Impact of tillage and wheeling on earthworm numbers

b) Traffic effects on tillage/planting energy requirements.

Figure 2. Wheel traffic effects on soil biological activity, and power requirements of field operations.

More energy (or power) is needed to till wheeled soil, and traction is more efficient on permanent traffic lanes. These effects are illustrated in Figure 2b which compares the total tillage power requirement of random conventional traffic with that of controlled traffic systems, with just the tractor, and then both tractor and grain harvester 'in the system' (ie on the permanent traffic lanes). Impacts of tractive efficiency change (permanent lanes) and decreased tillage draft are shown separately.

THE PRACTICE

In uncontrolled 'random' traffic systems heavy wheels drive over at least 50% of paddock area per crop, causing damage at 30cm depth and below, so root zone damage is almost universal in cropped soils. People can often accurately claim they see no clear evidence of damage from heavy wheels—because the whole paddock is already damaged! Soil damage occurs instantly, on the first wheel pass. Second and subsequent wheel passes over the same soil do little further damage. On dry soil the surface damage is less severe, but the extreme wheel loads of larger grain harvesters can penetrate a long way down the profile.

Natural soil repair processes of wetting, drying and biological activity work from the surface down through the profile. At depths of 20 -- 30 cm, this occurs on a timescale of years. Growers report improvements in their soil after one year's controlled traffic, but improvements at depth continue for at least five years -- with positive yield effects resulting from increased plant available moisture.

Under the right conditions, deep tillage has sometimes been shown to have positive effects, but the cost is rarely justified by the results. Beneficial outcomes have been reported only where it has been used to deal with clearly identified problems, and carried out under the right soil moisture conditions. Tilled soil is always weaker, so a wheeled tilled soil is often in worse condition than it was before tillage. The most important step is to keep wheels off -- so nature and crop roots can do the work for you.

Controlled traffic and zero tillage are a perfect match. Eliminating the surface ruts and soil damage caused by harvesters and tractors gets rid of one of the major reasons for tillage, and a major frustration for zero till farmers. Hard, permanent traffic lanes make spraying faster and easier, and timeliness of operation is improved. This is largely a matter of bringing forward the window of opportunity for field operations after a rainfall event.

This window usually opens when paddocks become 'trafficable' after rain. Compacted permanent traffic lanes of CTF paddocks are usually trafficable for planting and spraying at least two days before random traffic paddocks. This increase in timeliness of operations can provide significant direct yield benefits, and many indirect benefits, such as improved herbicide weed control. Equally, it can allow a smaller CTF tractor and planter to complete the job ahead of a larger tractors operating in random traffic systems.

Controlled traffic farming uses less power to achieve greater production with healthier soil which provides more plant available moisture. Without wheel compaction, soil disturbance is required only where there is an identified need, and even then it will require a lot less energy than current tillage.

CTF also allows a new approach to runoff management. Runoff is substantially reduced on account of the greater infiltration capacity of non-wheeled soil. A properly designed layout of permanent traffic lanes (even without raised beds) can ensure that runoff remains distributed across the whole paddock, rather than concentrating into erosive flows. This is achieved by providing positive drainage, which -- combined with an undamaged soil profile -- is also effective in preventing waterlogging. For the high-rainfall situation, raised beds provide a positive insurance policy against waterlogging.

THE FUTURE

We know a lot about the problems caused by wheel traffic, and some of the direct benefits which occur when these problems are eliminated. We still don't know enough about the broader system effects, simply because nearly all of our knowledge -- whether derived from research or practice -- is based on the issues of cropping damaged soil.

We are learning more about the immediate challenges of controlled traffic, and the solutions. Australian farmers and their suppliers have been the major innovators in developing and adopting accurate guidance systems, moving to a common track width, and achieving modular working widths. These are the immediate requirements of lining up all heavy wheels on permanent laneways.

We are also learning more about the immediate benefits: more rapid access to paddocks after rain, more efficient, timely operations with less power, less unnecessary soil disturbance, more moisture, more planting opportunities and better crops. We are starting to see more possibilities of using yield maps and satellite images to improve systems that are no longer compromised and confused by random traffic effects.

We are starting to learn more about the integration of these opportunities, benefits and challenges but the whole topic has still to register properly on the institutional research radar. We are still too busy investigating the old problems of soil compaction etc to notice the new opportunities of better access to undamaged soil with precisely positioned tools. These opportunities will occur in plant breeding, fertiliser management and weed control.

Machinery is still a major limitation. Equipment would be lighter, and farming would easier and cheaper, for instance, if:

- Depth control was independent of load-bearing wheels, without parallelograms on everything.
- More accurate implement guidance could be achieved with drawbar equipment.
- An integrated, multi-bin 'commodity cart' approach was used for all field materials handling.

Some innovative companies are looking at some of these issues, but it is a slow process.

Controlled traffic farming is the integration of all the challenges and benefits of permanent traffic lanes and uncompromised soil, to achieve a more productive, profitable and sustainable agriculture. The objective is to optimise cropping systems in the absence of the constraints of random wheel traffic. This is a matter of taking advantage of the opportunities of improved timeliness and greater precision. For instance, interrow planting immediately after harvest when soil moisture is available; capitalising on the ability to access growing crops without causing crop damage; using greater precision to better target the application of fertiliser and herbicide.

The research institutions might eventually address some components of this challenge, but the system issues will have to be sorted out by farmers, individually and in groups, working with input from scientists and consultants. The Australian Controlled Traffic Farming Association should be an important catalyst for on-farm research of these issues.

On Tracks at Dookie

Mark Harmer, Dookie, Victoria

Harmer Farms is a family partnership (Mark & his wife, Leiticia and parents, Ray & Lynne), based at Dookie in North Eastern Victoria.

Our business is a continual winter cropping enterprise over 1600ha in a 525mm rainfall zone. Soil types include sand, loams (grey & red), heavy grey clays, black self-mulching clay, gravel, stones and rocks.

HISTORY

We started direct drilling in 1985 and more seriously in 1987 with a Shearer Trash Culti drill, 3.8mt @ 180mm spacing. At this stage we still had a mixed farming enterprise, approximately 700ha crop, hay, 1200 sheep and clover and legume seed production.

1990 - 80% of crop was no-till, using home made knife points;
1995 - Pulse crops were succumbing to disease and weed pressure. Soils were becoming compacted due to sheep and a lot of random traffic. We started deep ripping some of the lighter soils. We also started growing TT Canola after a failed Lupin crop. (3.8 seeder, 18mt boom)
1997 - very compacted soil, poor root development and low water use efficiency.
1998 - we changed to an Air Seeder with more tyne break out pressure, and deep banding on 230mm (realised we couldn't keep scratching it in!) Rotation: Wheat, Wheat, Triticale, Canola. (7.5m seeder, 18m boom)
2000 - Root development had improved with deep banding. We started seeding up and back, to try to help with spraying and spreading accuracy also experimenting with spraying out some of the wheel tracks to make later in-crop management easier. (7.5m seeder, 18m boom)
2001 - Started Tram lining. Used a Contractor with 2cm GPS to mark out 90% of paddocks. A recently purchased sprayer was extended by 2m (4 nozzles @ a cost of $100.00) to spray 22.5m tip on tip. This was 3 multiples of our 7.5m seeder. The spreader we were and are still using is more than capable of spreading this distance. Sold the last of the sheep!

Since 2001 we have simply maintained these wheel tracks. All seeding is done by eye (no marker arms), and so far, we are still maintaining a good level of accuracy.
Our wheel tracks are 1.75m, which may seem an odd figure but it allowed us to run inside the wheel equipment of our existing seeder, so that the seeder levelling is not compromised by sunken or bogged tramlines from previous years. Our rotation for the last four years has been Wheat, Wheat, Canola … not very exciting but quite profitable in our area.

ADVANTAGES

Our system isn't the product of a master plan or design layout, the only cost was $5.00 per ha for the contractor to mark out the paddocks at 22.5m and approximately $100.00 to extend the boom … the results have been fantastic.

Our soils are soft to walk on. We don't have any run off or pooling of water. Water use efficiencies have increased from approximately 14-15kg\mm in '95 to readily exceeding 25kg\mm. All hillside contour banks have been removed and we now farm these paddocks up and down the grade. Crop management is so easy with tram lining there just isn't an excuse not to optimize every opportunity. We can spray and spread whenever we need or want to. It is not uncommon for our wheel tracks to have up to 10 operations on them per year.

PROBLEMS

Our current seeder isn't capable of handling our large amount of cereal residue and we believe that our system is or has plateaued out until we can retain this resource.

WHERE TO NOW

We are currently assessing different disc or disc type combo seeders to be used in conjunction with 2cm guidance. In May, we EM Surveyed the entire property and are intending to vary rate Nitrogen this year, and all other fertiliser inputs going forward. 3m x 9m idea is rattling around in the back of our plans as well.

CONCLUSION

Just do it! We can't believe everyone isn't! Even if it is only making what you currently have work in some form of CTF the benefits will fund the bigger changes down the track!

A 20 Year Journey from Conventional Farming to Controlled Traffic

St John Kent, Farmer, Jimbour QLD

I farm 800ha of black soil country on the Jimbour flood plains, 30km north of Dalby growing dryland cotton and various grain crops.

To us, early controlled traffic data appeared to be encouraging, however it was not overly successful at first with 30% of the field being compacted by tractors on 2m spacings, the spray rig on 1.6m and the header on 3m. As a relatively small operation we could not justify some of the initial costs associated in completing the adoption of controlled traffic farming by converting all machinery to 3 meters.

To gain some economies of scale, we have formed a unique partnership with our neighbor by sharing and modifying the use of one set of suitable and desirable equipment for the two smaller farming enterprises. Initially we used wheel spacers to modify tractors to fit the 3 meter centres, but mechanical problems continued. As a result we followed the lead of Jamie Grant and extended our axels, now a common practice in the region.

Today we experience improved soil health with the disappearance of long fallow disorders, earthworms have returned, overland flooding of the old ages are just a memory as water infiltration has improved dramatically. Our mechanical operations are substantially more efficient and less time consuming. Our operational costs have been reduced with the elimination of larger, more powerful tractors and less wear and tear on all machinery. All of these have significantly impacted on gross costs and therefore net profits.

CTF – Positive perspectives in the Border Rivers Gwydir Catchment, NSW

Brooke Phelps and Jennie Spenceley, Conservation Farmers Inc.

Summary: A survey of farmers and advisers in the Border Rivers Gwydir Catchment Management Area (BRGCMA) was conducted to gather data on the area of Controlled Traffic Farming (CTF) within the catchment, the benefits and issues CTF farmers are realising and to give some insight as to why some farmers to not feel the need to adopt CTF. While the response rate was low and mainly restricted to Conservation Farmers Inc. (CFI) members, the survey indicated that approximately 300 000 ha out of 1.37 Mha (22%) of dryland cropping in this catchment, are under CTF. The results highlight that Controlled Traffic Farming (CTF) continues to deliver benefits of improved yields, profits, moisture infiltration and ease of management. The results also highlight weed control issues, deep and rough wheeltracks and wheeltrack erosion are often experienced. These issues need addressing so that farmers can realise the full potential of a CTF system.

Harnessing Interactions between Plant Roots and Soil Biology in Undisturbed Soil

Michelle Watt and John Kirkegaard, CSIRO Plant Industry, GPO Box 1600, Canberra 2601.

KEY MESSAGES

• Controlled traffic farming systems originally developed to reduce the compaction caused by random wheel traffic across farmed land. The impacts of excessive soil compaction on plant roots and soil organisms have been widely demonstrated and generally accepted, but we will briefly review them.

• Modern controlled traffic farming systems usually incorporate no-till or minimum disturbance principals and increasingly feature guidance systems for more precise placement of seed rows and other inputs. As a consequence we are farming increasingly undisturbed soil.

• Our scientific understanding of the interactions of plant roots and soil biology in undisturbed field soil is generally poor because most information about interactions of roots and soil organisms have been conducted in laboratory media, uniform soil in pots or in disturbed field soil.

• We will highlight some recent examples where new scientific techniques are beginning to shed light on the interactions between plant roots and soil organisms in undisturbed soil. This understanding will assist us to design farming systems which avoid negative interactions and harness positive interactions between crops and soil biology.

COMPACTION AND SOIL BIOLOGY

Compaction can affect the soil biology by direct physical damage to plant roots and larger soil fauna, or indirectly through changes in aeration, pore size distribution and soil water status which affect roots and a number of soil micro-organisms. The majority of these effects have been known for many years as summarized in Table 1.

Table 1 – Roots and soil organisms are influenced by compaction

Organism/s	Effect	Reference
Roots	reduced growth	Atwell (1990)
Pseudomonas	increased	Watt *et al.* (2003)
Springtails/mites/earthworms	decreased number	Aritajat *et al* (1977)
Bean root rot	increased	Burke *et al* (1972)
Sugarbeet nematodes	increased	Cooke & Jaggard (1974)
Phytophthora (corn)	increased	Allmaras & Dowdy (1985)
Soybean rhizobia	reduced nodules	Voorhees *et al* (1976)
Mycorrhizal fungi	reduced infection	Safi (1981)

These negative impacts of compacting loose surface soil can be readily reproduced in laboratory or pot studies and we understand much about how they can ultimately influence crop performance. Agronomic benefits have flowed from alleviating soil compaction by mechanical amelioration, and avoiding re-compaction through adoption of controlled traffic systems. Increasingly, these systems incorporate no-till so that the surface soil moves from a cycle of compaction, disturbance and re-compaction to a permanently undisturbed state, while the sub-soils are rarely disturbed.

WHAT DO ROOTS SEE IN UNDISTURBED SOIL?

Undisturbed soils generally develop a very heterogeneous structure with zones of high soil strength and many large cracks and pores within which roots can be constrained. Often previous roots have occupied these spaces which become niches that successive generations occupy. The soil around these "biopore" walls can be rich in micro-organisms. Direct contact between the roots of current crops and those from many previous crops can be substantial, and the dead roots can harbour many different organisms. This close association can influence nutrient transfer, disease infection, symbiotic interactions and many other unknown effects on plant growth. The picture we may get by removing a soil core and mixing it for nutrient or disease analysis will be a very different picture to what the roots are really seeing.

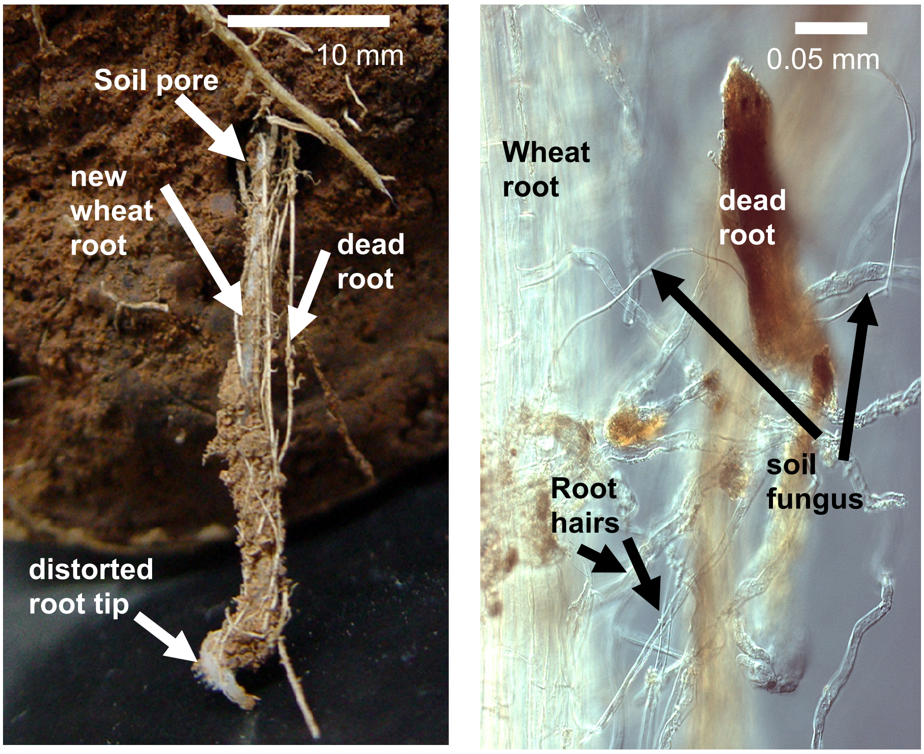


Figure 1: *Left*: Wheat root emerging from a pore in undisturbed soil, with many dead roots stuck to it. The growing tip is distorted and growing slowly from hard soil. *Right*: Microscopy view of intimate contact between crop roots, dead roots from previous crops, and soil organisms that occur frequently in undisturbed soil. (Images adapted from Watt et al., Functional Plant Biology, 2005)

THE HARDEN LONG-TERM STUDY - A CASE STUDY OF BIOLOGY IN UNDISTURBED SOIL

We have conducted a long-term study using no-till, control traffic principles at Harden in southern NSW since 1990 (16 years) and have compared many aspects of the soil biology in undisturbed, no-till system with that in a cultivated system. Despite improvements in most soil characteristics under long-term no-till as expected, the wheat crops consistently had reduced early vigour, an effect shown to be more widespread both across NSW and worldwide.

After investigating the usual suspects for reduced growth (temperature, nutrients, water, soil strength) the breakthrough came when we demonstrated that fumigation could overcome the problem – indicating the constraint was biological. Further investigations ruled out the major disease organisms but showed it was inhibitory bacteria called *Pseudomonas* specific to the root surfaces of wheat seedlings from direct-drilled sites that were reducing vigour – but how?

To understand how soil hardness and *Pseudomonas* bacteria were inhibiting growth we used new microscopy techniques to study the roots and associated soil organisms of intact field-grown roots. This revealed that most roots in no-till soil were constrained in cracks and pores made by previous roots and soil organisms, and grew much slower and distorted more than roots in cultivated soil. They accumulated the *Pseudomonas* bacteria on the slow-growing root tips (but not other bacteria), and the root tips were sensing the growth inhibiting substances and slowing shoot growth.

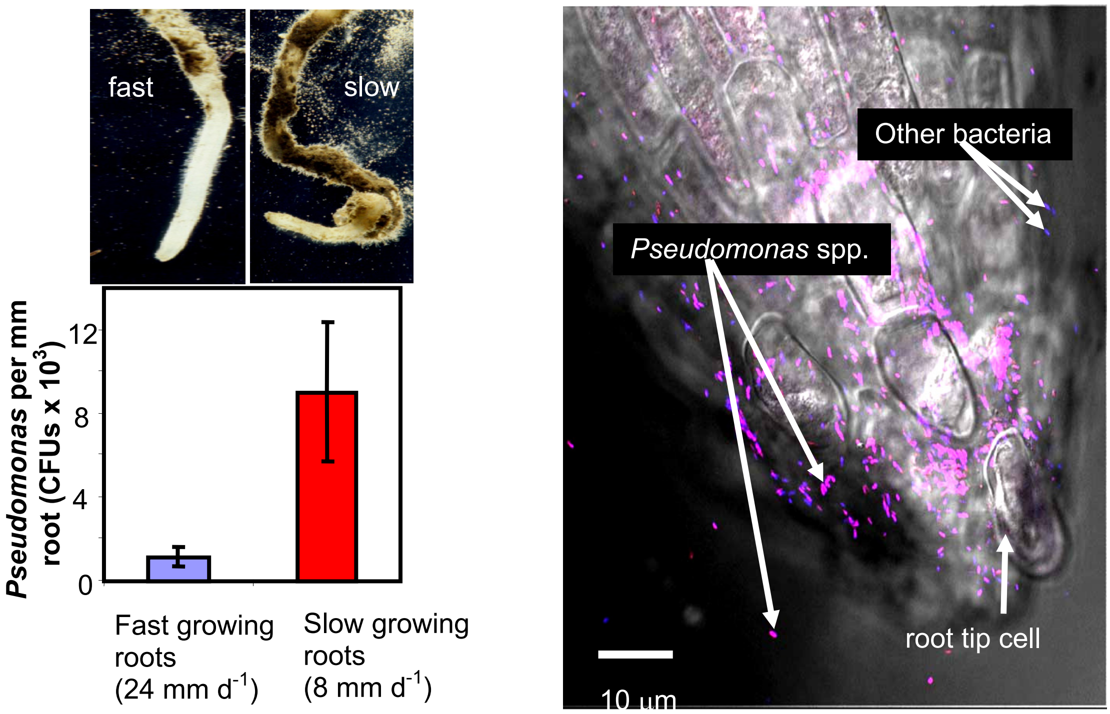


Figure 2: *Left:* Fast-growing wheat root tip from cultivated soil beside a slow-growing, distorted root from direct-drilled soil. The graph shows that slow-growing direct-drilled roots have higher numbers of Pseudomonas bacteria. *Right*: Wheat root tip with bacteria feeding off chemicals released from tip cells. Bacteria labeled with coloured probes. (Image adapted from Watt et al., Environmental Microbiology, 2006)

This exemplifies how important an understanding of soil biology in undisturbed field soil and its interaction with plant roots can be to explain crop response and develop solutions. These detailed studies finally explained how management strategies already used by growers such as early sowing into warmer soils and cultivation below the seed, reduced the negative impact of no-till. They also paved the way to investigate new cultivars of wheat and other crops with inherently fast root growth that may be better adapted to new undisturbed farming systems.

WHAT ABOUT PRECISION AND SOIL BIOLOGY?

Precision farming and controlled traffic provide an opportunity to control the placement of root systems – crop rotation in space rather than time. This has powerful implications for soil biology since the majority of potentially active soil organisms at sowing are stuck to dead roots from previous crops, and the new crop roots release carbon and signals that feed and stimulate these organisms. The net effect is a specific community of organisms very close to the new crop roots that can either inhibit (e.g. via diseases or toxins) or benefit crop growth (e.g. rhizobia and nitrogen fixation, nutrient mineralization, disease suppression, growth promotion). This contact is particularly high in undisturbed soils with high bulk density because dead and new roots are forced into the same spaces year after year (see again Images in Fiogure 1).

Reducing infection by root and crown diseases by controlling row placement in this way has been demonstrated by Matt McCallum in south Australia (see abstract in this booklet) and Steve Simpfendorfer in northern NSW (Northern GRDC Update 2005) with yield benefits from 5 to 10%. The approach was less effective under continuous cereals because enough inoculum remained in the original row position after 2 years to re-infect the crop.

Major disease pathogens may not be the only component of the soil biology which can influence plant productivity as demonstrated at Harden. Recently we started a project to investigate opportunities to improve the growth of successive wheat crops in undisturbed, no-till soil with a focus on rhizosphere bacteria. We are building on preliminary evidence that some wheat varieties perform better under these conditions, and that this is related to the different types of bacteria which accumulate around their roots. The differences are likely to be related to the different compounds released by the roots (carbon and signals that stimulate soil organisms) and the resulting profile of organisms left on root remnants. Opportunities may exist to manipulate these beneficial interactions using successions of selected varieties and/or manipulating row placement.

Controlled traffic and precision agriculture with no-till farming will benefit from better understanding about soil biology and roots in undisturbed soils. This will lead to many opportunities to manage the natural soil biology, and placement of introduced beneficial organisms such as inoculants.

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The Progression of CTF Systems on the Liverpool Plains

Ian Carter, "Connamara", Quirindi, NSW
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HISTORY OF CONTROLLED TRAFFIC FARMING (CTF) AND PRECISION AGRICULTURE (PA)

Our system has evolved from 2m (non matched) controlled traffic farming (CTF) in the early 1990s to 10cm accuracy auto steer in 2003. The CTF layout was re-designed using elevation data from topography mapping using an RTK GPS (2cm accurate). All equipment has been matched to multiples of 9m, and runs on 3m wheel centres. Wheel tracks are not cultivated or sown. Zero-till practices have now been used across Ian's farms since the 1980's.

Precision Ag (PA) equipment has gradually been upgraded to increase accuracy. In 1998 we purchased a yield monitor and GPS unit for guidance and yield mapping, and a light bar was used for spray guidance. In 2000 guidance with sub-1m accuracy was purchased, and in 2003 the John Deere auto steer system with 10cm accuracy was installed. With the addition of a base station this system can achieve 2cm accuracy.

"If I was starting today I would go straight for 2cm auto steer to gain all the benefits"

On our farm, we run all John Deere equipment. Due to difficulty in moving the displays and control units between the header, self-propelled spray rig and the tractor that pulls the Excel double disc planter, three units have been purchased.

"Having the same system in each machine is very useful for all members of the team, and the fact the system is based on one monitor makes learning how to use it much simpler."

In 2005/2006 summer crop, an average of 6.5t/ha was achieved across our farming country on only 51mm of in-crop rainfall. If we assume soil water storage of 220mm at planting (near the maximum), the Water Use Efficiency (WUE) was 38kg/ha/mm across the farm. We attribute this to the extra soil moisture storage from the CTF and zero-till practices allowing greater infiltration.

INVESTMENT AND RETURNS FROM CTF AND PA

The GPS on the self-propelled sprayer is not only vital for auto steer but also for precision spraying. Many of our paddocks have irregular shapes and, even with CTF, overlap on edges and headlands could not always be avoided, especially when using the 27m boom. The boom has five sections and we have purchased a Rinex auto-section controller, which switches off any boom section that is covering an area already sprayed.

"Basically the GPS continuously registers the location of each section of the boom, if that location has already been logged the controller switches off the overlapping section(s)."

The addition of the spray controller means there is no need to switch off the boom when turning, as it will automatically register that the headlands have already been sprayed. This allows the operator to concentrate on turning, eliminates misses and overlaps. Auto steer has also helped increase the accuracy of night spraying.

Although we have not used yield maps to create management zones we still finds the maps a useful management tool immediately after the season. As well as harvesting with our own machine, we use one or two contracted headers, all of which run the same yield monitor and software. Having the same systems means the data can be integrated and mapped using JD Office. We find these maps especially useful to assess areas of the paddock where we did not harvest.

"I use yield maps to assess trials and differences in management. For example, in an area of the paddock burnt by a neighbour's fire, we recorded a yield reduction of 2 t/ha, most likely due to the lack of moisture storage and subsequent evaporation without the stubble cover. Without a yield map we would not have quantified the impact of stubble removal."

WHERE TO FROM HERE

More education on the use of PA equipment is one area that I would like to see the industry develop. I feel most farmers using PA today have learnt by their own experience and then trained their employees. Having an experienced local dealer is invaluable.

I believe one of the biggest changes that are required for wider adoption of PA is in the area of software. I would like to see software that offers pre-operating check wizards and also that is more 'Windows' based. I would also like to see the creation of PA schools to provide employers and employees with an opportunity to learn how to strategically maximise the value of PA rather than learn by mistakes.

Soils: The Key Focus in Controlled Traffic Farming

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Abstract: Alleviation of soil compaction through controlled traffic farming (CTF) can lead to long-term improvement of many physical, chemical and biological processes that contribute to increased crop productivity. Results from a long-term trial on raised beds are used as an example of CTF to demonstrate the likely impact of the removal of compaction on soil and plant processes in the long-term. Since most of the cropping soils in question are inherently compacted or have undergone induced compaction through unsustainable farming practices, some form of initial tillage may be useful in restoring the lost porosity as a key to enhancing the beneficial soil processes, expected with the implementation of CTF.

INTRODUCTION

Crop performance in many farming systems in Australia and elsewhere are affected by dense subsoils. The high bulk density of soils can impact on rooting depth, water uptake and the storage of plant available water (PAW). Dense subsoils may be the result of an inherent soil characteristic, such as the case of volcanic soils where the process of weathering is slow and the large structural units are not easily broken down in the short-term. But equally important in the context of current farming systems is the induced compaction caused by overuse of machinery, intensive cropping, wet-weather grazing and inappropriate soil management practices. Controlled traffic farming (CTF) is considered to be one of the ways by which the impact of machinery on soil can be minimised. It also has the potential to assist other soil processes that in the long-term improve the physical, chemical and biological properties of soil.

It is estimated that soil compaction costs over $850m per year in lost production in agriculture (Walsh, 2002). Lowered production limits the addition of organic matter into soil, which is a key component in reducing the impact of compaction. The resulting low mineralisation can also increase the costs of crop nutrition. Increased compaction also increases the energy requirement in the use of agricultural implements. Therefore alleviation of compaction alone by CTF can lead to a range of benefits to the farmer. If a soil environment can be created for improved root proliferation, it may have the potential to ameliorate the subsoil through the process of biological drilling (Cresswell and Kirkegaard, 1995) by certain primer crops and the subsequent crops in the farming system are likely to exploit the additional porosity created by these primer crops (Elkins, 1985, Yunusa et al., 2002). The 'ideal' macroporosity of 15% for root growth and water infiltration (Cockroft and Olsson, 1997) is highly unlikely at depth in many agricultural soils in Australia and the conventional approach of improving macroporosity through tillage and ameliorants (Olsson et al., 1995) is often short-lived under conditions of indiscriminate trafficking. Controlled traffic farming therefore creates an enormous opportunity to explore root growth, soil structure, soil water movement and the role of primer plants under a completely different set of environmental circumstances that have evolved in recent times. This paper briefly examines some of the relevant work conducted in Victoria and elsewhere and explores possible amelioration options that could catalyse the soil processes under CTF when compaction is not a part of the equation.

SOIL PROCESSES IMPROVING PRODUCTIVITY

Soil structure and soil biology are both important components of a healthy soil. Therefore in the management of soils, our primary concern should be the facilitation of processes that lead to the creation and stabilization of the soil aggregates. In soils high in clay content, as is the case in most high rainfall zone (HRZ) soils in southern Victoria, the shrink-swell process plays a very important role in the creation of soil aggregates (Loveday, 1972; Sarmah et.al., 1996). This happens through the wetting-drying or freezing-thawing cycles that occur during climatic events. The stabilization of aggregates formed is, a process dependent on biological activity in the soil including those of roots, hyphae, bacteria and earthworms. Appropriate tillage also favours the creation and stabilization of soil aggregates (Oades, 1993) and may become a useful tool in dealing with soils that are severely compacted through long years of indiscriminate trafficking.

EVIDENCE OF 'BETTER' SOIL ENVIRONMENT

Raised beds as a form of CTF

Raised beds were developed by farmers in the HRZ to overcome the effects of waterlogging in a range of soils. By design, minimum tillage (MT) and controlled traffic (CT) are essential components of a raised bed farming system. In a farming systems trial conducted near Geelong in South-west Victoria, the hypothesis was tested that the crops on raised beds will experience a different root environment over time. A black self-mulching (BMV) Vertosol (Isbell, 1996) and a grey sodic Vertosol (GSV) behaved differently in response to MT, CT and the alleviation of waterlogging. Three years after the installation of beds, crops on raised beds experienced a lower bulk density and a consequent higher total porosity in the root zone compared to the flat (Table 1). These differences in soil structure were also detected below the depth of initial tillage (20cm) suggesting that processes other than the wetting-drying cycles were impacting on soil structure under the beds in the long-term. These processes may be explained in part by the processes that are triggered by the removal of compaction, compared to conventional farming practice (Holland, 2006). Three years after installation of raised beds, crops experienced an increase of 12 – 21% in the plant available water capacity (PAWC) to a depth of 40cm in the soil (Figure 1). Increases in PAWC of 34% associated with improved hydraulic conductivity below the depth of seeding have been reported by McHugh *et.al*., (2003) under CTF on Vertosols, which is consistent with our observations. The additional PAWC could result in a reduced impact on crop performance under conditions of below average rainfall.

Table 1. Measured differences in soil bulk density on controlled traffic raised beds under different farming systems and soil types relative to a flat perennial pasture. Negative values indicate a lower soil bulk density value in the corresponding depth under the raised bed system

Response area		**Depth Interval / Soil bulk density (g cm^{-3})**			
		0-10cm	**10-20cm**	**20-30cm**	**30-40cm**
Rotation					
	2x2	-0.15	-0.17	-0.25	-0.30
	4x4	-0.19	-0.13	-0.22	-0.23
	Continuous crops	-0.18	-0.02	-0.16	-0.23
Chi square probability **l.s.d. (P=0.05)**		**ns** **0.141**	**<0.05** **0.142**	**ns** **0.174**	**ns** **0.100**
Soil Group					
	Black Vertosol	-0.24	-0.18	-0.26	-0.37
	Brown sodic Vertosol	-0.11	-0.03	-0.16	-0.13
Chi square probability **l.s.d (P=0.05)**		**<0.05** **0.124**	**<0.05** **0.125**	**ns** **0.152**	**<0.001** **0.087**

The evidence suggests that depending on the inherent characteristics of the soil, the simple removal of long-term compaction alone could contribute towards the improvement of the hydraulic properties of the soil. The high soil BD would initially act as a deterrent to deep root penetration and to the access of soil water at depth. The roots would initially be confined to areas between the large structural units, not being able to exploit the volume of soil water trapped within. However, once compaction process is removed, root growth and the thorough exploitation of the profile for water would be facilitated by other processes such as wetting and drying taking place simultaneously in these clay soils (Oades, 1993; Whitebread *et.al*., 1998). If wetting and drying of the profile would occur regularly, it would be a trigger for aggregate formation and the general amelioration cycle to proceed, with plant roots gradually proliferating into the deeper layers of the soil. Because of the rapid drainage of excess water from the root zone, raised beds offer a good opportunity to set that wetting-drying cycle in motion.

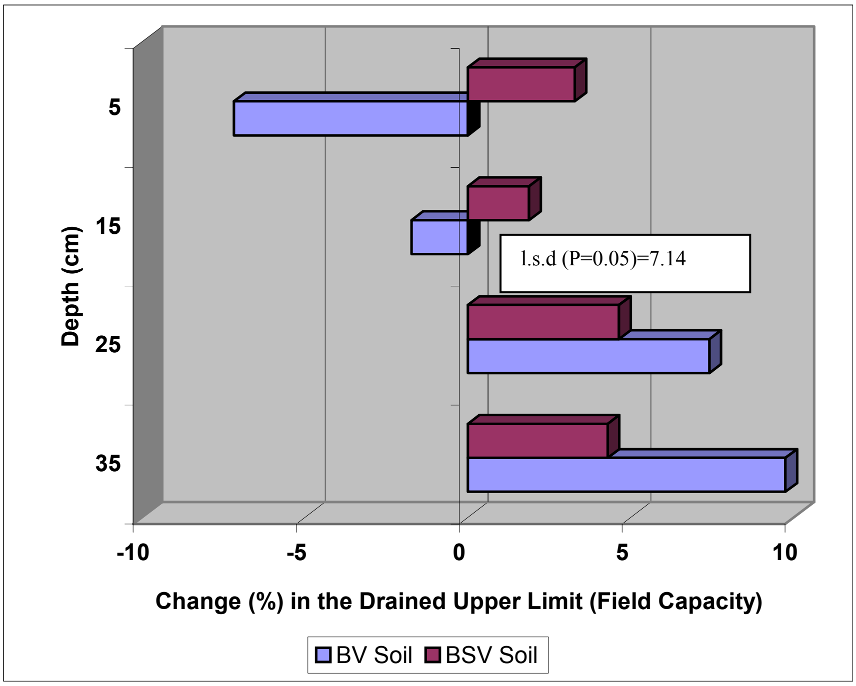

Figure 1. Measured differences in the upper level of plant available water (field capacity) in the black self-mulching Vertosol and the Grey sodic Vertosol to a depth of 40cm in the soil profile under CTF on raised beds.

TILLAGE OPTIONS IN CTF

As different soils behave differently, 'raising the bed' will not be the only solution to address inherent or induced compaction. However, 'controlled traffic bed farming' may still require the initial use of appropriate tillage to set the beneficial soil processes in motion in heavily compacted soils.

In agricultural situations where compaction is severe (bulk densities of 1.6 – 1.8 t m^{-3}) and soil organic matter is low, it is almost a necessity to create some disturbance at the surface to reopen the macropores between the large structural units of the soil. The soil disturbance must be sufficient to ensure that the displaced surfaces will not return to their initial position (Spoor, 2006) through swelling despite the absence of subsequent traffic. Such a disturbance of the soil referred to as a tensile disturbance (Hettiaratchi, 1987), can cause an overall reduction in soil density with little or no density change within the units themselves. In soils with low organic matter or in subsoils with high exchangeable sodium (sodic soils) addition of gypsum and/or organic matter may be useful in preventing the rapid return of soil into its original status (Hamza and Anderson, 2003). These ameliorants in the subsoil could contribute in several ways to the improvement of PAWC and the consequent higher harvest indices from crops both in the short and long-term.

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CT Farming Patchewollock

Peter Walch

My farm is situated in the Mallee region of North West Victoria. The soil type consists of mainly sandy loam to sand and the annual rainfall is 325mm, with the GSR at 220mm. The rotation is mainly cereals for example, W-W-B-W and I commenced tramline farming in 2003. The system is designed on 3m wheel tracks.
More operations are now occurring because of different farming technology and techniques, for example 4-6 spraying events per year. Auto steering and CT farming are a perfect fit. After repeated operations on your paddocks the logical step of matching your equipment size is obvious.

EQUIPMENT

- **12m air seeder bar with 300mm spacing**

The tractor currently being used in seeding operations has dual wheels, however looking to place the tractor on 3m-wheel spacing in the future. A 12 ton air seeder cart is also on this spacing.

- **24.6m urea boom**

The urea boom is home made, which is towed behind the air seeder cart. This enables the use of variable rate control.

- **36.9m boom spray**

A new axle was installed on the boom spray to increase the span to 3m. An articulated tractor had 4 wheels removed and the remaining 4 wheels moved out to 3m.

- **13m harvester**

The 13m-harvester front from Midwest Fabrications [www.midwest.net.au] was mounted on the center of the machine, which led to problems with the auger length, chaser bin width and residue spreading. A Redekop residue management was installed [www.redekopmfg.com] which spreads chaff and chopped straw the width of the module. The harvester's wheels are also on 3m-wheel spacings.

- **Chaser Bin**

The chaser bin is on 3 m wheel spacing and the top of the bin has been widened to 4.5m it travels 95per cent of the time on tramlines except when emptying the harvester.

ADVANTAGES OF CT

- Do not need to be concerned about the weight of machinery as all operations are on permanent wheel tracks

E.g. Harvester: 22 ton
Seeder: 15 ton
Boom Spray: 8-10 ton

- Can both increase the water holding capacity or decrease the evaporation rate of the soil, which in dry land farming systems can be the difference between producing a crop and not
- CT can change your management of the farm, and the operations carried out on the farm begin to take on more direction
- Inter row seeding using auto steering has huge production benefits for a continuous cereal rotation
    - Paddock landscape is easier to manage with the ability to conduct skip runs
    - Input costs are reduced due to zero overlap (5-10% savings)
    - Less fatigue, especially for older farmers

- Straw is better managed with the combination of CT and auto steering; the direction of travel should be the same for the seeder and the harvester.
- Tall stubble can be managed using auto steering and inter-row seeding, which speeds up the harvesting operation and reduces the need to spread large volumes of straw (less power requirements). Taller straw creates better protection for the soil and there are fewer issues for the next year's crop
- It is very important to have the harvester on tramlines, as I believe it does the most damage. In the drought of '02 the crops did not grow on the previous header tracks (unsure about duels on the harvesters)
- Tend to become wary of your soil, for example digging, probing, and looking for the build of the mulch
- You start to realise the importance in the operation efficiency

PROBLEMS

- Choosing the direction of the tramlines is confusing: some research indicates E-W and others N-S. In my case, I have looked at where trucks can efficiently access the paddocks to determine the direction. As a result I have made some mistakes
- Farm layout: plans should have been made with the image of no fences in mind – perhaps consider employing a consultant prior to commencing CT
- Computer mishaps
- Wind erosion of tram tracks can be an issue, but maintaining high residues should minimize this.

COSTS

- If your next purchases are made with a CT plan in place, the costs should be minimal and the gains potentially enormous

Developing Raised Beds in SW Victoria

Colin Hacking

THE POTENTIAL

The "cool climate high rainfall" zone of Southern Victoria has an extremely large potential for sustainable and profitable crop production. In most areas this potential is far from being realised. It is estimated there is conservatively 500,000 hectares of traditional grazing land that could convert to cropping or a mixed farming operation in southern Victoria alone.

BACKGROUND

Historically, the area has relied heavily upon wool production as its major source of primary production income. It can also be argued that wool production has served the area well with very good returns being possible prior to the dramatic downturn in prices in the mid 90's. Despite the downturn in the price for wool, many farmers still have wool production as their major enterprise, although this has changed for some producers over the last few years with cropping becoming a more significant part of their operations.

Why is crop production a very low priority for some farmers? The reasons are many, however factors including waterlogged soils, poor soil structure, too many weeds, inadequate nutrition and poor management are the main ones. In many cases, crops have been grown to supplement the livestock enterprises and have been used as a means to "clean up a paddock" to prepare for the sowing of a new pasture. Crops have often been viewed as an opportunity enterprise when conditions were seemingly right. When crops failed because of climatic conditions beyond the control of the grower, such as too much winter rainfall, then this has generally been accepted as something that could not be avoided.

THE CHALLENGE

Southern Farming Systems began in 1995 to objectively look at the cropping and livestock enterprises in the high rainfall zone and realised that there needed to be a change made to the traditional farming system, to enable farmers to capture the opportunities that the area presented. One of the major driving forces was that of profitability, as it was identified that unless something was done to dramatically change the economic situation of farmers in the region, that many of them could not survive the projected long term wool downturn. The farming community was also very aware that any new system needed to be sustainable in terms of responsible land use.

A detailed analysis and consultation process was undertaken to identify the strengths, weaknesses, opportunities and threats for the region. It was identified quite early in the investigation, that one of the region's strengths was the excellent rainfall, which in most years was well distributed and was quite reliable for winter cropping. In fact, the growing conditions for crops were recognised as being far superior to those experienced in the Mallee and in many areas of the Wimmera. It was also recognised that whilst the rainfall was a significant strength to the region, it also presented significant weaknesses with regard to winter waterlogging of the region's predominantly heavy basalt soils. This was mainly a result of the significant water-holding capacity of the soils and the low ambient temperatures resulting in low crop evapotranspiration.

Strengths and Opportunities

One of the real strengths of the “high rainfall cool climate” zone of Southern Victoria is its potential for crop production, particularly that of oilseeds. The long and cool growing season means that canola is particularly well suited, with oil quantity and quality generally being very high because of the extended cool finish to the season. Other oilseeds such as linseed are also well adapted to the region and offer a greater rotation flexibility. The opportunity exists to establish South West Victoria as the premier oilseed producing region of the State.

The area is also very well suited to the production of high quality malting barley. The cool finish and extended growing season is conducive to large grain size and good malting characteristics. A large plant situated in Geelong has the capacity to service significant tonnages out of the region.

Another clearly identified strength is the ability to grow the winter feed wheat varieties becoming available. The long growing season suits the genotypes well and perhaps gives the opportunity to undertake a grazing if sown early enough. The vernalisation requirement of these cultivars would also mean that the risk of frost damage at flowering, is significantly reduced. The opportunity is there to significantly increase the feed grain production out of South West Victoria to service the needs of the expanding feed grain dependent intensive livestock market. This potential is being recognized by many private seed companies, with investment in breeding of better adapted feed wheat varieties for this region being undertaken.

With improved agronomy techniques, many producers are looking to grow high quality wheat crops. There has been considerable investment by CSIRO and others to produce better adapted milling wheat lines for the high rainfall zone.

Another major strength for the area is the ability to grow a range of plant species and the opportunities to establish flexible rotation systems. There is the ability to grow crops and pastures for nearly 12 months of the year in many areas. This significantly reduces the likely threats associated with market collapse of individual enterprises.

Threats and Weaknesses

The major weakness or limiting factor identified is winter waterlogging of the region’s soils, although in the last 10 years there has been a period of significantly lower winter rainfall. The ability of plants to extract nutrients is reduced in a waterlogged soil due to the anaerobic soil conditions. Weed problems such as toad rush can also be attributed largely to the wet soil problem over winter, along with associated soil structural problems

Another significant problem identified is the declining soil structure in cropped soils and the ability to only grow profitable crops after a prolonged pasture phase in the dispersive heavier soil types. This declining soil structure is amplifying the negative affects of winter waterlogging and makes cropping extremely difficult. It is also significantly restricting the paddock options available to growers.

Another threat is that as cropping intensifies the risk of developing herbicide resistant weeds and other long term cropping issues also becomes greater.

As a result of the analysis the major opportunity to come to light was to change the way that we managed our soils so that we could capitalize on the climatic strengths that the region possessed. If we could reduce our winter waterlogging problem, then significant gains could be made in plant yields. Given the opportunities emerging in the oilseed and feed grain areas, attention was turned to trying to significantly increase crop yields.

THE VISION

Southern Farming Systems back in 1995 set the target for wheat yields to increase from 2.1 Tonnes per hectare to 5.5 Tonnes per hectare as a regional average by the year 2005. It was also envisaged that 7.5 Tonnes per hectare for wheat should be a reasonable target yield for the top 10% of growers. These targets have largely been achieved by growers implementing the raised bed system.

THE SYSTEM

Southern Farming Systems is embarking on a new system of growing crops, on raised beds using controlled traffic technology. Actually the system has been around for years, particularly in the irrigation areas in NSW and QLD and also in the vegetable growing industry. What we are really doing is applying irrigation technology in reverse. Instead of using raised beds to apply water down the furrows, we are using them to get rid of the excess water during the winter. The adoption of controlled traffic technology, a major feature of raised bed farming, is an integral system component in order to improve soil structure in the long term.

Why has it taken so long to wake up to trying this new approach? Well once again we have been blinded to this opportunity for many years, because we have grown to accept that our crops get water-logged over winter and that there is nothing we can do about it. We have had to unlock our minds to the new opportunity. We have in fact, had to look at converting a weakness into a real opportunity.

The system of raised bed farming simply means that furrows are formed approximately 2 metres apart and crops are grown between the furrows or on the “beds”. The beds are raised approximately 20 centimetres to get the crop out of the waterlogged soil. All traffic such as planting and spraying is confined to the furrows to avoid compaction. Harvesting is the only operation to take place on the beds, although over time this too will change.

Excess water is drained off the paddock over the winter and spring months and in many cases is collected to be re-used on high return crops over the summer.

THE RESULTS

The results so far have been very encouraging with significant increases in crop yield, across a range of soil types and crop types. These results have been achieved largely in broadacre farmer demonstrations and not in replicated trials.

In a series of farmer case studies, despite relatively dry conditions over the last 10 years, the average net financial benefit to farmers using the raised bed system compared to flat land cropping was approximately $78,000 per annum. This takes account of the extra yield and costs of the raised bed system (including machinery) compared to a flat paddock situation (Blackburn & Assoc 2005).

Farmers are also reporting that there also appears to be a significant improvement in soil structure in a very short period of time. Studies conducted by Southern Farming Systems in 1997 also indicated that in just two years, soil structure in the raised bed treatment compared to the control at its Gnarwarre (Geelong) site improved dramatically. Table 1 clearly shows this. Further investigation by Dr Renick Peries (Soil Scientist DPI Geelong) substantiates this finding.

Table 1

Test	20 metre wide raised beds	Underground drainage	Control – spoon drained	1.5 metre narrow raised beds
PH (Water)	5.7	5.7	5.8	5.4
Aluminium	10	11	<10	<10
Electrical Conductivity (Water)	0.18	0.16	0.17	0.34
Total Soluble Salts	.06	.05	.05	.10
Olsen Phosphorus	10	11	11	12
Potassium	260	290	310	220
Sulphur	40	29	51	160
Dry aggregate slaking	Partial	Partial	Partial	Water Stable
Dry aggregate dispersion (2 hrs)	Nil	Nil	Slight	Nil
Dry aggregate dispersion (20 hrs)	Nil	Nil	Moderate	Nil
Remoulded aggregate (2 hrs)	Strong	Strong	Strong	Nil
Remoulded aggregate (20 hrs)	Strong	Strong	Complete	Nil
Oxidisable Organic Carbon	1.6	1.9	2.1	1.9
Organic matter	3.1	3.6	4.0	3.6

DISCUSSION

In terms of dispersion and slaking, the narrow raised beds were given a completely clear bill of health. The soil was in excellent physical condition, whereas the other treatments show some signs of slaking and dispersion. This corresponds very well with the “eyeball analysis and feel tests” conducted. Right throughout the summer period, the narrow raised beds maintained excellent structure whereas the other treatments set quite hard.

It appears from the results in Table 1, that waterlogging may have a greater damaging effect on soil structure than cultivation. The controlled traffic is also contributing to this improvement in soil structure. These results are extremely encouraging and back up what we are seeing in many farmer paddocks across SW Victoria.

If we can improve the soil “health”, then we are well underway to developing a much more sustainable farming system.

ADOPTION OF THE NEW SYSTEM

There are many factors to consider before setting up a raised bed cropping systems, including :

1. Movement of water off the paddock. Care must be taken that water coming off the paddock does not contain pesticides or nutrients. It is envisaged that given soil structure is improving along with significantly greater plant growth, “drainage water” may in fact decrease over time compared to a traditional flat land system.

2. The timing and rates of nutrient application need to be re-assessed, given that we are looking at a totally new system. Since we should be able to traffic the country at most times over winter, then we can be far more strategic in our timing of nutrient application.

3. The water that is coming off the raised bed country should be contained on the farm to be re-used on possibly high return summer crops. Downstream effects of water flow needs to be reduced to a minimum.

4. Drainage needs to be thought about carefully. There were instances in 2001 where trafficability in bedded country was restricted due to the inability to effectively drain the paddocks.

5. Erosion problems and washouts in 2001 were evident in some situations at the tail drain area. More consideration needs to be given to the design of the collector drains relative to the slope and length of run. The beds and furrows have proven to be very robust with insignificant erosion occurring in the wet year of 2001.

FURTHER POTENTIAL

The system certainly does uncover the possibility of more crops and pasture species being adapted to the high rainfall cool climate zone. Where we can overcome waterlogging, crops along with Lucerne can be grown on our heavier basalt soils. The gross margins from prime lambs grazing Lucerne on raised beds have been shown to be comparable to the best cropping gross margins in 2003 and 2004 (Grain & Graze Project South West Victoria).

The use of raised beds has meant that producers are far more willing to apply the inputs such as fertilizers to their crops, than in a situation where crops can fail due to waterlogging in a flat paddock situation. This “risk management” tool has been recognized as one of the major benefits to the use of raised beds.

There is the possibility that the system may have some application in saline country. Given that we can keep the plants out of the salty water in the beds, then we should be able to establish the seedlings in a relatively salt free environment. By the time the plant roots reach the soil containing higher salt loads, plant tolerance will have increased.

The investigation so far certainly indicates that increasing the cropped area of a farming system with the use of raised bed technology is a viable option for farmers in the high rainfall, cool climate zone of South West Victoria. It certainly is not suggesting that cropping should replace the grazing enterprises, however if carried out in such a way as to reduce the possible risks, then it offers greater flexibility for the producer in the region.

9. Relevance to Controlled Traffic

Raised bed cropping involves controlled traffic. Confining the wheels of tractors and implements to the furrows means that there is no compaction of the area where the crop is grown. Hence many of the benefits associated with raised beds are the result of the controlled traffic aspect.

There are many paddocks that are unsuited to raised beds because of rocks, gradient and other factors. In this situation controlled traffic alone without raised beds is a real option.

Many producers find it difficult to take the step into the raised bed system. They simply don’t like furrows in their paddocks. For these producers the controlled traffic system being implemented on flat ground offers a real opportunity.

ACKNOWLEDGEMENTS

I would like to pay special tribute to the efforts of Bruce Wightman (agronomist DPI Geelong) who was largely responsible for the drive behind the raised bed system. Bruce was also supported by Chris Bluett (DPI Ballarat). The co-operation of the farming community was also extremely important in the

early days of developing the system and there were several producers such as Bruce Wilson, David Langley, Rowan Peel, Andrew Morrison and others who made a considerable contribution of time.

I would also like to thank the many Agribusiness Companies who supported the raised bed project. This included National Australia Bank, J.B. Scott Pty Ltd (Andrew Cleary), Watson Machinery (Rex Watson) and many others.

The linkage of raised beds with the controlled traffic system is obvious. The work being undertaken by Andrew Whitlock (DPI Ballarat) and Dave Stephens in association with Southern Farming Systems in developing a Controlled Traffic Precision Farming Systems Site, will further develop the controlled traffic programme in SW Victoria.

Controlled Traffic Farming takes Conservation Agriculture into China

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INTRODUCTION

Soil compaction, a form of land degradation, is widespread in cropping lands and occurs largely as a result of random field wheelings and land preparation from agricultural machinery. According to Whalley, *et al*. (1995), the processes of machinery and tillage are often disruptive and harmful to soil ecosystems. The use of tillage to remove compaction can be expensive, not only in terms of the increased power requirement, but also in terms of fuel usage (Tullberg, 1998). Compaction is cyclic under conventional farming systems and is persistent (Alakukku, 1998). According to Brussaard and van Faassen (1994) understanding of soil amelioration by natural process is required to optimise farming processes. Most clay soils are very susceptible to soil degradation, but it is widely believed that they can regenerate, effectively breaking up compaction. However this is only true if cyclic compaction from random traffic is removed. Controlled traffic farming systems (CTFS) have been widely adopted in Australia, primarily to reduce the effects of compaction, but its adoption also has a number of other benefits. Such as facilitating zero tillage, stubble management, irrigation management and reducing farming inputs. Until recently very few studies had looked closely at what happens to a degraded soil environment when traffic and tillage is removed. Even more recently others have demonstrated that soil compaction significantly influences soil hydraulic properties, reducing the saturated hydraulic conductivity and alters the shape of the soil water retention curves (Zhang, 2006).

In terms of amelioration, people have only thought of tillage effects, and not traffic removal and its effects on soils and processes. Traditional farming systems in the People's Republic of China (PRC) are characterised by routine cultivation (mouldboard ploughs and rotary hoes) and removal of crop residues from the field (for animal fodder and household fuel). Pressure on the farming lands of the PRC to maintain productivity has been increasing at a phenomenal rate, to support the current national population of 1300 million (with an estimated annual increase of 4 million) and the fastest growing economy (10% per annum) of any major world country. This pressure, in association with the harsh cultivation and residue removal regime, has led to severe land degradation, contributing to the PRC's unenviable status of having "among the most severe (environmental) problems of any major country" (Jared Diamond, 2005; "Collapse – How Societies Decide to Fail or Survive"). Especially affected are the PRC's dryland areas, which occupy 52% of the nation's total area with 43% of the PRC's population. These lands are inherently fragile due to a combination of harsh seasonal variations in climate, inherently low soil fertility, annual rainfall of less than 500 mm and years of severe drought.

The PRC government and the Chinese people have been most aware of the growing land degradation issues and have been actively creating several farmland-based approaches to combat desertification and erosion. A vital approach is CA. CA is a further development of the practices commonly termed Conservation Tillage (CT). CT is defined as "all conservative farm practices that leave a minimum of 30% of (crop) organic residues in the field". In contrast the key elements of CA are: zero (or reduced) tillage, careful management of residues, and the use of cover and rotation crops to maintain ground cover, increase organic carbon and soil biodiversity and minimise crop diseases, a balanced application of chemical inputs (only as required for improved soil quality and healthy crop and animal production), and the precise application of all inputs, including maintaining permanent wheel tracks for all in-field equipment, and the precise application of pesticides, fertilisers and weedicide. Each of these elements are important in there own right. However, the "power" of the CA system is gained, not from focusing on any one element to solve a specific limitation, but rather from the synergy (interplay) of the various elements. In this way, multiple benefits of CA are gained from an integrated approach from the farm to the ecosystem level.

The aim of this study was to assess changes in soil following the implementation of a controlled traffic-zero till farming system after 100 years of conventional farming and then in subsequent years apply that understanding to high altitude arid farming regions of North western China. This technology transfer would introduce conservation agriculture (CA), by using practises such as zero tillage and permanent raised beds (PRB), to reduce irrigation water use, maintain farm yields and improve farmer incomes because long-term simulations have shown that soil management strongly influences the magnitude of the water balance components.

METHODOLOGY

An Australian study was conducted on structurally degraded black cracking clay, which had been cropped conventionally since 1945 in the Lockyer Valley, Queensland to demonstrate the natural regeneration of soils and the impact of traffic removal. A CTFS was established on 3m wheel centres, in four, 80 by 12m blocks. Three tracks in each block were either wheeled once, twice or three times at planting and harvest. After each planting, over four seasons, soil measurements and observations were made in track and cropping zones. Rate and depth of soil amelioration from biological activity of previous cropping seasons was assessed by changes in hydraulic conductivity (K_s) and plant available water capacity (PAWC).

RESULTS AND DISCUSSION

At the start of the study K_s was very low in comparison to well structured Vertosols. After 7 months of nil traffic K_s increased by 60%. After 22 months K_s increased 4 fold at 100mm below planting depth to $125mm.h^{-1}$, with 200 and 300mm depths increasing by $50mm.h^{-1}$ on initial values. Track zone conductivities remained constant ($\sim 22mm.h^{-1}$) over the four cropping seasons (Figure 1).

Under conventional tillage conditions field capacity was measured at $0.36g.g^{-1}$ and after 22 months of nil traffic it increased by 7% to $\sim 0.39g.g^{-1}$. Moisture content at wilting point improved by 6.5% after 22 months of nil traffic changing on average over the 0.3m depth from $0.29g.g^{-1}$ to $0.267g.g^{-1}$. PAWC was less than 10mm per 100mm depth of active rooting zone under conventional tillage conditions. However, after 22 months of nil traffic, PAWC increased by 63% to >15.9mm per 100mm depth of active rooting zone. Track zones PAWC remained constant at <10mm per 100mm in the top 400mm of soil (Figure 2).

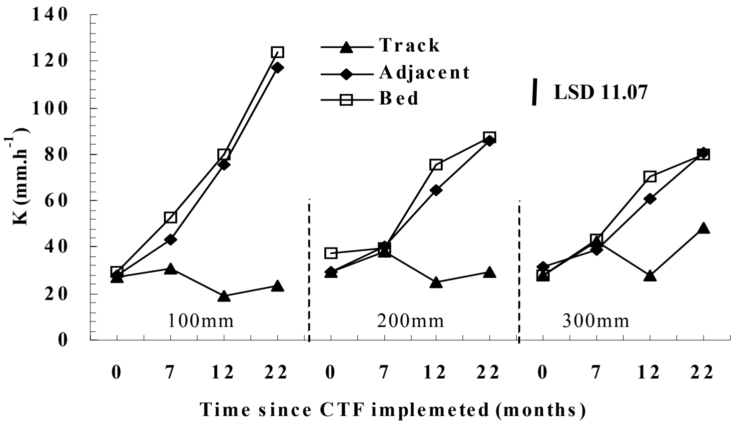

Figure 1. The average unsaturated hydraulic conductivity of the soil matrix (K_{matrix} mm.h^{-1}) grouped by depths and position for months after nil traffic (after implementation of CTF) through four seasons.

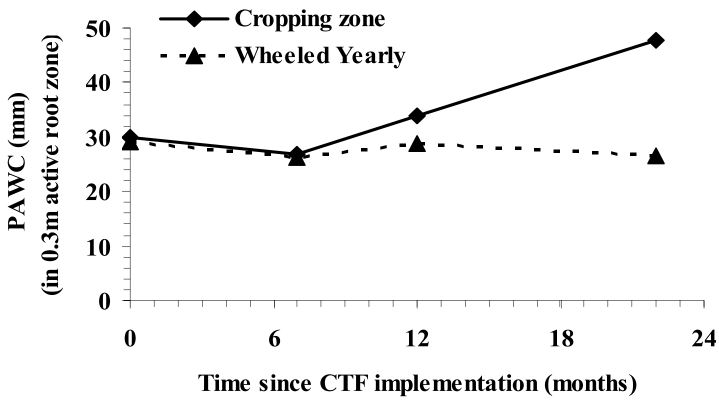

Figure 2. The change in PAWC (mm) in 0.3m of active root zone for the cropping and wheeled zone after 22 months of controlled traffic farming on an area previously cropped conventionally (random traffic).

The change in hydraulic conductivity and PAWC indicated movement away from a soil profile with a predominance of micropores (<30μm) to include a range of larger transmission pores up to 350μm over the period of the study. Development of micro cracks, larger planar voids and biopores formed by drying processes persist in non-wheeled soil, increasing pore interconnectivity and pore size distribution. Seasonal improvements in soil structure accrued and expanded down through the profile. However the rate of change was very dependent on cropping zone ageing processes since the last tillage/traffic event. Initially any changes in structure due to reduction or absence of tillage and traffic were small because it remained difficult for roots to penetrate the soil. Once a few roots penetrated and effects of drying accrued, and the natural cycle of amelioration proceeded. The better the drying, the better the structural improvements, the better the root environment and quickly the entire biological and physical systems interact, moving toward the soils natural structure. However based on this study data, to naturally ameliorate the soil from a degraded state to a condition, that is, halfway toward a non-degraded clay soil, could take 5-9 years. However even over the short study period the transitory nature of tillage was demonstrated and even the soil moisture characteristic can be affected by agronomic management.

Significant gains in production can be made by zero till CTFS through increased pore interconnectivity, pore size distribution and oxygen status. The improvement in soil structure and subsequent increase in productivity is based on the integration of four elements, controlled traffic, zero till, organic matter improvements and soil inspection. In comparison to conventional cropping practices this approach leads to a lower input self-sustaining farm management system.

SUMMARY

Soil amelioration in the cropping zone was evident after 3 years of isolation from wheel traffic. This was demonstrated by:

a. Hydraulic conductivity increased by 65% (all layers 0-400mm).
b. PAWC increased from 9-16mm per 100mm of active root zone in top 400mm.

This study has demonstrated the effectiveness of natural amelioration when the unique properties of Vertosols can be harnessed via controlled traffic zero tillage farming systems. Under conventional (random traffic) farming operations, this level of amelioration may be achieved at considerable cost by soil amendments and intensive tillage, but the results are often transitory and is inadequate for a self-sustaining cropping system. Taking a simplistic view of controlled traffic farming systems, amelioration is achieved at no extra cost and offers an opportunity for improving the productivity and sustainability of mechanised cropping.

INTRODUCTION OF CONSERVATION AGRICULTURE TO CHINA

Gansu is a north western Chinese province in the yellow river upper drainage basin and between Gansu and neighbouring Inner Mongolia lays a distinct valley, the Hexi (*Her She*) Corridor.
In the past (~4000 years), reliable snowmelt water from the adjacent Qialian (*chil lian*) mountains has sustained the irrigated agricultural areas along the length of the valley. In more recent times (last 30 years), reduced snowmelt water has led to significant reductions in available surface water, whilst over extraction and decreased recharge has lowered water tables in groundwater driven systems. As a consequence, severe water restrictions are being placed on farmers (up to 50% reduction in allocations). Although delivery losses are being reduced, through better channel lining, few practical solutions are being offered to farmers to cope with the policy driven cutbacks in water allocations, water price increases, pumping costs and the demand for food. Other crop production issues associated with water restrictions, such as small farms, low levels of mechanisation, high inputs, conventional tillage, high wind erosion, soil degradation, low incomes and the loss of young men to the cities, are placing further pressure on farmer livelihoods. Therefore the aim of this project is to introduce and develop conservation agriculture using practises such as, zero tillage and permanent raised beds (PRB), to reduce irrigation water use and wind erosion, maintain farm yields and improve farmer incomes.

Preliminary studies by the Gansu Academy of Agricultural Sciences (GAAS) have demonstrated the effectiveness of PRB farming, showing similar water productivity and yield gains to those found in PRB systems at the Shandong Academy of Agricultural Sciences (SAAS), the Indian Subcontinent, Australia and Central America. These, and other effects of soil management practices on the soils' hydraulic properties have been shown to alter the partitioning of the water balance, decreasing soil evaporation and increasing transpiration, infiltration (Figure 3) and deep percolation, leading to increased wheat yields and WUE in Shaanxi Province PRC (Zhang, 2006)

However key constraints to the practical implementation of these elements of CA in Hexi are; the lack of appropriate machinery, farmers are steeped in conventional tillage and flood or basin irrigation methods, competition for crop residues and whether or not an economic benefit exists from implementation of PRB in this region. The continuation of GAAS PRB research, and the extension of the PRB work in Shandong province into north-western China, will allow agronomic, water and residue management and mechanisation practices to be drawn together under the banner of CA and be tested under real world conditions. On-farm research will directly demonstrate to farmers the agronomic benefits to be gained from CA in this region, while the cost benefit analysis of the changed farming system will provide evidence of improved income, while using less irrigation water and other farm inputs.

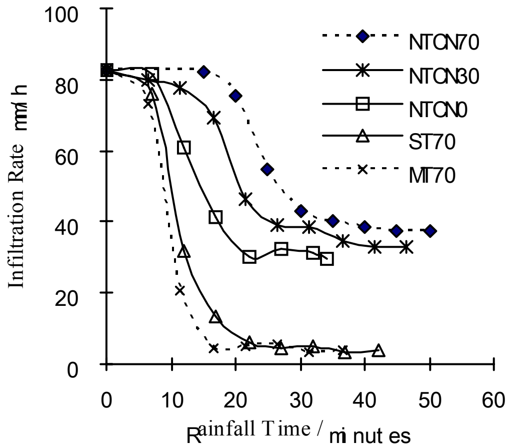

Figure 3. The change in infiltration rate with changes in level of compaction and cover. Where NTCN = No tillage no compaction plus cover (0, 30, or 70%), ST70 = compaction with small tractor (1.2t) + 70% cover, and MT70 = compaction with Medium tractor (3.6t) + 70% cover. (After Wang *et al.*, 2005)

EPILOGUE

Conservation tillage has been proven to combat drought and improve soil physical conditions in china. Increased water infiltration and reduction in water and wind erosion is achieved through no-tillage or minimum tillage, and stubble cover. Conservation tillage research started with the support from the Ministry of Agriculture (MOA) and an Australian Centre for International Agricultural Research (ACIAR) project in 1992. By the end of 1990's CT research was seen as very successful and therefore in 1999 MOA established the Conservation Tillage Research Centre to lead CT research in China. Following continued success, MOA established an ongoing CT demonstration project in northern China during 2002. As a result, by 2004 there was more than 4,000,000ha in 100 counties from 14 provinces under CT. The MOA initiative has spurred Northern provinces to commence their own trials and demonstrations of CT, further increasing the area under this advanced farming system. After 3 years of field demonstrations, CT adoption has been proven to increase farmer's net income by increasing yield and reducing production cost. CT also protects the environment by reducing water and wind erosion, and improving soil condition soil through no-till and stubble retention in the field. CT is viewed as a new agricultural revolution by many agencies in China. The challenge now is for Chinese agricultural to embrace the next step in the agricultural revolution, Conservation Agriculture.

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Murdeduke - Raised Beds and CTF

Lachie Wilson

BACKGROUND

The Wilson family own the 3000 hectare property "Murdeduke" and manage a further 1400 hectares in the high rainfall zone of south-west Victoria, near Winchelsea. We receive an average rainfall of 550 mm in winter/spring predominantly. There is a mix of enterprises (60% cropping and 40% livestock) including:

- 2400 hectare cropping system with a typical rotation of canola, wheat, barley and oats.
- 200 stud Angus cows and 450 commercial Angus cows, with an extensive Embryo Transfer operation
- 3000 first cross ewes prime lambs
- 800 wethers, with numbers reducing to increase prime lamb production
- 170 hectares of lucerne – providing excellent gross margins from prime lambs and great for drying the subsoil profile
- 1500 sows run on three 40ha units in the crop rotation, run as a separate business 'Pastoral Pork'

The country ranges from well drained rolling lunette's to flat swampy country. Lunettes represent the deposition sites of wind blown sands and clays from swamps and lakes. The soils on the lunette's are dominantly highly fertile deep black self-mulching sandy clays over a deep cracking clay. The majority of the lower lying soils are gradational self-mulching black clays (Vertosols), which are often sodic at depth.

WHY CONTROLLED TRAFFIC?

Soil structure and fertility is a key driver of any farming system. We believe controlled traffic farming is a common sense approach to improving our soils and thus profitability. Forget all the science and complexities associated with controlled traffic farming just look at the broader picture and the intricate details will happen naturally.

Our systems

The introduction of raised bed farming (2m centres) in 1996 has revolutionised our lives and has allowed us to expand the cropping enterprise to paddocks, which would otherwise lay waterlogged in an average season. It is basically reverse irrigation technology. This has allowed the cropping operation to expand through leasing and purchasing new land.

Raised beds forced us to have our machinery on 2 m wheels centres except the header which is on 4 m centres to straddle two beds. In 2004 an RTK auto steer system was implemented which gave us confidence that adequate repeatability could be achieved to implement a tram line system on conventional country in 2005.

The tillage system is basically no till, however we are adaptable to circumstances as no system is perfect and cultivation maybe used. Some full stubble retention and inter row sowing was achieved in 2006.

Raised Beds

- Always considered the lunette paddocks to be like 'one big raised bed'
- 1200ha 2m wide raised beds.
- Knife points and press wheels for depth control improve plant distribution and crop establishment.
- Beds lead to rapid soil improvements in just one year. Heavy sodic clays converted to friable healthy workable soil in year 1, and this happens every time! The soil structure improves due to the removal of waterlogging and wheeled compaction and thus the soil health improves through more organic matter and more frequent wetting and drying cycles.
- Gradually reinstalling beds with the autosteer to eliminate the problem of uneven bed widths, which cause trouble particularly at sowing.
- Beds improve water infiltration rates and crops achieve higher water use efficiencies. These factors limit the amount of run-off from raised beds.
- Drainage determines the layout.
- The next step is to improve the design of main collector drains which run perpendicular to the furrows.

CTF

- 1300ha in crop CTF (2005 is the first season).
- 24m tram tracks for spraying and spreading.
- Tramlines run east west to minimise wind damage to canola windrows unless impractical
- Block seeding tube off to leave visual tramline. Means not all machines require auto steer. No green seeds or inferior quality grain at harvest from wheel track damage. Weeds may become an issue in tramlines.
- Stubble management at harvest is proving a challenge?
- Believe inter row sowing to be the most efficient way of retaining stubble.
- Burning is a vital management tool, but should not be relied on every year.
- Livestock are they a useful management tool or a hindrance?
- Early stages and will evolve over time.

Paddock layouts

- Rocks are a big issue. Have cleared many rocks at great expense, but the return on investment says it is worthwhile. Improves productive capacity as well as capital gain in land value. Have crushed some rock piles and will use for internal roads.
- Need to determine CTF design to maximise harvest efficiencies. Maximum 500-600 m runs for baling and chaser bin operating efficiencies. Centre headlands work very well although initial additional cost to implement.
- Undulating paddocks are difficult to install effective raised beds. May need to laser level. (will it pay?)
- Contour maps are critical for determining paddock design for raised beds.
- Some planted tree lines reduce machinery operating efficiency and are gradually been removed. Trees are replaced on paddock boundaries and waterways.
- Property was originally fenced for livestock, thus some less than desirable paddock shapes. Causes overlap with wider applications such as spreading and spraying. Not considering refencing at this stage, auto shut off on the boom is potentially the best solution. On lease blocks will generally remove all internal fencing to achieve operating efficiencies.

MACHINERY SYSTEMS

- Own all machinery. There is significant capital invested in development machinery. A contractor is used to provide a second header and only at others times when timeliness is becoming an issue. There is a management advantage is doing your own work, although it can impact on lifestyle at times.
- All tractors, spreader, chaser bin and baler on 2 m wheel centres.
- Header on 4 m wheel centres with a 10.9 m front. (only use 10 m on beds)
- Tillage implements 8 m and spraying and spreading at 24 m thus a 3:1 system. A 3:1 system is ideal as it fits perfectly on boundaries. Most limiting constraint is spreading urea due to windy conditions. Historically can get wet, so minimising weight is a consideration.
- Did consider a 10 and 30 m system but became costly due to stability issues with a 10 m seeder on 2 m centres. So sacrificed operating efficiency for less capital investment and the reassurance the job was done properly!
- Guidance (2cm RTK *GPS-Ag* autosteer) fitted to 2 tractors. Proved it's worth – a fantastic initial investment. Less fatigue, less inputs, and no delays from fog and dust. You know exactly where you are – allows site specific management
- 2 sub metre lightbar guidance systems from pre auto steer days. Great stepping stone in learning the capabilities of GPS. Now partially a luxury in auto steered country but still very useful on pasture and lucerne paddocks.

AGRONOMY

- Independent consultants employed who do fortnightly inspections.
- Based on UK/NZ production model.
- Canopy management.
- Strict monitoring and thorough understanding Zadock's growth stages.
- Timeliness critical especially with fungicide management.
- Rotation of Canola, wheat and Barley or oats. A reliable profitable legume would be very welcome. Lucerne is working well but it is 3 year phase minimum.
- Integrated pest management, understanding levels of beneficial's. Only use insecticide when necessary. Involves strict monitoring and employment of a consultant.

PRECISION AGRICULTURE

- The collaboration of CTF, autosteer and yield monitoring allows for accurate strip trials
- Spatial info includes 5-6yrs yield data, EM surveys, contour maps, aerial photos and satellite imagery.
- Managing spatial data requires technical support. Computer systems include PAM, AgriMaster (financial) and Farm Works. Getting different software to talk the same language is a challenge.
- Will begin this year to test consistent trends in paddock variability to determine potential for variable rate (VRT). Pig paddocks introduce significant variability, which may be worth managing?
- Yield data is good for identifying large scale differences such as large scale trials such as lime and manure (pig paddock) responses.
- Satellite imagery provides a more intense picture of responses and should be useful for understanding and then managing spatial variability.
- Purchased IKONOS satellite imagery last 2 years and found it to be valuable at highlighting problems.

- Will not continue at this point in time as it is only reinforcing what we already see and we are not getting any economic gain at this point in time. Probably will do some progress updates every few years.
- Satellite imagery provides a more intense picture of crop responses and should be useful for understanding and then managing spatial variability.
- Satellite imagery is a great management tool for absentee owners.
- Will play with real time imagery this season using a green seeker. Can envisage if mounted to sprayer prior nitrogen application, the image could be used to apply variable rate nitrogen.
- Basically have built up a data bank of info, trying to find ways of using info and pip pointing which variable is causing the problem.

CTF AND OTHER ENTERPRISES

- Where do livestock fit? A proportion of the country is rocky basalt unable to be cleared. A National Landcare Program funded project 'Grain and Graze' has five integrated projects to help mixed grazing and cropping farmers increase profits and enhance the environment – stubble management, lucerne on beds, integrated pest management, native grasslands and pastures on beds. We are part of this project particularly focusing on lucerne.
- Diversification of enterprises is an integral part of our production and economic risk management strategy.
- There is no doubt livestock hinder the cropping enterprise but our gut feeling is the economics do not stack up to remove livestock from the crop system. I believe it would reduce our carrying capacity by at least 2 dse/ha.

CHALLENGES

- Getting people to adhere to CTF principles when time is an issue as it usually involves the slow way around.
- Management of runoff water.
- Will weeds become an issue in tramlines.
- In some paddocks deep wheel tracks may become a problem.
- Maximising operating efficiencies with layouts.
- Fitting fodder machinery to the system, incidentally a fodder crop returned the highest gross margin last year.
- It would be ideal to get the harvester in the CTF system which would mean going to 3m centres. Would 3 m beds still prevent water logging? Would the capital investment required to change machinery system be justified?
- Trash management.
- Interested in determining ideal press wheel pressures. How should it vary with soil moisture?
- GPS technology is a specialised field, you need a company which offers good backup and support when your whole farming system relies on it.
- Finding ways to utilise the spatial data we have collected. Will we ever be able to pin point which variable is causing the problem. It may change from season to season.
- Getting software which all talks the same language.
- To make all enterprises work together to achieve the most sustainable and profitable outcome.

Raised Beds to Add Profitability

Kellie Shields, "Gunwarrie", RMB 210, Frankland 6396

INTRODUCTION

I farm a 4600Ha, 100% cropping property called "Gunwarrie" in Frankland, Western Australia. This is located in the South West corner of WA, 330km South of Perth and 100km Nth of Albany. Annual rainfall is 550mm and soils are predominantly duplex- sand over clay. Our family purchased the property in 2002 to complement our 325mm sandplain property in Wongan Hills. Frankland is predominantly a livestock and vineyard area and when we acquired Gunwarrie it was a100% pasture property running sheep and cattle.
Our rotation has been Canola-Wheat-Barley and we are in the process of trialing legumes (Peas, Faba Beans and Lupins) to try and introduce a legume into our rotation.

After a 140mm opening rain 10 days after property settlement we knew we were in for a different farming experience to the Wheatbelt. By July in the first year it became obvious that to get profitable crops wall to wall, we would need to manage the waterlogging. Every year 20-30% of the property is significantly yield affected due to waterlogging. Traffic-ability was also a major issue. We were getting excellent yields in WA standards however could see the potential was much greater. We quickly identified waterlogging as our most significant yield limiting factor.

RESEARCHING RAISED BEDS

In August 2002 my father and I travelled the South Coast of WA to Esperance to investigate grain-drying systems. It was on this trip we were introduced to Raised beds and were very enthused by what we saw. This stimulated extensive research into raised beds in Southern WA and Victoria. By 2004 we were keen to try some raised beds however I didn't feel we were at a point in our research to justify spending the money on capital.

The opportunity arose to contract Ag Dept equipment on six foot spacing to do a 100Ha raised bed trial. This enabled us to do a paddock sized raised bed trial without purchasing equipment. This trial was extremely successful producing an additional paddock yield of 1T/Ha Barley, effectively paying of all the expenses of the beds in 1.4yrs.

This encouraged us to continue on the raised bed research in 2005. In addition to numerous farm visits we went through the following processes

Alternatives ways to reduce waterlogging

- Contour Banks-These definitely improve waterlogging problems however the number required is costly and makes Controlled Traffic Farming nearly impossible
- Alternate Land use-Stock-It will be an ongoing option to go back to stock and may occur one day for rotational reasons however in terms of waterlogging it is only hiding the problem. The paddocks may be green all over however are not producing quality feed in waterlogged areas.
- Alternate land use- Bluegums/Trees-The waterlogged areas are not evenly shaped or on land contours therefore would be very difficult to isolate to trees.

FINANCIAL ANALYSIS OF RAISED BEDS

Cost of putting in beds

Mapping	$10
Levelling	$15
Forming	$12
Drains	$150
$/Ha	$187
Capital $/Ha	$57
(Over 4000Ha)	
Cost/Ha	**$244**

T	$/T		Pay Off
0.25	$200	$50	4.8
0.5	$200	$100	2.4
0.75	$200	$150	1.6
1	$200	$200	1.2

SUBJECTIVE ANALYSIS OF RAISED BEDS

Positives

- Potential yield benefits from reduction in waterlogging
- Increased traffic-ability for spreading/spraying
- Controlled Traffic efficiencies
- Reduction in salinity

Negatives

- Rougher on machinery and Slower!
- Erosion-Sloping country (like ours) is not recommended for raised beds by numerous researches
- Downstream water effects-Large volumes quickly
- Turning areas may become un-trafficable in wet seasons
- Community Attitudes

Why 3m Beds

- Controlled Traffic Farming- 3m tramlining
- Baling-behind header
- Less loss of area in furrows
- Equipment resale trends
- Swathing--Possible

THE GUNWARRIE RAISED BEDS-2006

Gunwarrie Beds!

- Drainage Expert appointed
- 3m Beds formed with a Gessner Disc Bedformer, MT765, GPS Ag Auto Farm
- 50m turn around areas around the edge
- Extensive drainage on turning areas

- Experimental drainage-different designs
- Orientation-predominant slope

Machinery

Current equipment suitable for seeding/spraying/spreading/harvesting beds

- MT 765-3m Tracks 2cm GPS Ag Guidance unti
- Flexicoil 2320 Airseeder- Very close to 3m
- 12.4m (overlapping slightly) Biomax disc bar
- 27m Nitro spray boom
- Spreading-MT 765 and Flexicoil Bin
- Lexion 580 Combine 42ft Honeybee

Raised Beds/Controlled Traffic Farming-The future

- Existing equipment not on 3m spacings will be upgraded as required to 3m.
- CTF integrated across all paddocks
- Establish 300Ha-600Ha of beds annually on most waterlogged areas
- Understand where beds are/are not required/profitable

I would also like to take this opportunity to thank everyone along the ways who has assisted with our research. What we learnt from other farmers and researchers was invaluable to our final product.

Precision Agriculture on Farm and SPAA

Malcolm Sargent, "Brook Park", Crystal Brook, S.A.

BACKGROUND

Property is 1800 ha west of Crystal Brook in the Mid North of South Australia. 400mm annual rainfall. Half the farm is loamy soil with the remainder mainly dune/swale with sandy loam and some rising country contoured with sandy loam. Continuos cropping with wheat, barley, field peas, faba beans and canola. Sheep are purchased to graze on the stubbles over summer.

DIRECT DRILL

After the 1997 season where half our wheat couldn't be sown until the middle of August we decided to change to direct drilling. We suffered a 1.2 t/ha penalty. Since 1999 we have sown almost all of our crop with a Concord bar with Anderson points deep banding the extra fertiliser that we would have incorporated earlier. The airseeder was set up with electric drives to enable VRT.

PRECISION AGRICULTURE

Over the years we had noticed that our crops were not even. In 1999 we purchased an Agleader yield monitor and began yield mapping. Over the following years we conducted EM surveys to try and establish a reason for the yield variation. At seeding we discovered that the seeder monitor would not talk to the controller.

Issues such as problems interpreting the yield maps, what sort of software to use and other compatibility problems. With others experiencing similar issues this lead to the formation of the Southern Precision Agriculture Association (SPAA) in April 2002. It is a group comprising farmers, advisors, researchers and industry interested in promoting the adoption of PA. Its membership is across southern Australia.

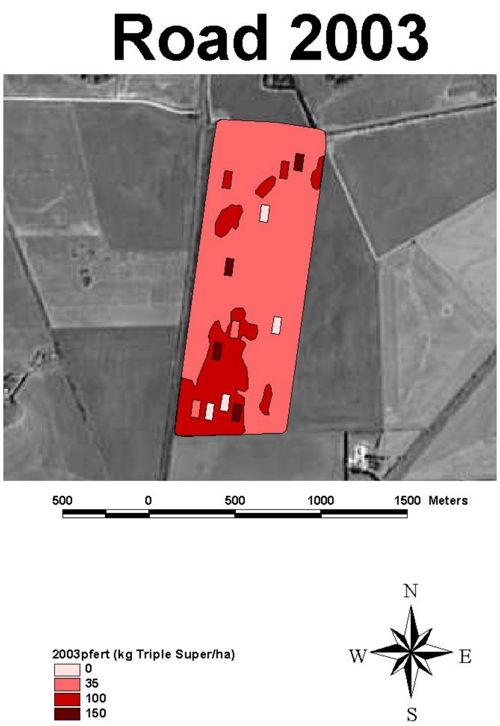
SPAA after receiving initial funding from the South Australian Grains Industry Trust Fund (SAGIT) has been involved with the GRDC's SIP09 Precision Agriculture initiative and is running trials across South Australia and Victoria.

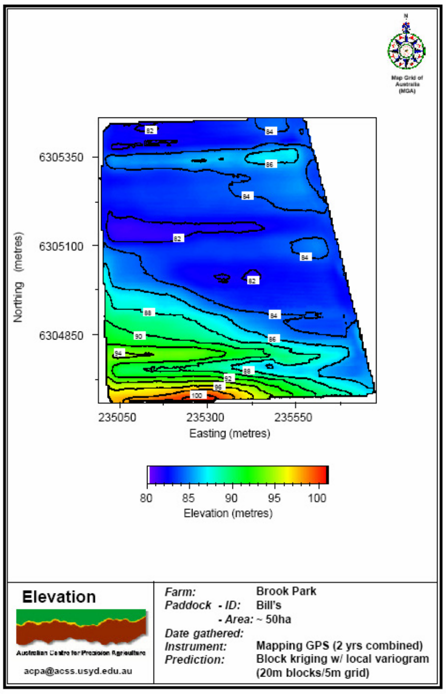
INTER-ROW SOWING

Having purchased a light bar in 2002 we could see the advantages of guidance in improving spraying efficiency we decided to get into auto-steering in 2004. The light bar with beacon correction had enabled us to spray accurately at times of poor visibility (dust, stubble and night) without the problems of a foam marker.
Moving to our Auto-Farm steering system straight away reduced the overlap associated with seeding. It also enabled us to start inter-row seeding. The initial benefit is that sowing between the rows avoids some of the problems with stubble clearance and the sed is sown into a trash free seedbed. The other benefit was avoiding the root diseases in the stubble row. Our whole system seems to have reduced the problems of root diseases. There still is a small problem of Rhizoctonia.
Currently we sow with a 14.4m bar, spray with a 36m boom and reap with 11.9m front at right angles (to reduce the impact of chaff windrows). By default we now have a quasi controlled traffic system based on the AB lines based on the seeder, sprayer and header runs.

ZONE MANAGEMENT

SPAA has been conducting trials in two of our paddocks. As well as the yield maps and elevation data collected since we started in 1999 extra data such as gamma-radiometric surveys were conducted. "Bill's" paddock has been a variable nitrogen trial. The results have varied with the season. The "Road" paddock has been a phosphorus trial and has generated positive returns in varying the amount of fertiliser applied to the paddock. The "Road" paddock is loamy soil and the initial phosphorus levels were 27ppm in the high yielding area and 57ppm in the low yielding area.





The trial has been based on applying one third of the fertiliser on the poorer area saving $40/ha and increasing the yield on both areas. We have extended the results to the rest of our farm using the gamma-radiometric survey as the basis for varying the amount of fertiliser applied. Many of the benefits of Precision Agriculture are difficult to quantify. I am much more conscious of the topography of our paddocks and how that might affect crop yield and disease/weed population.

FUTURE ISSUES

Q A – It could be an easy extension after PA.
Canopy management – difficult to see how it can work given our problems with ryegrass.
Controlled Traffic - by default. We need to quantify the losses from wheeltracks vs the extra costs.
Climate/ Weather – using "Yield Prophet" to monitor crops, but at present sceptical of forecasts.

Farming at "Llanthro"

Ryan Millgate, "Llanthro", South Australia

"Llanthro" is a 3600ha property situated 5km North of Apsley in Western Victoria on the Vic/SA border. Apsley is a traditional grazing area with a rainfall average of 540mm over the last 10 years. Cropping was originally started on "Llanthro" as a way of controlling onion grass and yarloop clover in a pasture improvement program. Since 1997 cropping has been undertaken in earnest, due largely to the downturn in wool prices and the run of drier seasons. Today around 1720ha is cropped, with 15000 sheep and 100 cattle also run on the farm. Cropping is now of significant financial importance, contributing more than 65% of the income for the property while only using 47% of the total land area.

The 2006 cropping program consists of 275ha of Canola, 90ha of Monola, 385ha of Wheat, 261ha of Barley, 203ha of Oats (hay and grain), 190ha of Lupins, 55ha of Peas, 110ha of Clovers and 52ha of Ryegrass for seed production. The cropping rotation is generally Canola, Wheat, Barley, Legume, Canola although there is a large degree of flexibility in the system to deal with issues such as weed numbers. The soils are very mixed, ranging from non wetting sands to very heavy cracking clays. The pH ranges from 5 to 6.5 (in water), and the main limiting factor to the cropping enterprise is without a doubt compaction.

The original system for sowing was based on minimum tillage, although some paddocks were worked with sweeps prior to sowing, stubbles were mainly burned, and the prickle chain got a fair work out. No type of guidance or auto steer was used and paddocks were worked and sprayed in the traditional round and round pattern. In this type of system the general program at sowing was to apply a knockdown, sow using full cut points, trifluralin was sprayed post sowing, incorporated by prickle chain then dual gold was applied post prickle chaining.

In the first few years of cropping at Llanthro, paddock yields were very good. After 4 years of cropping the paddocks were running out of structure, becoming wet in winter and concrete hard in the summer. This meant that crop yields started to decline rapidly. When I came to manage the property in mid 2004, I realized that there was something wrong with the soil - it was rock hard in late October, while only a month earlier it could have bogged a duck!

After a lot of research, it was decided that if we were to successfully crop at "Llanthro" some major changes needed to be made. To break the hardpan created by 150yrs of sheep, a horwood bagshaw parallelogram seeder was purchased enabling us to rip to 150mm and place the seed at 20mm. We also made a decision that stubble had to be retained to help with organic matter and moisture retention. A KEE ZYNX 2cm auto steer unit was also purchased to allow inter row sowing into the heavier stubbles that are produced in our rainfall zone. At this stage controlled traffic was not used, the seeder was 9.6m, the boom 24m and contractors were used for harvesting.

Towards harvest we had the opportunity to purchase an excellent second hand header at a very attractive price, so it was added to the "big toy" collection and we fitted it with yield mapping to collect yield data. At the completion of harvest we realized that our average wheat yields had jumped 1.2t/ha on the previous year and we had received 57mm less growing season rainfall. This massive jump could only be attributed to the deep ripping into the hardpan which increased our WUE from 9kg/mm/GSR to 14kg/mm/GSR, a 55% increase.

This large increase had really excited me as to the potential of cropping in our area and more research was done into how to make the system more efficient and realize more of our potential. I decided that Controlled Traffic Farming was the next step because it could reduce compaction, and make operations more efficient and most importantly we would be utilizing our auto steer to it full potential.

9m was chosen to be the base width, which suited the header and the 3m tracks. Adapting machinery was not going to be a great concern, but a great learning experience.

Autumn 2006 was very busy getting the cropping machinery standardized. Although the airseeder bar had 3m wheel tracks, the tine spacing had to be changed to be able to leave bare wheel tracks. After much measuring and head scratching, 320mm was the final spacing that worked with our system. The airseeder is now at 9m with 26 tines. Also added to the airseeder was a boom to apply trifluralin using direct injection to increase the efficiency of the product and how we apply it. The air seeder cart was a simple job to space out to 3m also. The next job was to replace the boomspray axle and extend from 24 to 27m. The wheels on the 8520 John Deere were wound out at the back and front spacers ordered from Queensland. With an engineer moving in next door, we had an extra set of capable hands to be able to achieve the changes needed at home.

Sowing came and the 3m spacing worked well, especially with the boomspray with no foam marker needed. Inter-row sowing worked very well into 5t/ha wheat and barley stubbles with no blockages or clumping experienced, even with the change from 300mm in 2005 to 320mm spacing this year. Crops sown into stubble in the dry winter have far out performed other crops in the district sown on similar dates and the deep ripping and press wheels have again proved their worth. The trifluralin boom worked very well and we have had excellent ryegrass control. The pressure was taken off the boomspray during sowing, which helped efficiency on the farm.

Next on the list is to extend the auger on the header by 1m to allow the chaser bin to stay on the tramlines and the wheels on the chaser bin will be extended to a 3m wheel base. This will complete the conversion to controlled traffic.

Total cost for all the wheel track conversions is less than $10,000 with a lot of the work being done on farm. The trifluralin boom costed in the vicinity of $10,000.

Looking to the future changes that will be made are a boom on the rear of the airseeder to apply post emergent chemicals in one pass, and possibly refinements in paddock layout etc. Using disc seeders to sow legumes into thick residue on wider rows (640mm) is also something I am keen to investigate along with deep ripping paddocks coming in to crop from pasture, to fast track the improvements in soil health.

On reflection on our conversion from minimum tillage to no till and controlled traffic, we have seen some instant gains in production and reductions in costs with many more to be realized as we get further into the cycle. With the very dry winter we have just experienced there has been increasing interest in our system with the crops still looking very good.

Making Money out of Zonal Management

Adam Inchbold on behalf of PA Project Team (listed at end of paper), Riverine Plains Inc.

KEY MESSAGES FOR IRRIGATORS:

- In the Riverine Plains, zones have been successfully and easily delineated using EM38 surveys. However, elevation surveys can also be used;
- Once they are delineated, check zones with yield maps and historical knowledge;
- Monitor/test in zones. Even if no variable prescription is desired, differences in chemical fertility, soil physics and biology (including disease burden) often varies between zones, so the first impilication is even when undertaking paddock average monitoring, knowledge of zones is important to ensure representative sampling;
- Use soil test decisions to write input prescriptions;
- DSN (where applicable) and crop monitor in zones;
- Test strips are a good approach to testing the profitability of variable rate;
- Different zones within paddocks have been clearly shown to have large differences in soil-water characteristics, leading to differences in yield potential;
- Yield map! Yield map! Yield map!

INTRODUCTION

Riverine Plains Inc, has previosuly identified variation in important soil parameters within paddocks. Other workers in Australia, have already developed a means by which this information can be brought together with yield maps and other spatial data to delineate management zones within paddocks. However, most farmers are yet to adopt this technique on a commercial scale. Consequently, a project was designed to delineate and ground truth management zones in paddocks in the Riverine Plains and then investigate options to manage these zones more appropriately, according to their own unique characteristics.

Paddocks at three sites across the Riverine Plains were selected as project paddocks. Broadly the sites are at Yarrawonga, Vic ("Grand View" - Inchbold), Burrumbuttock, NSW ("Yaralla" – I"Anson) and Urana, NSW ("Bogandillan" - Hamilton).

FORMALIZING SOIL VARIABILITY

2003 was the first year of this project. In general terms, information that already existed on the project paddocks were combined with an updated Em 38 survey to delineate potential management zones within each paddock. An extensive array of measurements were taken in each zone. In 2003, ground truthing undertaken in each zone included 0-10 cm soil tests, 0-60 cm deep soil nitrogen (DSN) tests, data from in crop monitoring, and soil moisture data using Gopher meters. This ground truthing continued in 2004 and 2005.

In 2004, an effort was made to physically survey the characteristics of the soil across several of the project paddocks at Yarrawonga. The surveyed evaluated the soil monitoring sites already existing in the projected paddocks using all of the known systems of classification including Isbell, Northcote and Great Soil Groups. This survey yielded some very interesting results.

Essentially the properties of the topsoil remained similar across much of the area surveyed, however the properties of the sub-soil changed significantly as the soil surveyor moved down the slope from the tops of the hills through the mid slope to the points of lowest elevation. The sub-soil characteristics of greatest interest for analysis are considered to be:

1. The presence of sodicicty in the profile where soil aggregates disperse;
2. Soil permeability.

On the tops of the hills, the topsoil basically overlaid a mix of B/C horizon (partially broken down parent material) with no A2 horizon present. Moving down the slope, an A2 horizon became present (chromosol), and then more pronounced. As this was happening the sub-soil became more clayey, and eventually became sodic (sodosol).

The extent of this variation is highly significant when thinking of the actual characteristics that vary in the soil through these different soil classifications. Many of the these properties potentially have a marked influence on production, giving rise to the potential to target different levels of production on these different soil types. An understanding of how these vary across the paddock will provides a key to identifying when and where the crop runs out of available soil water in drier seasons, and where areas of superior drainage benefit in wetter seasons.

TEST STRIPS – A COMMON THEME

Nitrogen

In 2003, the amount of available N from DSN tests taken from 90 sample sites ranged from 31 to 320 kg N/ha. Statistics (analysis of variance) indicate that significant difference occurred between the zones, with no significant difference in values occurring between replications (*$P < 0.05$*). This indicates that DSN values were consistent within each zone, and therefore differences in DSN status between zones was meaningful.

As a result of the significant DSN results, an N fertilizer response experiment was set out, according to the guidelines developed by the ACPA (Australian Centre for PA). This involved the laying out of a replicated N rate trial in each zone to determine the response of each zone to varying rates of N (Figure 1a). Yield maps (Figure 1b) were used to evaluate crop performance across the zones and also to determine the yield results of the test strips. Analysis of the yield response in each zone to applied urea in 2003 performed by Brett Whelan, ACPA, is shown in Figure 2.

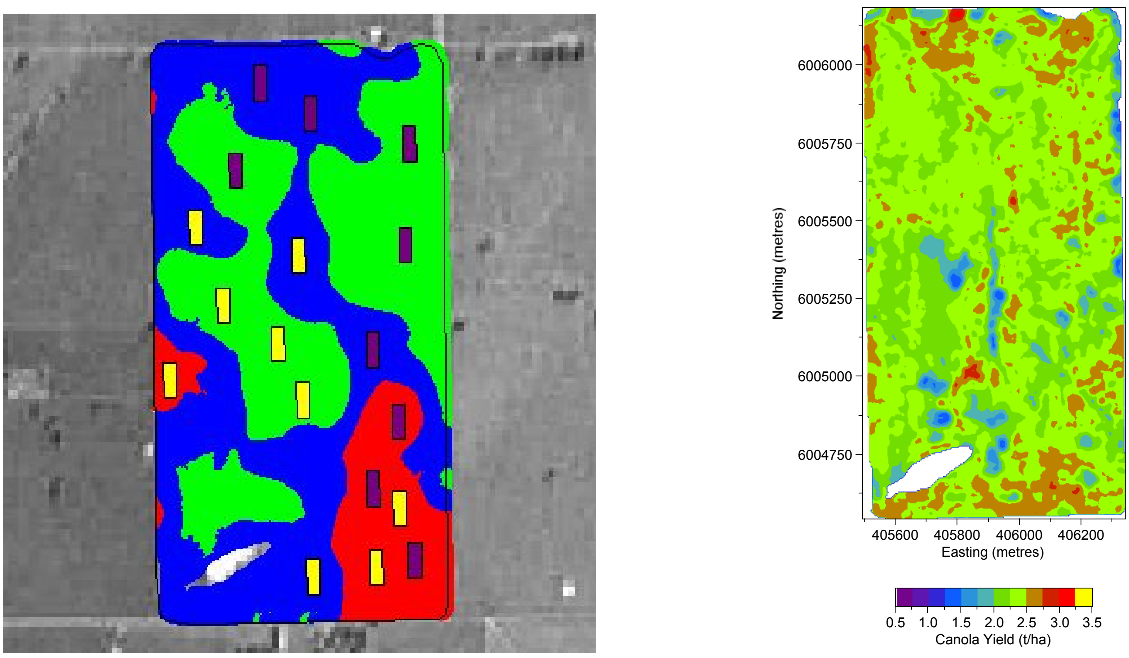


Figure 1. (a) Urea fertiliser application layout – yellow plots received 0 kg/ha, purple plots received 200 kg/ha, rest of the paddock received 100 kg/ha. (b) canola yield map for 2003.

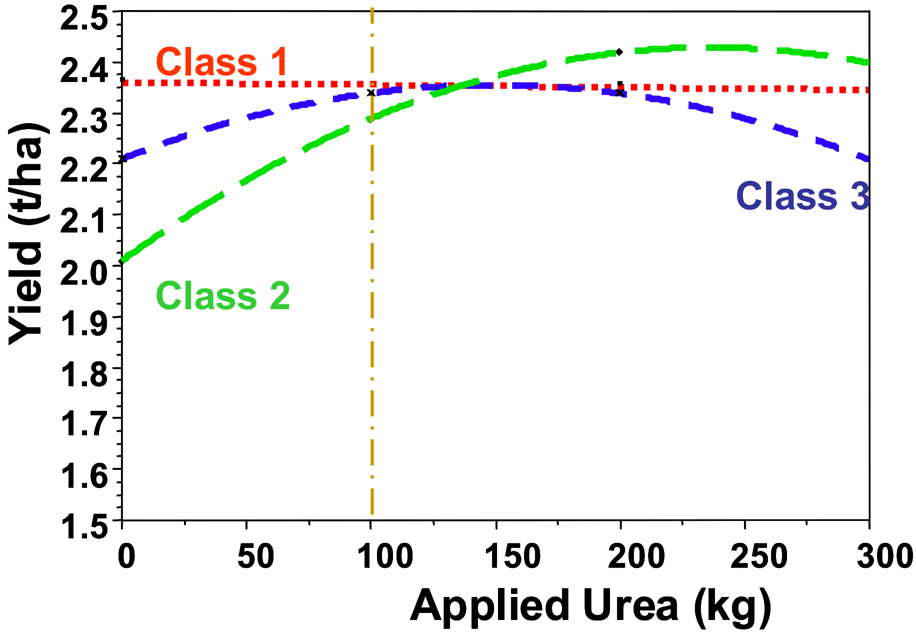


Figure 2. Yield response to applied urea in each potential management class. The paddock average of 100 kg/ha is shown to provide a relatively even yield across the classes, which is confirmed by the yield map.

The yield map is generally uniform across the paddock and this is reflected in the response function analysis. The majority of the paddock received 100kg/ha and the variation between the zones at this rate was calculated to be just 0.1 t/ha on average. However, an economic examination of the response data shows that the output from the different zones would have been optimised by applying different average rates in each. The urea rate for maximum yield and economic optimum urea rate for each zone using a marginal rate analysis is shown in Table 1.

Table 1. Urea rates to achieve maximum yield and economic optimum per management class.

	Urea Rate for Maximum Returns (kg/ha)	*Urea Rate for Maximum Yield (kg/ha)*
Class 1 (Red – High EM)	0	0
Class 2 (Green – Low EM)	169	237
Class 3 (Blue – Medium EM)	72	151

Using these response functions it is possible to make a simple estimate of what gains or losses in gross margin would have been made if this information had been used to formulate fertiliser decisions at the beginning of the season. Table 2 documents a comparison with the paddock average treatment of 100 kg Urea/ha.

Table 2. Analysis of gross margin losses from fertilising at 100 kg/ha paddock average

Fertilizer waste	***ha x kg = t***	***x \$400/t =\$***
Class 1	18 x 100 = 1.8	720
Class 3	59 x 18 =1.06	424
Yield loss		***x \$400/t =\$***
Class 2	53 x 100 =5.3	2120
Total Loss		3264 (25.10/ha)

As can be seen in the breakdown, in 77ha of the paddock there was more fertiliser used than required, and in 53ha of the paddock an extra application of 69 kg/ha would have brought in over 5 tonne more canola. The total loss in this scenario is \$3264 or \$25.10 per hectare.

If this information was used at the beginning of the season, the 2.86 tonne of extra urea applied in Class 1 and 3 would have been distributed to Class 2, which would still require an additional 0.8 tonne of urea to be purchased for Class 2. The cost of the extra fertiliser would have been \$320 for a gain of \$2120 in yield. The difference of \$1800 (\$13.85/ha) in gross margin would have been gained.

The true result for the 2003 season then (in gross margin terms) is that with this information at the beginning of the season, instead of essentially costing \$25.10/ha more for the return it achieved, the paddock could have improved its gross margin by \$13.85/ha. The total turn-around in gross margin is therefore potentially \$38.95/ha.

In 2004, similar DSN results were observed between zones. This was encouraging as a relatively even yield map had been observed in 2003, giving support to the concept that genuine differences in N status between zones existed. Varying rates of N were applied to a wheat crop in paddock 44 in the same test strips that were used in 2003, to continue to test the varying production potential of the different zones. Figure 3 shows the N response functions for the three zones produced from the yield map of the wheat crop in 2004.

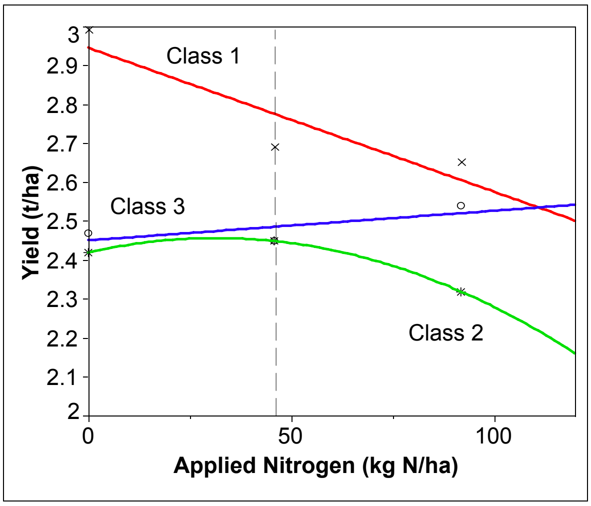


Figure 3. N response functions from 2004 wheat crop grown in 2004

2004 had an extremely dry finish to the growing season. Not surprisingly, the high conductivity zone, with its still high N status exhibited a strongly negative correlation to extra N. Extra N in the low conductivity, with its low water holding capacity also reduced yield.

The N response functions for 2005 are shown in Figure 4. 2005 was a much more favourable year. It can be seen that the response functions resemble to a degree those seen in 2003. The low conductivity zone with its poorer soil, continues to respond to extra N when there are regular additions to its moisture profile, ie in a favourable season. The medium zone with its intermediate N statues also responds to extra N, but the response curve tends to flatten out. The high conductivity zone, with its higher N status, responds the least to N.

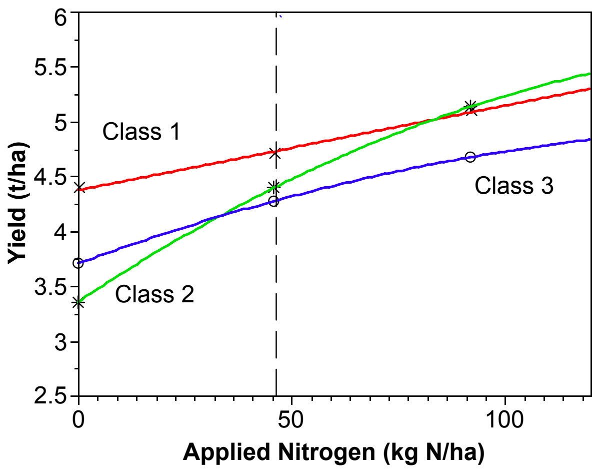


Figure 4. N response functions for 2005 barley crop

Phosphorous

In a similar fashion to paddock 44, test strips were also laid out in zones in paddocks 46 and 49. These strips however have had varying rates on P applied to them in 2004 and 2005. Figure 5 shows P response functions for the 2005 wheat crop in paddock 46. The key aspect here is the significantly different response to extra P in the high conductivity zone compared to the other two zones.

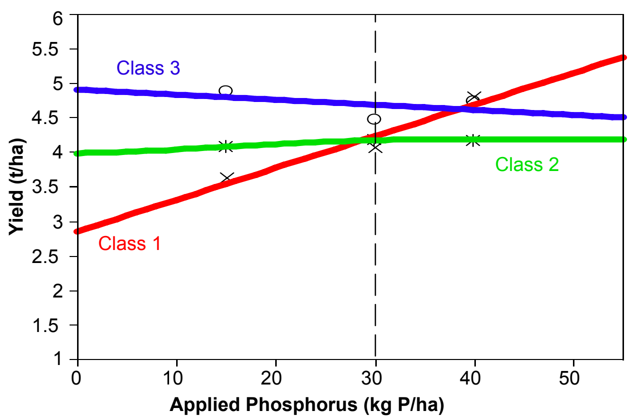


Figure 5. P response functions for three zones in paddock 46.

Soil-water, one of the drivers?

Soil moisture tubes are located within management zones at “Yaralla”, Burrumbuttock, and “Grand View”, Yarrawonga. At each site, at least three moisture tubes are located in each management zone to provide some replication of results. In 2003, 2004 and 2005 soil moisture was measured at 10cm intervals down the soil profile with a moisture measurement sensor down to 1 metre. Readings were taken during the growing season twice weekly.

The soil-water measurements that are being taken are proving to be a highly valuable dataset. It can be seen that the soils in the different zones have vastly different soil-water profiles. This is obviously crucial for a zones ability to yield, and hence the picture that will develop from further measurements in this area will give a more insight into an individual zones’ ability to yield. In Figure 6, the High Zone (Blue line) in Paddock 12 extracted more water than the Medium and Low Zones. In Paddock 44 all three zones extracted a similar amount of water (i.e. have similar trends) however the Low Zone had less water to begin with.

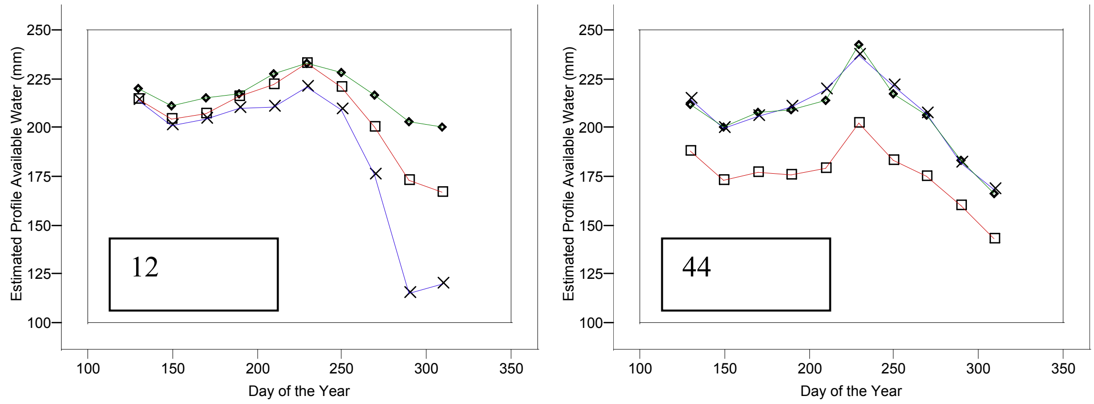


Figure 6: Graphs of the change in Profile Available Water (mm) for the three management zones as the growing season progress.
Blue = High Zone, Green = Medium Zone and Red = Low Zone.

The above is also supported by the results from the test strips. In the end, the test strips in each zone give an indication of the production potential of that particular zone. For example, in a favourable year, the low conductivity zone has the potential to perform as well as the high conductivity zone. However, when moisture is more limiting, the low conductivity zone will generally yield lowest. The high conductivity zone seems to have the highest inherent potential to yield, as it can store more water.

Results from the N strips in 2005, have been added to DSN results for these strips prior to N application and graphed against yield to give a yield response to total available N for each of the three zones. The difference in response curves between zones is marked, supporting the notion that there is a significant difference in yield potential between zones (Figure 7).

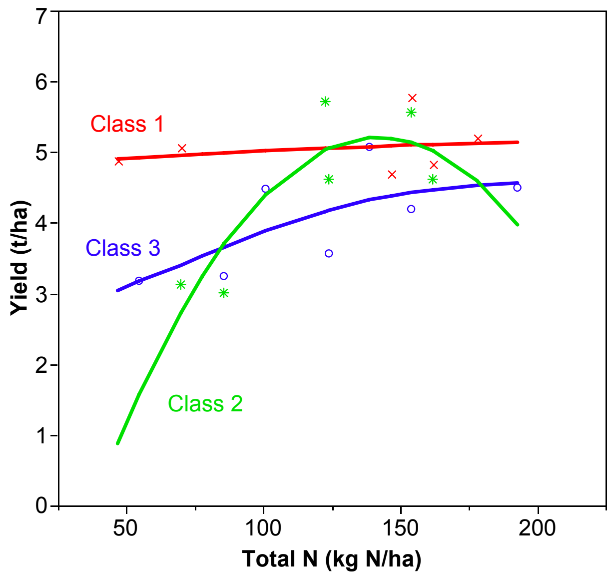


Figure 7

This is an area that represents the next step in zonal management. If farmers know which zones have a higher production capability, then different yield targets can be allocated to different zones, resulting in a more sophisticated and more appropriate fertiliser strategy. However, it is important to remember that a very sophisticated variable rate fertiliser strategy requires very good knowledge of a particular paddocks variable characteristics to guard against costly errors. This of knowledge will be built up over time. At this stage, it would seem that there are a number of simpler steps that should be taken by farmers getting into zonal management that don't necessarily require such a comprehensive understanding of their paddocks eg variable rate lime and gypsum applications.

How much money is in variable rate?

Not surprisingly, the answer to this question is dependant on the characteristics of each particular paddock. However, it can be seen from these examples, that paddocks do vary significantly in important production parameters, and that treating these zones differently can result in an improved gross margin. In this project we have seen the potential to make money through variable rate applications of Lime, Gypsum and Nitrogen. Furthermore, a highly complex approach is not required to undertake variable rate applications. Firstly paddocks are split into two or three zones, and then these zones are simply tested as if they were individual paddocks, instead of testing across the whole paddock as an average. Inputs are then applied to individual zones according to their particular test results to achieve a more optimum level of input for the system as a whole. A generic protocol to get farmers started in variable rate has been established by the project team. It is as follows:

- EM survey & zone paddock/s
- Check EM & zones (yield maps,NDVI etc)
- Ground truth – soil cores & surface samples
- Develop VR lime & gypsum plots (+ standard paddock. strip)
- DSN test to zones
- Crop monitor to zones
- Yield map

EXTENDING THE MESSAGE

Aside from the extension of results from this project through general information days, Riverine Plains are extending results from this project to farmers through a series of discussion groups that will give farmers that chance to hear about results from this project, as well as discuss and learn about other PA related issues. Over forty farmers have signed up to be a part of this group from the general membership base. In 2005, Riverine Plains gave giving the members of the discussion group the opportunity to lay down there own own-farm trial plots to assist in the adoption of zonal management on the commercial scale. This will continue in 2006, with other PA issues such as guidance and controllers also being discussed and evaluated.

Riverine Plains "Zonal Management in the Riverine Plains" Project team

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Opportunities and Strategies - The Big Picture

Don Yule, CTF Solutions, Queensland

At the 1998 Controlled Traffic conference, just nine years ago, I said that we had developed a collection of unconnected ideas (controlled traffic, downslope layouts, zero tillage and water use efficiency) into a farming system called Controlled Traffic Farming. Technically this was radical but straightforward and successful. Our process depended critically on partnerships with growers, mutual respect, recognition of opportunities and commitment to on-farm actions.

The birth of CTF depended on a clear vision of opportunities and a flexible, structured approach to achieving the vision, a strategic planning approach. Actually there wasn't much planning, there were opportunities, strategies and actions. It all happened very quickly, in three years we developed CTF and in 10 years we had changed about 1,500,000 ha of Australian croplands. I think the keys were the strategies - we all worked very hard to see how the pieces could fit together. We knew what we wanted to do and then, through the on-farm focus, we worked out how to do them. Strategies involve what and how, and then just do it.

At last year's conference we concluded that the "what to do" and the "how to do it" were proven by grower experiences, so the motto was "Just do it, but do it right". Growers have now established that CTF systems are an effective and efficient platform for all forms of cropping. The key words are systems (includes everything) and platform (a launching pad for today and the future). The basics of the systems (the must haves) include strategic thinking or longer term goals (property management plan), action planning (short term), designed farm layouts, controlled traffic, matching machinery, auto-steer, precise row, inter-row and wheel track management, high cover levels, farmer/adviser/supplier partnerships, measure to manage and continuous improvement. These are the goals and opportunities, and the strategies aim to achieve them.

CTF is also a platform - new ideas and technologies can be easily added and new ideas and technologies work very effectively in CTF. This is the story of CTF - the pieces all fit together and are complementary - the whole is much greater than the sum of the parts.

The platform aimed to remove constraints and to create opportunities. Initially, we focussed on two constraints - controlled traffic to manage soil compaction and designed layouts to manage runoff and erosion. This platform was fantastic for zero tillage, high cover retention, managing water logging, whole farm efficiencies, crop growth, flexibility and precision. It simply achieved a wide range of positive outcomes, in fact all the positives we could see. Independently, the same ideas worked for raised beds, these are very robust concepts.

Another constraint was also addressed. It is described by Jamie Grant as "between your ears". Our process of on-farm "have a go" towards a strategic vision enabled all of us to challenge "between our ears". In retrospect, I think that growers have taken this challenge very well as the level of change testifies but the off-farm people in agriculture have found it much harder.

In this paper, I will address the current opportunities and strategies to achieve them. These will be considered at the farm, district and national levels in terms of adoption, R&D and continuous improvement, and include management, marketing, tools and technologies.

ON-FARM OPPORTUNITIES AND STRATEGIES

Complete CTF. The first and foremost on-farm opportunity is the adoption of complete CTF systems. I am frustrated that about 90% of growers who claim to be doing CTF do not include the harvester in this. Indeed, of the eleven basics of CTF, most growers would probably do three or four, but worse, have made recent decisions, e.g. machinery purchases, that are not consistent with the strategic vision of CTF, their strategic plan. Our strategy needs to publicise more farmers on complete CTF. We need to champion them. I will show here that more growers on standardised CTF systems allow a wide range of new opportunities. I call this cooperation with independence.

Partial CTF. This partial CTF misses most of the on-farm opportunities and also constrains the whole CTF community. I suggest that these growers give the impression that a little bit is ok and this is an easy message for others to accept. It is only ok as a transition step in the strategic vision. Partial CTF creates a risk, to move growers from one comfort blanket to a somewhat better comfort blanket without breaking through the barrier. Then it may be harder to continuously improve. But “If you’re on track but standing still, you still get run over.”

Productivity and WUE. The on-farm opportunity is productivity. Cost reductions will happen but the big benefits are in productivity and quality gains. The key indicator is water use efficiency and many growers have now achieved paddock WUE of 30 kg/ha/mm. Ten years ago, the theoretical maximum was 15 kg/ha/mm, CTF has set new boundaries. And how can the same grower produce the highest yields in the district and have the highest cropping frequency? After achieving yields of 3t/ac, this grower was asked “What is you yield target now?” Answer “5t/ac, then I’ll get to 4t/ac really easily.” I am sure that these water use efficiencies will be exceeded, we know from yield monitors that some parts of every paddock yield significantly higher than the average.

Soil types and CTF. I am also hearing more and more reports that soil type differences become much less after a few years CTF. Near Geelong, a paddock with major soil differences has very even crop growth and yield - the grower has removed soil variability by his management, and it is not variable rate. In central Queensland, growers report that differences between deep and shallow soils become much less - “the soil boundary has disappeared in my crops.” Similar experiences are reported from south-western NSW, and will be described at the conference. Managements to remove the constraints of soil compaction, runoff, erosion and waterlogging, to address pH and to improve the general soil fertility (manure, mill mud) are very effective. The results imply that storing water deep in the soil is not too important and crops can do very well with a shallow root zone. We need to document these results and new emphasis on measurements will achieve that. We need new goals to break.

Fence-lines. Another on-farm opportunity is fence-lines; these can be reduced to row spacing width - no structures, the whole area managed, no weeds, no resistance build-up, no pest sanctuaries, and no mess. This has been common in the sugar industry and on the Darling Downs, it is proven technology. The strategic decisions include dealing with livestock, farm record keeping (rectified imagery) and integrating infrastructure (roads, drains, trees) with crop areas (farm design).

On-farm Strategies. The strategies to achieve these on-farm opportunities are to encourage and assist growers to use the capabilities of your CTF systems to test your ideas, to push the limits, and to apply the new technologies to support your continuous improvement program. Farmer driven, on-farm R&D is crucial and easy, but you need support to ensure the rigour, applicability and analyses, and you need to record and measure. The bottom line is that growers can have confidence to have a go, there are no “between the ears” constraints.

I suggest we need strategies to provide support for grower adoption and information about successful stories to build grower confidence and we need to develop on-farm R&D services. These strategies could be themes at CTF07 conference - complete CTF systems and transitions to get there, on-farm R&D, development programs for professionals to provide more services, and approaches (by ACTFA) to agencies for funding to develop on-farm R&D processes and services.

DISTRICT OPPORTUNITIES AND STRATEGIES

At the district or regional scale, the opportunities revolve around cooperation and sharing. This includes machinery, contractors, imagery, GNSS base stations, marketing, purchasing, services, etc. These are business and not social decisions because sharing with "local" people makes business sense. There are also environmental and management opportunities - drainage integration, nature corridors, roads and communications, area wide pest management, spray drift, etc. Some of these clearly have a social dimension, for example, boundaries between conventional and organic farmers. Any success of CTF growers to address these issues through "local" cooperation, will be another leap forward for CTF in resource management, productivity, profitability, the environment, lifestyles and communities.

Machinery sharing. A particular risk for CTF growers seems to be that after a few years of controlled traffic the farm has clearly defined wheel tracks and crop zones. If machinery breaks down, one wheeling of the crop zones will destroy most if not all of the improvement achieved and quite possibly (if it is wet) machinery on a different wheel spacing or implement width won't be able to operate at all.

Technology co-operation. Imagery and GNSS (GPS) technologies are spatial, they don't recognise farm boundaries and deliver information to areas - satellite imagery has a minimum area and base stations a limited range. Cooperation is cost effective. Compatibility across manufacturers and support services will improve if growers group together. On-farm computing, farm record keeping and GIS services will improve. CORS GNSS networks offer quality, up-grading and reliability, but the cost, availability and timing have not been determined. An opportunity is to re-direct the considerable current investment. Issues with telecommunications are uncertain.

Strategies. The strategy with base stations is at the minimum share within the 10 - 15 km range (independent of colour) and in the longer term to have networks of stations that will increase quality, upgrading and reliability at a lower cost. Our strategy is to facilitate the development of CORS networks in agricultural districts by linking current bases. There are few technical GNSS issues.

Standard machinery wheel tracks and widths locally is a necessary risk strategy. At a "local" level, the fundamental strategy is cooperation but cooperative structures have a generally sad history. New approaches are being tested; does your change to CTF create clear goals for cooperation and simple rules of operation? Does CTF provide a platform for simple negotiation; does CTF respect your independence while fostering cooperation? Contracting could be a major driving force in this. Contractors must comply with certain basic specifications, and inevitably this will restrict some individual farm options. Is this a bad thing?

Different approaches across the grains, sugar, cotton and horticulture industries will identify opportunities. The massive changes in the sugar industry will include moves to cooperatives and contracting. Although less obvious, the same basic issues are widespread in all industries. Our recent moves to foster communication and discussion among the industries through CTF Conferences and ACTFA provide strategic support for these changes.

NATIONAL OPPORTUNITIES AND STRATEGIES

At the national scale, CTF provides a platform for all cropping industries to combine around the common issues of soil, landscape and environment management; provision of technology, services and infrastructure; product identification, labelling and marketing; and access to markets and value adding. CTF provides strategic common ground for combined industry approaches and policies to governments, machinery manufacturers, service providers, etc. This could break agriculture's long history of playing one industry off against another, and product differentiation to prevent compatibility. The ACTFA initiative could provide the vehicle, and interactions established at CTF05 last year indicate the potential. We need industries to say that CTF is our platform to the future.

A key national opportunity is R&D. Across all industries there is little CTF R&D. Each industry has its own dedicated body, structures, even culture with highly developed and entrenched directions and operations. CTF is only a small part of these cultures (and the provider linkages) and, interestingly, these agencies have been much slower to change than growers. We need these agencies to say that our R&D will support the CTF platform.

New technologies have provided the tools needed for on-farm R&D. GPS logging of operations, satellite imagery to measure growth and yield monitoring to measure yield and quality, all provide automated, digital, computerised recording of 0n-farm R&D, with very little disruption to normal farm operations. But farmers need support in experimental design and implementation, data management, analysis and interpretation, and what's next. This creates a large training need for current agronomists (they too have to change) and an opportunity for many in current R&D roles to apply their skills to on-farm R&D instead of working within institutions and research stations. This is a massive change in R&D strategy and that change will need a lot of drive and support. But this change will drive the future of CTF and is essential to achieve our potentials.

New technologies. The positive interaction between new technology and CTF (CTF needs technologies and these technologies are maximised in CTF) is another indication that CTF is on the right track. 2 cm guidance and auto-steer in CTF ensure a perfect job to achieve our clear goals, in any other system it just relieves stress on the driver. In CTF, yield monitors provide accurate and easy to analyse data, in other systems yield monitors produce poor data due to variable filling of the comb and uneven coverage of the paddock. These data are difficult to manage and statistical methods are often used to "hide" this created variability. Satellite imagery measures the on-farm performance of CTF growers and responses to management and changes. The high resolution of imagery is matched to the accuracy of operations to allow assessment of the causes and impacts of variability. We are calling this forensic agronomy - what caused that variability, how large are the impacts? How can we respond? Forensic agronomy is "understand the cause and effect, provides the solution". This analysis is totally confounded in random traffic systems and with large pixel data.

Technology improvement will be in terms of upgrading GPS systems, reference station networks, and redesigning the rovers (specifically for agriculture); increasing the accuracy of yield monitors and adding quality sensors; effective ground sensors of soil and crop condition, particularly less dependent on reflected natural light as used by satellite and aerial methods; and the biggest change will be in data management, GIS applications and delivery processes to the farm computer. Future farm record keeping and software packages will provide effective tools for decision making.

Reference station networks will displace the farm base station and save a lot of money. We guess that farmers are spending up to $10 million per year on base stations and this could be much better spent. Networks offer better quality and reliability, easy upgrading and ensured quality. The cost, as with all these spatial applications, depends on how many subscribe. Wide access to 2cm RTK signals and manufacturer's changes will support a major move to 2cm auto-steer and encourage widespread adoption of CTF. Historically the development of GNSS has been driven by military and surveying applications. The surveyors are critical as they can guarantee the accuracy of the technology, a complex task as our continents drift around. Recently the GNSS community has recognised that agriculture offers a large user base, so there will be increased interest in the short-term. CTF growers are in the best place in agriculture to influence the GNSS direction, and ACTFA can have another role as "spokesman" for the industry. The CRC for Spatial Information is a focal point for the latest advances in GNSS and spatial information generally.

I think there is potential to improve the rovers, they are expensive, growers need several on most farms and they duplicate services. I don't know what is possible but expert input should be rewarding.

Availability. Inherent in these improvements will be increased availability. Telecommunications are key and there seems to be a real expectation that wireless broadband services will be available soon. This implies that rural people will have the same access as urbanites without the cost of hard wire provision. There should be an opportunity for a mega-leap forward and I hope our rural politicians have sufficient vision. Availability will also be increased by reference station networks, incorporating technology into new machines and software development. Data and information management provides new challenges. While growers need training to up-skill, the provision of specialist services is a necessity. What does a farmer do, what does a consultant/service provider do? Clearly, the solution will be individual. This is not rocket science, just good business practice and many other industries have been through these changes. We can learn from them and not make the same mistakes.

Product identification - knowing where the product parcel came from on the farm. This will be attached to the smallest marketable unit and has opportunities through the whole value chain to the final marketplace. The potential to link farm product to final markets is enormous and a wide range of information could go with the product - the farmer, the farm, the management system and inputs, the yield and satellite image, all as a small snapshot joining the product to the producer. This has already happened in beef but each CTF grower can provide unprecedented data. A big challenge for us is how can this help you to manage the farm better?

Value chain. The link from farm to processor offers benefits. Sugar growers could use the mill calculated sugar content from individual bins to calculate a sugar yield map instead of a cane yield map. Grain growers may have similar options as grain handlers measure more quality parameters on each truck load. Vegetable growers could construct product quality and value maps. Many growers will have opportunities from product segregation because of this better information. Over the next few conferences we will hear many reports of successful applications because CTF growers have the best possible platform to use the technologies.

Marketing. Is there potential for a CTF tick of approval, a label? We all know that CTF growers have a better product and deserve a higher price.

New sensors and measurements will be developed. A current focus is on-machine sensing for immediate variable rate applications. Most of this technology seems to be a long way ahead of the science. What is the sensor measuring and what is the best response? An example is N sensing. The technology is available and linking to an applicator is easy, but is N the main driver, and should you put on more or less? Our work has not yet shown an obvious application for VRT but as we manage the farm better, opportunities will arise. VRT is one of the later technologies to adopt. Again, CTF growers have a platform to use VRT.

Controllers will continue to improve and we have a range of excellent suppliers in a competitive market. Farm office software is a different story - access to spatial information has left the software behind. There seems to be a reluctance to change and few new players, but this is not new in other industries, we just have to go out and find it, and show we are a big, viable market.

Service providers and advisers, including those in government, agencies and the private sector, are our largest opportunity. While CTF Solutions is very proud of our position in your industries, as a whole, this group has minimal understanding of CTF and, expresses little interest in changing. The Victorian Department has CTF expertise, other State Departments have reduced their inputs. SRDC and GRDC recognise CTF but national agencies, Universities, catchment authorities, etc. invest little on staff or training. I can't recall a CSIRO publication that has recognised CTF. ACTFA has a big job ahead of it.

National Strategies. The primary strategy is to gain recognition that CTF is the farming system platform for all cropping industries across Australia. We need more people in all sectors of all industries committed to the CTF future, then we will obtain the breadth of support we need.

ACTFA is the vehicle proposed. With a large and widely distributed membership, ACTFA can be an effective, national voice with the advantages of being across the nation, across industries, focussed on the universal basics of farming systems but outside the controversial, agro-political issues. A number of possible ACTFA roles have been discussed; it will take time to achieve them.

R&D and Adoption strategies. The general strategy here is that we can learn from each other, and if we have common issues, the wider diversity among backgrounds, the more we can learn. National CTF Conferences are crucial and local mini-conferences will create local and district solutions, and increase participation and publicity of innovations.

Research and development of new on-farm R&D processes that use the combinations of CTF and technologies is essential for continuous improvement and increased adoption. An integrated ACTFA approach across industries' funding bodies will quickly achieve robust and applicable processes and build a CTF snowball. We have clear and simple goals that apply across all industries, so our opportunities are huge if we coordinate. Again CTF Conferences and ACTFA provide a launch pad.

The strategy for change and adoption is that every change you make means it is easier to make the next change. Every adoption that provides learning and improvement builds confidence to keep building, removes the "between the ears" constraint to continuous improvement. A major challenge for CTF nationally is that some adoption has occurred, some big gains have been achieved, so let's just enjoy it! National funding bodies have responded that CTF adoption is happening and will continue to happen by itself, it needs no more funding. This is a smokescreen that maintains the status quo for funding allocations, i.e. plant breeding, crop protection, environmental impacts, etc. There is a role for everyone interested in CTF to be strong advocates in every forum, committee and meeting. We need a strong national lobby group to change the national thinking and ensure a strong R&D and adoption support program for CTF. This is a role for ACTFA.

Technology strategies. CTF growers are leaders in the use and application of new technologies. We can collectively influence manufacturers and suppliers with our collective needs and innovations. Our strategy is to open communications, to invite them to CTF Conferences and to hold joint meetings. Availability and on-farm practicalities are priorities and our focus will be on compatible solutions rather than proprietary ones, on building a bigger pie rather than offering bigger slices.

People capacities. The proposed on-farm R&D process creates hands-on training and capacity building for everyone involved – growers, researchers, advisers, service providers, etc. Because the on-farm goals and expectations can be clearly defined, it will quickly identify deficiencies in people capacities and training or up-skilling needs. I expect CTF growers to lead this as both the ultimate purchasers and beneficiaries, and a massive training effort is required. But our on-farm R&D process will be the next revolution, the driver of industry and individual profitability and sustainability.
And the time and place are perfect – EUREKA.

Professional Farm System Design: Planning and Implementation of Practicing Controlled Traffic Farming

Stewart Cannon, Rural Property Design, Gowrie Junction, QLD

Firstly, there are some basic concepts that need to be understood when planning Controlled Traffic Layouts :

1. The differences between a "map" and a "drawing" or a "photo" and photos' can be a panorama or horizontal and Geo-referenced.

2. The understanding of "I" and "You". This may seem of little relevance but it is very important to achieving high quality layouts at the first attempt. A critical reviewer of your planning will considerable value to your planning process.

MAPS

A properly made map has 5 elements:-

1. It has a TITLE
2. It has a BORDER
3. It has a NORTH SYMBOL
4. It has a SCALE
5. It has an AUTHOR

Why is it important to highlight these elements of a properly made map?

Irrespective of the image on the page a map is a 2 dimensional representation of a 3 dimensional model, the earth, and therefore there are difficulties. However maps allow detailed planning using either hard copy or desktop applications to be confident of adopting this planning "on-farm".

TITLE

Each map is based on a theme, therefore the use of a title.

It tells what the map represents. At this conference we will review topographic maps, either based on contour lines, drainage systems or drainage patterns using point runoff directions. Computers add value in reviewing these different applications. The basic 'x,y,z' co-ordinates collected by high resolution G.P.S. equipment may be presented in different formats.

I have coloured impaired vision and colour wash does not appear to add value to my planning. Chose one that is suitable for you.

BORDER

Most people, in this room over the last 20 years or so, would have attended some form of Property Management Planning Workshop, latterly computer supported, where you were given, or purchased, a "Whole Property Map" based on air photos, or photo mosaics for larger properties. With Controlled

Traffic Farming (C.T.F.) layouts we tend to start at the paddock scale and move toward a whole property layout, therefore a border allows a clear focus to the area, which is important

The critical element of planning, from my perspective, is 'access', the ability to move machinery, inputs and product as quickly and efficiently as possible.

At the paddock scale it is critical to evaluate access in terms of planting, spraying and harvest but not in conflict with the down-slope layout.

At the whole property scale access is critical for collecting, storage or straight to delivery. Again, boundaries allow you to focus on the most important element.

Contour maps (topographic maps) at different scales should be your first preference for planning, access and at any scale but may need manipulation of contour interval.

NORTH SYMBOL

All maps feature a "North" symbol and usually the text is West to East (text for streams, rivers, etc are usually aligned with the shape of the drainage system). This is convention, but we can use this to plan layouts, particularly for light (day length) sensitive crops. In the lower latitudes of Australia one needs to be more sensitive to row or bed direction. Canola or grapes, for example, probably need to run North-South and this will bring maturation together.

In relation to the North symbol, you should investigate your map, if using G.P.S. derived images, a number of different map projections are being used, either based on latitude and longitude or map grids.

Modern maps should be based on M.G.A. (Map Grid Australia 94) this is the standard used. This is not a magnetic projection, but based on a system of grids a number like 55/56 the "Parallels" North to South and the letter 'J' etc the parallels East to West.

This map system is convenient in that basic tools, such as a ruler, can measure (on a map) or a tape (on the ground) from one known point to an unknown point.

I don't know if the difference between Magnetic North and Grid North has a significance when planning for bed and row direction.

SCALE

Usually, in properly made maps, scale is one of two formats, 1:25,000 or a scale bar, or in a well made map both scale bar and numeric scale will be indicated. Both are relevant and because, these days, it is easy and cheap to copy maps either using computers or photocopiers. It is critical that the scale bar (at least) is included on a map.

In the reproduction of a map the basic image may be at A3 but most copies are on A4.

The scale of the map will be different, but a ruler will allow you to reconfigure the actual scale of the content of the image. Even a photocopy or a facsimile reproduction may vary the scale.

It is my experience that G.I.S. Technologists do not understand the value of scale, or the importance of representation of a useful scale, e.g. 1:100,000, rather than 1:100,200, or 1:20,000 rather than the enlargement 'fit to page' of 1:17,625.

AUTHOR

Not so important, but particularly relevant if you are using images and then an overlay to do basic planning, using a paid or unpaid Consultant. Always add the planning date.

At some time in the future you may compare the overlays or do more planning. The Author and date will allow you to remember the decision making process. This is also where the "I" and "You" come in.

Whether you are using a Consultant, paid or nor, a friend, family member etc., value their input, they can help in your planning

People who don't understand your day to day operation may add considerable value to your planning process by asking basic questions, "Why do you do it like that?". There are no "right answers", just some a lot better than others.

A logical preference for planning a C.T.F. layout is based on the following elements:-

1. Layouts which are free draining
   There is now a body of evidence that strip cropping is not a free draining layout and 'race track' layouts are not free draining.
   Water logging, ponding, at any time of the cropping cycle is detrimental to yield.
   Rainfall which exceeds infiltration needs to be managed ????
2. Access in paddock – whole farm should be focused on ridges or constructed.
3. Use "can't change" as a basic tool e.g. boundaries, etc
4. Diversion structures where needed are integral to layout protection.
5. Try agronomic protection before mechanical support, e.g. drainage.

Planning and Implementing Controlled Traffic Farming

Neale Postlethwaite, St Arnaud, Victoria

WHAT IS CONTROLLED TRAFFIC?

The driving of all vehicles along the same wheel tracks across the paddock throughout the year.

Why do we need to control our traffic?

- Reduce compaction
- Target our weed control more appropriately.
- Remove overlap/underlap to reduce costs.
- Convenience – all field tasks are more pleasant when the previous rows are there to follow as a guide.

BACKGROUND

Our 2000ha farm in the Wimmera has been operated as a "No Till" farm for the last 24 years. During that time many different challenges have been faced and addressed in various ways to allow us to crop continuously. With a 275mm average growing season rainfall (GSR) and having no livestock in the system we have been able to meet the challenge.

By maintaining our crop residues, reducing compaction and better soil structure we have been able to store an extra 50mm of sub soil water each season. This has meant that we have not needed fallow in the system to store water. Five years ago the move was made to go fully "controlled traffic". We had been halfway there for a number of years, having our boomspray a multiple of our seeder width.

HOW DO YOU MAKE CONTROLLED TRAFFIC WORK?

The most important thing is to reduce the impact of wheeled machinery over the paddock. Once soil structure has been improved by increasing the soil organic matter from retaining stubble then compaction can be addressed. In Queensland zero till didn't work initially because they had such poor structure, particularly in the summertime when rains meant bogged headers and the like. This lead to very poor soil, and it was only when the traffic was restricted on the paddocks that the soil structure started to improve.

In the Wimmera the self cracking clays tend not to be as poor, and as a result the damage caused by compaction can be partially repaired by the soil itself. However, we have found that once the soil structure improves, it is very obvious that we are suffering a yield penalty anywhere that wheel traffic is obvious across the paddock. One major factor of course is that livestock must be removed as a priority, as the compaction they cause is just as damaging.

The starting point is making the boomsprayer match the seeder. Ideally it would be three widths of the seeder, however with some thought it is possible to set a system up on two widths. All machines then need to have a similar wheel base. The coming standard will be three metres, as boomsprays, seeder tankers and headers are relatively easy to set up this way.

The next step is to tramline sow the crop with a different row, or pair of rows to make it easy for following through the season. With an obvious mark to follow, the operating window for spraying opens up to nighttime, this improves the efficiency of operation. Overlap is eliminated, or at least becomes consistent, allowing better budgeting of sprays. (It can be annoying running out of spray with 200m left to go in the paddock!)

THE MECHANICS OF OUR SYSTEM

All our machinery is based on 3m wheel base. We have an 11m seeder, 33m boomsprayer and 11m centre discharge header front. Our chaser bin also has 3m wheelbase, and a loading hopper extension to keep it on our tracks. We use AgGuide GPS autosteer to establish our tramlines, keeping all the traffic to an 18.4" wide wheeltrack each side of each machine. We don't sow the wheel tracks; this reduces the risk of infection and spread of disease through the crop from plant injury as machinery drives over the paddock.

SOME BENEFITS OF CONTROLLED TRAFFIC

The full benefits of controlled traffic are possible when it is part of a system. Using it in conjunction with zero till allows many new options for weed control, and disease control to be possible. We use 2cm GPS to set up the tramlines, to target areas of the paddock for special treatment. For example we can side dress fertilizer beside the crop row, so that only the crop has access to it, and not the weeds. This also means we don't have to wait for a rain to allow the nitrogen to wash in, as is the case with topdressing.

The most exciting development that controlled traffic allows is the more targeted use of herbicides and fungicides. We have halved our fungicide and insecticide costs because of controlled traffic. Wide row spacing, while controversial, is still a major part of the system. Utilising the stubble blanket as a means of reducing evaporation allows the flexibility of widening the row width without reducing crop yield in some crops. This then can allow the strategic use of shielded sprayers to target weeds and reduce herbicide costs by approximately one third. To explain how this is possible is more than space will allow, however timing of spraying is critical for a good result. There are also more opportunities to rotate chemical groups this way as well.

Figure 1: Three point linkage TPOS shielded sprayer (11m wide) in a crop of barley.

PERCEIVED PROBLEMS

To many people the cost of getting into a new system is going to be limiting, however with controlled traffic it need not be the case. Some lateral thought is required first. You need to get around your machinery and think about how it may be used, as it is, then prioritize what can be modified over time. Work out what can't be changed and make the rest of your equipment fit around that. The main thing is to standardise on machinery width. A smaller boomspray isn't necessarily a problem when you can drive it for more hours in the day.

With any new technology there is always a steep learning curve to climb, so speak to as many people as possible to find out how others do it so that you can avoid "re-inventing the wheel."

TAKE HOME MESSAGE

If you are looking at reducing your costs, and improving the health and structure of your soil, then consideration must be given to zero tillage and controlled traffic. With our grain legume crops in particular being more expensive to grow we need to target the pests and diseases more carefully in order to make money and be environmentally sustainable in the longer term.

Adopting Controlled Traffic Farming

Warwick Holding, NSW

FARM PROFILE

Name:	Warwick (and Di) Holding
Location:	Yerong Creek, eastern Riverina, NSW
Rainfall:	Median annual 507 mm; median GSR (Apr-Oct) 334 mm
Soil types:	Clay loam to clay (low pH and associated high exchangeable aluminium) Sodic clays
Area farmed:	1260 ha
Crops:	Wheat, canola, faba beans.

BACKGROUND

The important factors of our cropping system include: soils (structure and fertility); weed management; sowing time; timely and effective application of pesticides; and no livestock on cropping areas.

We have moved to a CTF system in a series of steps. Along the way we were happy with the direction and pace at which we were changing. However looking back over the past four years we can clearly see the lost potential. With hindsight, we wish we had moved to CTF in 2003, as opposed to doing it this year.

Even though we have changed to CTF this year and there have been benefits already, the first year is the setting up year. Year 2 will be more interesting and rewarding with opportunities including full stubble retention, inter-row sowing, not sowing into old tramlines.

Year 1 – 2003 – moving toward CTF

We purchased a new airseeder and started sowing up and back, on 9” row spacing, with disc marker arms. We removed a tine four in from the right hand side of the cultivator. Two sowing passes (11.3 m) established tramlines to suit 1 boom width (23 m) with 0.4 m overlap as a safety margin for manual steering.

Year 2 – 2004 – moving toward CTF

We added a guidance system, subscription 10 cm differential GPS. This enabled recording of operations and mapping different treatments (of on farm trials) and improved the accuracy of operations.

Year 3 - 2005 – moving toward CTF

We added tines to the airseeder (seed 11.75 m, spraying 24 m) giving a half metre spray overlap for manual steering prior to autosteer. The additional tines (extra width) lead to a change in the position of the tramlines.

*Observations***:** In 2005 we saw big clods and poor germination on the old tramlines. It was obvious we needed to have permanent tracks. Once we started to concentrate our in crop traffic to dedicated tracks we started to notice two things:

1. The area between the tracks was improving – soil structure, seedbed.
2. When the position of the tracks changed and we sowed old tramlines, they were hard and compacted, and we got poor establishment.

Compaction from the airseeder cart in wet conditions also resulted in poor crop emergence (sometimes no crop at all).

Year 4 – 2006 – adopting CTF

Sowing tractor: duals left on for this year while establishing the system. Outer wheels are on 3 m, so next year we will remove inner wheels and run outer wheels only on the tracks.

Cultivator: Flexicoil, effective width 12 m. Rearranged tines from 228 mm to 308 mm spacing. We also replaced the air-kit to improve uniformity of product delivery across the width of the cultivator. The prickle chain was replaced with individual press wheels.

Airseeder cart: Simplicity, trailing quad, already on 3 m wheel centres. This was a conscious decision made when it was purchased.

Spray/spreader tractor: cotton reels used on front axle to spread wheels to 3 m spacing. Rear wheels moved out on axles to 3 m centres.

Boomspray: Goldacre (24 m). We made a new axle to spread the wheels to 3 m which simply bolted on.

Spreader: three point linkage spreader uses the permanent tracks and spreads to 24 m.

Guidance: Both the sowing and spraying tractors have been wired and hydraulics plumbed to take an A5 Autosteer RTK 2 cm system by GPS Ag. We currently have one screen and receiver which stayed in the sowing tractor as the priority. Spraying was done using manual steering on the tracks, or auto-steer when the sowing tractor was idle. Once sowing was complete the auto-steer stayed in the spray tractor.

Windrower (self propelled): a reasonably light machine. We plan to windrow up and back putting the windrows out one side, placing two rows together, side-by-side. The two windrows can then be harvested in one operation. This keeps the header on the tracks while harvesting canola and other windrowed crops, such as faba beans and lupins.

Header: the draper front is only 10.7 m (36 feet) offset. We believe the header must be on the system but are unlikely to achieve this in the current season. Instead we will harvest cereal crops at an angle to help trash flow at sowing next year (wheel tracks for and against the direction of sowing can cause problems). Other growers harvesting on the angle significantly reduce these hassles. We plan to put auto steer into the header for this season's harvest.

Chaser bin: The chaser bin can be modified to 3 m wheel spacing by simply changing to narrower tyres. A catching bin will need to be added on the side of the chaser bin to suit 12 m track spacing. The spray tractor (already on 3 m) also goes on the chaser bin.

Observations: In recent years we have progressively sown more and more of our crop by the calendar. This year all crop was sown by the calendar, well before 10 June, the first significant rain event.

This year we created very little dust when dry sowing. Small rainfall events (5-6 mm) are marginal for germination and historically sowing under these conditions produced an unacceptable cloddy seedbed. This year we kept sowing in dry and marginal conditions and produced fewer clods and a better seedbed than previously experienced under similar conditions. The only exception was where we sowed into old tramlines. This highlighted the importance of having permanent tracks and the need for all traffic to follow the permanent tracks year after year.

BENEFITS OF CTF

I see the following benefits of adopting CTF:

- Plants grow better in well structured soils that are not compacted
- Wheels work better on hard, compacted soil
- Reduced implement draft (fuel savings)
- Reduced driver fatigue
- Reduced inputs (removed boomspray overlap, 2% reduction compared to tramline system)
- Inter-row sowing (with 2 cm autosteer) will:
    - Allow us to retain more stubble which in turn reduces soil moisture losses due to evaporation (particularly in autumn), measured by WUE records.
    - Reduce the impact of root diseases as seen in recent Australian research trials.

CTF is a complete farming system – so much more than straight rows and permanent wheel tracks. CTF is opening up a whole new and improved way of farming that is very exciting. We are very confident of increased yield potential and significant economic benefits with the system.

AUSTRALIAN CONTROLLED TRAFFIC FARMING ASSOCIATION (ACTFA)

Diane and I have been involved with ACTFA since CTF05. We hope ACTFA will give growers a voice to guide the direction of future funding for CTF systems research. ACTFA has the potential to put a vast number of resources and experiences at your fingertips.

Don't try and reinvent the wheel – someone has already done that. Learn from others. Take the fast track to the next level and fine tune the experiences of others and adapt them into your system. Let others help you overcome challenges as they present themselves.

Controlled Traffic Part of the System

Mark Wandel, Willawayup, Scaddan, WA.

We are a family farming operation in the mallee region of Esperance Western Australia. The farm is in partnership with parents Neil and Mary Wandel, brother Scott and myself. We farm two properties of 14800Ha, 10400Ha at Mt Ridley 350-400mm rainfall and 4400Ha at Scaddan 425-450mm Rainfall. All farms are continuously cropped. We also have a grain handling business in Esperance Esperance Quality Grains with 3500T of elevated storage with drying and cleaning facilities.

I manage the Scaddan operation with my wife Hayley and our 3 children. The soil types are mainly loams through to grey clays with pH of 5.5-8.0 to a depth of 10-30cm over clay. Cropping rotation consists of a standard rotation for our region of;

- Legume , Faba Beans , Feild Peas and vetch
- Wheat
- Canola
- Wheat
- Barley

CONTROLLED TRAFFIC

What started me thinking about controlled traffic was:

- Soil structure- I could see damage from traffic especially in dry starts and clay soil types with poor crop establishment on traffic areas and good establishment on low traffic areas.
- I was noticing the good soil structure on the first 15ft of paddock where there was no traffic due to the fence and it getting worse with traffic, particularly the boom spray wheel marks that were obvious.
- Reading articles from eastern states on what they were achieving with the improved soil structure from controlled traffic.

This got me thinking that there was a more efficient way than driving everywhere over the paddock and this system could give us improved agronomic opportunities knowing where every operation had occurred.

I made the decision in 2003 that we had to start working towards a controlled traffic system because, I could see the long-term benefits that it would bring to our operation. We have been 100% no-till seeding since 1994 and could see that controlled traffic as the next step to make the farm more productive and sustainable.

PLANNING

Our first step to adopting controlled traffic was to write down what machinery we had now and what we wanted to get in the future and worked from there. In 2003 I decided to go on a controlled traffic tour to QLD with DAFWA supported by GRDC which was excellent. The tour showed me that controlled traffic had to be implemented straight away because it works. We had a look at many different systems and gained lots of ideas

So out came the graph paper and I was into it. In the end we came out with a 9 metre system on 3m wheel centres with 300mm row spacings. I practically started with the header and worked my way back from there. Our system that we have and are working towards is this;

- 18m seeders 300mm row spacings
- 27 and 36m boom sprays

- 9m Header
- 9m SP swather deck shift double up to 18m rows
- 9m wide row seeder and shielded sprayer want to go to 18meter
- 9, 18m spreading width
- All on 3mwheel centres

I think at the end of it all we had a choice of either 9meter or 12meter width system. We came to the conclusion that 9m was the best for us because;

- We wanted to run 18m seeders due to their efficiency
- We had self propelled sprayers on 3m and 27m boom widths already and wanted to go to 36m in the future
- Swathing, had a 9m SP swather and was concerned about making a neat swath with a 12m front
- Spread gypsum and lime and was concerned about getting an even spread at 12m and 24m for super.
- Can unload into chaser bin with both machines remaining on the tramlines
- Can increase the speed of the header 80-90% of the time to compensate for the reduction in width, plan on growing more grain to keep them full.
- Had 9m flex fronts and 10.3meter draper fronts
- Concerned about the even distribution of straw across the paddock at a width of 12m thought 9 m was more manageable
- Higher percentage of our machinery fitted the 9m system would have cost more to go to the 12 m system in the short term.

IMPLEMENTATION

To implement the system we:

- Purchased a John Deere RTK base station and upgraded receivers to RTK
- Purchased 18m airseeder and bin on 3 meter centres
- Cotton Reels on JD 8520 and wound rear axels out
- Built 9m three point linkage toolbar for seeding and shielded spraying beans on wide rows
- Put 3m axel on spreader

FARM PLANNING

We were very lucky that all the blocks are north south in length and so we came up with the plan of having one set of run lines for the whole 4400ha at Scaddan on 180 degrees. This keeps it simple for operators, as there is no changing run lines between blocks and stuffing it up. Most of our laneways are east west through the farms which work out well for access and we drive over these during operations. We have realigned some of these to go directly east west.

RESULTS

We have been very happy with the results and improvements have occurred quicker than first thought. Some benefits are:

- The soil has become softer more even and easier to work
- Less horsepower and fuel is used to pull implements
- Increased soil water holding capacity
- Improved traffic-ability when wet
- Improved trash handling and crop establishment with inter row seeding
- Increased opportunities to control weeds
- Burn 18meter header trails tramlines help as fire breaks

Controlled traffic has opened up many more opportunities in our system and I think there is a lot more to find. Controlled traffic has given us the opportunity to establish crops on less rainfall, given us the ability to do operations exactly were we want to do them to improve overall efficiencies.

PROBLEMS

As with everything, everything has its problems, such as;

- Getting the old man's head around it so it can all happen,
- Ryegrass in tramlines,
- Rutting and water pooling on heavy clay wet areas,
- Head land management,
- Trying to get everything to fit on tramlines with minimal expenditure,
- Swathing barley with the direction of seeding trying to stop it from collapsing in between the rows (used to go at 45degrees to seeding direction),
- Educating casual staff on what we are trying to achieve (don't drive everywhere).

We have tried to overcome some of these problems by:

- Ryegrass in tramlines- fitting shields on to front of sprayer to knock out tramlines while spraying rest of paddock.
- Headlands- in the process of setting up run lines on the headlands to have tramlines on headlands in every block.
- Swathing barley using inter row seeding to seed in between the previous years wheat stubble leaving that standing and undisturbed to use as a support to hold up the swaths.
- Rutting – keep driving straight through them (still working on this one).
- Educating casual staff – code of conduct explaining what happens.

CONCLUSION

Implementing controlled traffic has been interesting but rewarding transition in our farming system. I believe that it has improved our overall profability in the short and long term. It has created many opportunities not present before to improve our farming operation and production. Looking back on were we have gone in the last three years the key things that I believe are essential to making controlled traffic work are;

- Planning – right down to the row spacings and the guess row, think were you want to be in the future not were you are now. (Before you get the oxy out);
- RTK – Repeatability is the key word of controlled traffic;
- Applying – doing everything possible with what you have to get were you want to be in the shortest period of time.

Machinery Standards for CTF – Pipe Dream or Logical Necessity

Wayne Chapman, CTF Solutions, Taroom, QLD

Abstract: The introduction of CTF standards across the Australian grain industry would promote adoption; lessen the degradation of our productive soils and lower machinery capital costs to manufacturers and growers. With standards for wheel track and operating width most farm sizes and systems can be catered for and resale value is assured.

The current proliferation of operating widths and wheel spacings is wasteful of both natural and financial resources. Manufacturers are unable to tool up with any degree of confidence, prices are higher, and every machine is a special build. Yields are reduced; costs are increased and competitive advantage lost.

A simple set of standards are proposed, their applicability across a range of industries discussed and a framework to progress outlined.

Keywords: CTF, standards, 3m,9m,12m, harvester, system

INTRODUCTION

Standards are an everyday part of mechanised agriculture. Every time a farmer attaches a PTO shaft, or picks up a 3pl. implement, they are depending on the manufacturer building that equipment to the relevant standard. In the absence of standards there is chaos, as the current mushrooming of black boxes in tractor cabs testifies.

The call for an Australian CTF standard is not new, Peter Walsh and Troy Jensen first outlined the case for standards at CTF 98, Jeff Tullberg, Peter Walsh and the author recommended the adoption of standards in the KDI00004 project report to GRDC in 2003. Our consultancy has been advising growers of those informal standards since then.

DISCUSSION

Wheeltrack standard

Chapman (1998) identified three common wheeltrack spacings, based on the spraying equipment used at the time of moving to controlled traffic.

- 1.5-1.8m - spraying with utility or tractor,
- 2m - tractor or truck and
- 3m with modified tractor or SP sprayer)

The narrower systems were unable to accommodate the grain harvesting operation, although some hay production systems are working successfully on 2m. Only 3 meters enables graingrowers to progress their system to include all heavy wheels operating in the paddocks. All current model harvesters can be optioned to a 3m setting and narrower tyres of sufficient capacity are available.

In the high rainfall zone, dual systems utilising beds, have developed which involve 2m centres for the tractor and 4m centres for harvest and sometimes spraying. As can be seen from Table 1 these systems are at best a compromise, resulting in a larger proportion of crop suffering wheel induced compaction. Configuring raised beds to suit a 3m system would provide benefits in terms of limiting wheel traffic, reducing capital costs by alleviating the need for both bed and flat equipment and drainage capacity could be improved by installing minor furrows at 1.5m intervals in the wetter areas.

Table 1 Common systems - %wheeled

System	% wheeled
2m centres 15m planter, Auto steer, 30m sprayer, random harvest 11m	29%
2m centres 8m planter, Auto steer, 24m sprayer, 10m harvest 3m centres harvester on 800mm tyres	22%
As above but all 500mm tyres and harvester on 4m centres	16%
9m CTF	12%
12m CTF	11%
2m CTF cane 800mm twin rows	50%
3m CTF cane 1.5m rows	33%
Horticulture 2m CTF	25%

Operating width standard

This standard is best described by the narrowest practical width operating in the system.
It should:

- match the width of the harvester fronts available
- it should be a multiple of the wheeltrack width
- suit the majority of situations across Australia
- be simple and concise

This paper suggests that 9m and 12m fulfil all the above conditions. These systems offer the lowest % of wheeled soil, the widest range of planting and spraying capacity and the easiest harvesting solutions.

Choosing which standard width is best suited to an individual's farming system should be based on a comprehensive review. CTF Solutions take clients through a process, which looks at but is not limited to:

Farm size
Timeliness of all operations
Labour
Budget
Goals

Application of standards

While standards may not appeal to the rugged individualism of Australian farmers and manufacturers, it should be stressed that the absence of clear guidelines is costing the industry millions of dollars every year. Production costs are increased by higher tooling costs and inventories needed to offer a range of sizes to tempt the buyer. We are seeing evidence of this as companies decrease their product range in an effort to survive.
It does not "lock" a grower to that standard, a manufacturer will still build what the grower wants, but they will charge more for a "non-standard" machine and justifiably so. The smaller grower is not excluded by the adoption of standards. The key objective is to bring all facets of harvesting a crop into the system; currently this is easier at sizes under 9m.

It should be noted that it is not harvesting per se which is difficult to achieve under a CTF system but rather the unloading of the harvester *on the go*, which requires the most effort. This requires the transfer of grain from the harvester bin to a chaser bin running on the adjacent set of wheeltracks. Some machines, at either 9m or 12m, require modification to both unloading auger and chaser bin. Table 2 provides details of some models and the extent of modifications required.

Table 2. Harvesters, 3m compatibility, auger length and distance to adjacent track

Make	Model	Auger length Std. (m.)	Gap to 9m centre (m.)	Gap to 12m centre (m.)	3m centres
CaseIH	1688	5.28	2.64	5.7	Yes
	2188	5.28	2.8	5.86	Yes
John Deere	9610	6.1	1.8	4.86	No

Impact of standards

Can two module widths satisfy the differing conditions, variation in climate and crops occurring across Australia? Successful farming systems based on these widths already exist in all states. Planter sizes from 9 to 24 metres are possible as multiples of either 9 or 12 metres. Sprayers up to 36 metres are in use in the WA grain belt. 12 metre fronts allow modern Class 7 and 8 harvesters to be operated efficiently in lower yielding crops.

Timeliness of operations is an integral part of the CTF system and growers should consider all facets of the system before deciding on operating width. Managing systems is not a new exercise for growers but many issues need to be considered.

Depending on speed, planting widths from 9m to 24m can give a range of 48 to 200 ha per 12 hour shift. Spraying capacity is a function of the spraying window and the area to be covered, northern farms may be expected to have more spray capacity due to less favourable climatic conditions during the fallow period.

Chaser bins, drying, windrowing or simply bringing additional harvesters in for the large crops, can increase harvest capacity. Some clients have been able to reduce capital expenditure on harvesters. The choice of front size can impact harvester capacity in light crops. (Table 3)

Table 3 Theoretical Harvester capacities based on 100% field efficiency

Width	T/hr [1]	T/hr [2]	T/hr [3]
9	37	27	15
12	50	36	20

[1] Wheat - 6t/ha and 7km/hr
[2] Wheat - 3t/ha and 10km/hr
[3] Wheat - 1.2t/ha and 14km/hr

APPLICATION TO OTHER INDUSTRIES

It is unlikely all the standards proposed above will provide solutions for diverse industries such as sugar and horticulture. What is suggested is a process providing a blueprint for those industries to move forward.

Irrigated crops

Row spacing configurations driven by machinery and tyre selection appear to characterise flood irrigated agriculture. New technology adopted for water use efficiency gains may allow many irrigated crops to move to compatible row spacings with the standards outlined above.

Sugar

As can be seen in Table 1 cane on 2m CTF still suffers 50% wheelings. Unfortunately, like the grains industry in the 90's, the industry is constrained by a lack of compatible machinery. Three metre CTF may well be the ideal solution however there is no harvesting equipment available and little industry support or enthusiasm for such a radical change.

Horticulture

Combined with guidance CTF offers tremendous advantages to many horticultural producers. Controlled traffic alone has been shown to increase yields in a range of horticultural crops by 10%. (Gan-Mor & Clark, (2001) quoting Hadas, (1987) This translates to significantly higher profits per hectare, which could be used to fund RTK guidance delivering further savings in production costs.

CONCLUSION

Walsh (1998) quoting the ASAE (1983) states, "Standards are developed and adopted because of a need for action on a common problem." Australia's broadacre grain systems can benefit from the introduction of a simple set of standards. Stakeholders should lobby funding bodies and industry groups to pursue the implementation of Australian standards for controlled traffic farming machinery as outlined above. Other agricultural industries can benefit considerably from the introduction of controlled traffic and have an opportunity to promote adoption by addressing the issue of commonality early in the process.

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Driving Straight – Get Over It!

Hugh Ball, NSW

PROPERTIES

"Gorian" 6000 hectares, "Oodnadatta" 5000 hectares, north-west NSW.

SOIL TYPE

Black self-mulching.

CROPS

Predominantly cereal, with rotations of pulse and summer crops, i.e. Prime hard wheat, durum, chickpeas, fabas beans, canola, sunflower, sorghum, mungbeans, dryland cotton.

Precision farming controlled traffic enterprise.

RAINFALL

"Gorian" 500mm, "Oodnadatta" 650mm

- Grid farming, 5000 hectare modules
- Machine module width 12m
- Machine axle width 3m
- Use BEELINE auto steer 2cm GPS Guidance System, used for band spraying and inter-row fertilization
- Properties marked off one line, 12m internal roads, 24m main roads
- 2 x 250 HP F.W.A. tractors 36m booms
- Industry standard water truck and batching tanks
- 12m Janke, parallelogram no till planter on 333mm spacing cereal, 1m multiples summer
- 12m Vacuum planter on 1m spacing

CSIRO Sydney University, Department of Agriculture conducts various summer and winter trials each year. In search of economic equilibrium where minimal inputs achieve max return sustainably. In order to achieve this, we are searching for the ideal seeding rate, horsepower, row spacing, implement width, labour unit.

$ / Kg / ha / cm of soil moisture.

Constantly reviewing capital invests per hectare within the module.

VITAL INGREDIENTS

1. Agronomy - on time / competent
2. Marketing - attitude to risk and opportunity i.e. variety of crops and planting windows
3. Management - up to speed, included in decision-making process

Timing of recommendations critical. We pride ourselves on gaining efficiencies and view our business as a whole farming system aimed at more efficient use and absorption of rainfall, hence increasing planting opportunities and cropping frequency in an environmentally sustainable manner.

From Cultivation to No-till to Tramline Farming

Owen Brownley, Lake King, WA.

We decided to change our farming system in the mid 90s when it was decided we couldn't get the best out of a stock system and a crop system at the same time.
Some reasons for this were :

1. Sand movement from wind on bare soil surfaces was not sustainable.
2. When removing grasses from good legume pastures to control root disease build up for the following cereal crop, the sheep didn't have a balanced diet on pure legumes so were not performing as they should. These medic type pastures were also harbouring nematodes that damaged the roots of the following cereal crops preventing them finishing properly in a dry finish. Also the selective sprays used to remove grasses were the same as used in a grain legume or canola crop so not giving a rotation of killing modes to avoid chemical resistance.
3. Wind erosion leading up to and during summer on legume pastures after sheep was frustrating .
4. Stock were also removing residues that should have been recycled back to the soil for organic matter that have many benefits to soil life.
5. Stubble laid over by stock walking on it made seeding trash flow difficult.
6. Bare or low residue covered soil were drying out and getting hard.
7. Sheep grazing on wet soils were packing the surface making it hard.
8. Burning grass residues to control disease or prevent seeding blockages also dried out soils making them hard.
9. Cultivating the soil was breaking down its structure and lowering carbon levels and also causing hardening.

These hardened soils were holding back the seeding program on lighter or late rainfall seasons where the biggest yield potential comes from earlier seeding. Wide cultivator points were ripping out old stubble leaving it loose on the surface making it prone to bunching together by wind or moving with water into dams or on fence lines. Due to the above we decided in 1996 to get out of sheep and continuously crop the total arable farm with a no-till system.

NO-TILL DEVELOPMENT

Moving into continuous cropping still had some stubble handling problems at times with cultivator points still too wide at 100mm (4'') and a 175mm(7") tine spacing. This was ripping out stubble and blocking the machine. We then tried 50mm cast points and stubbles were cut no higher than 30cm. With no stock to knock down stubble this system worked better but still had some blockages and we decided it was still to much cultivation. A triple disc seeder was also purchased to try even less disturbance and also for situations where the tine machine may block with residue or pull up too many rocks. A disadvantage of this machine is that as residue levels rise we are finding more hair pinning of stubble around the seed and with a coating of residual chemical on this layer of residue, it is causing crop damage and at times poor germinations.

A new seeding bar and airseeder cart were purchased in 1999 with 25cm (10") row spacings and 12mm wide points. The machine was lengthened in depth from front to back to give more clearance around tines. This worked better but still had some stubble blockages. I wish we had made the move to knife points years earlier instead of slowerly working our way down through the point sizes. We still use this 12mm points now and love them.

AUTO STEER

We tested a GPS guided auto steer tractor in 2002 so the traditional round and round working of paddocks moved to up and back straight line working the following year. This enabled us to sow down between last years stubble rows so not ripping out standing straw making trash flow a real breeze.

An example of this potential showed when we decided to harvest some frosted wheat by cutting just under the heads to slip over green ones that had shot from the bottom of the plants. This left tall stubble to seed into the following year that didn't give any trouble while working between old rows but due to GPS programming we sometimes got every tine over an old row ripping it out blocking up really bad. Also tall stubble infected young plants with leaf disease when a similar crop type was sown the following year. Now no crops are left tall to seed into.

TRAMLINING

Setting up tramlines became easy with our existing auto steer tractor so a decision to match as many machine wheels to the same width wheel base was made. The harvesting machine determined this as it could not be narrowed under three metres. The articulated tractor was traded on a 3 metre wide track tractor and the existing air seeder cart only needed the rim centres on two wheels moved out 90mm.

Fortunately the boom spray was due to be replaced so a new one was ordered with a hydraulic movable wheel base to 3metres and a three times seeder width boom. Our existing spray tractor had its axles sent to Queensland to be widened out to three metres.

A seeding bar of 12 metres was decided on to try and match a harvesting front. Our existing 16mt (52ft) air seeder bar had its wings removed and all tines were made the same spacing on either side of the machine so we could travel in either direction the following years and still match tines to old stubble rows. A 300mm (12") row spacing was chosen so that when sowing on wider rows by removing every 2nd or 3rd row we could use a shrouded sprayer in legumes or summer crops. This sprayer can spray fungicides up each side of a crop row and over the top as well as a knock down on any weeds between rows.

After moving to tramlines we have noticed that if a heavy machine drives in a different direction to the tramlines it can be seen in the retarded crop growth in the following year right through to harvest. We haven't put a yield to this but it gives an indication of compaction by machines now that the soils are staying softer from less traffic. Sometimes this effect lasts for years.
We can now start seeding at a certain date instead of waiting for a rain to soften the soil. We know we can germinate a crop on 5mm of rain if already sown with a V shaped trench above it to harvest water.

HARVESTING

Straw

The harvesting machines cut the 12.3 metre(40ft) seeding width with centre mount platforms and all straw is chopped . As crop growth got heavier the spreading of residues wasn't wide enough causing some seeding blockages with thick layers of residue. Also when harvesting on the same tramline every year with the residues not spreading the full width of the fronts, especially into the wind, uneven nutrition and organic matter levels would develop over time. To overcome this we developed our own spreaders to give a wider coverage. These will spread chopped straw the full width into a 20 klm hr wind.

Weed Seeds

With tramlines not sown it has enabled us to place the weed seeds separate from the straw out the back of the header onto one tramline. We then spray these rows out in the crop during the next growing season with a knock down herbicide under a hood mounted behind the wheel of the tractor. Some of this is sprayed in the same operation while running the big sprayer over the paddocks or just as its own application. This system is used to prevent applying crop selective chemicals of which weeds became resistant to. It's another tool to keep resistant weeds under control. At present we are trialling a 1000 degree flame burner to attempt killing weed seeds and so not relying on chemical.
Windrowing all residues out the back of headers then burning the rows for weed control is not an option as we want to return all the straw for organic matter, microbial food, moisture retention and erosion control.

Chaser Bin

Chaser bin is matched to tramlines and travels on them all the time except when actually emptying the header when the left hand wheels are moved to the right hand tramline having one set of wheels off the tramline. This is not perfect but is 80% there. We plan to address this after other tramline changes have been made.

SUGGESTION

If wanting to spend the least amount of dollars to give tramlining a go, just put auto steer on your seeding tractor to sow straight crop rows that can be easily followed by your other machines.

CT for the Vegetable Industry – What will it take?

John McPhee, Department of Primary Industries and Water, Devonport, Tasmania

INTRODUCTION

The Australian vegetable industry is a $1.66 billion business (farm gate, 2003/04), with value adding bringing the total to $2.36 billion. The industry is very diverse, with enterprises of every conceivable scale in every state growing a wide range of products. Although accurate statistics are difficult to obtain, it seems that the fresh market sector accounts for about 75% of the industry value. The Tasmanian situation is the reverse the national picture, being 75% processing based. The Tasmanian vegetable industry is worth $160 million (farm gate) and $360 m packed and processed. Potatoes represent just over 50% of the industry value and are the dominant crop (75%) of the processing sector. Potatoes, onions, carrots, peas, beans and broccoli represent 90% of the value of the industry. The Tasmanian industry is contract based in both the processing and fresh sectors.

A wide range of temperate vegetables are grown including potatoes, onions, carrots, brassicas, peas, beans, pumpkins and leafy vegetables. To add to the enterprise mix, many farms also grow pyrethrum, opium poppies, cereals, pastures for hay and silage and run livestock. The main vegetable growing areas have traditionally been in the north-west and north-east hinterland, but over the last decade, production has expanded in the midlands and north-east coastal belt. There are distinct differences in soil type, topography and farm size between the older and newer production areas (Table 1).

Table 1. Comparison of the main vegetable cropping regions in Tasmania

North-west/north-east	Midlands and north-east coast
Ferrosols (red clay loam on basalt)	Clay loams, sandy and duplex soils
Well drained soils	Well to poorly drained soils
Undulating to steep (10 – 20% common)	Flat to gently undulating
Water run erosion issues	Wind erosion issues
Small holdings (typically 100 – 150 ha)	Larger enterprises (typically about 200 ha)
Expensive land	Cheaper land
Big gun irrigation, pivots and linear increasing	Predominantly pivot irrigation, some big gun
About 75% of vegetable production	About 25% of vegetable production
Greater diversity of crops with some livestock	Smaller range of crops, livestock more likely

About 30% of potato production is on leased ground, a figure that is likely to increase. Contractors are used heavily in some farming operations, particularly harvest. Peas, beans, poppies, pyrethrum, cereals, carrots and onions are almost exclusively contract harvested. About 80% of potatoes are contract harvested. Although crops are planted, grown and harvested year round, vegetable production is predominantly a summer irrigation based enterprise. Planting intensifies in the Sep – Feb period, with harvest concentrated in the Jan – Jul period.

BENEFITS OF CT TO THE VEGETABLE INDUSTRY

The broad benefits of controlled traffic are well known through research and experiences in the grain industry. The benefits include improvements in soil structure and biological activity, infiltration, yield and operational efficiencies through lower fuel use, lower power requirements, spatial accuracy and timeliness. Additional advantages that are likely to be important for the vegetable industry include:

- Elimination of heavy tillage operations to improve opportunities for direct drilling and allow retention of crop residue and use of cover crops for controlling erosion and weeds
- Isolation of compaction to reduce clod load in the soil and make harvest of root, bulb and tuber crops easier and cheaper
- Direct drilling and guidance to improve opportunities for permanent or semi-permanent drip irrigation systems, with consequent benefits for water use efficiency and foliar disease management
- Potential to achieve more uniform maturity in many vegetable crops, with consequent improvements in product quality and harvest and processing efficiency
- Improved opportunities for mechanical weed control through better guidance, which may become important with the development of herbicide tolerance in weeds

Clods can be a major issue in the harvest of potatoes, carrots and onions. Clod load at harvest is influenced by soil type, soil moisture, tillage practices before and during planting, and inter-row traffic during the growing season. Clods are removed by mechanical and manual grading on the harvester, or post-harvest grading. Use of clod windrowing prior to planting of potatoes is increasing. The benefits of clod windrowing give an insight into what might occur in a controlled traffic situation. Observations some years ago indicated that clod windrowing could reduce clod load at harvest by 65%, which would equate to about a 30% reduction in harvest labour requirements. Misener and McLeod (1986) observed increases in harvest rate of 50% with the use of clod windrowing. Dickson et. al. (1992) recorded 30% more clods when harvesting conventionally grown potatoes compared to those in a 2.8 m track width controlled traffic experiment. The same research also gave an average 18% increase in marketable yield over 3 seasons, and a 40% reduction in draught requirements for post-harvest tillage.

SOME OF THE CHALLENGES IN THE VEGETABLE INDUSTRY

Machinery Configurations

Achieving commonality of wheel tracks will be a major challenge in the vegetable industry. The most common tractor track widths used in Tasmania for in-crop work are 1625 mm and 1730 mm (dictated by potato row spaces of 32″ and 34″). Other potato growing areas in Australia are based on 1730 mm. Most vegetable crops are grown in rows or beds based on one of those track widths. Some growers are moving to 1830 mm centres for primary tillage and harvest operations. Tractors of the power ranges used in the vegetable industry (80 – 140 kW) are usually able to attain track centres of 1500 – 2200 mm without exceeding manufacturers' standard configurations. For in-crop work, tyre tread widths are 330 – 360 mm, whereas for primary tillage and harvest work the range is 460 – 600 mm. Some vegetable crops, and other non-vegetable crops in the rotation, use equipment with a range of alternative track centre widths and tyre tread widths. Crops grown on a typical Tasmanian vegetable farm, and relevant equipment track and tread width characteristics, are shown in Table 2.

Table 2. Crops and harvest equipment characteristics typical of the Tasmanian vegetable industry

Dimensions (mm)	Potatoes, carrots, onions, brassicas	Peas, beans	Cereals, pyrethrum, poppies
Tractor track width for in-crop work	1625 or 1730	Not critical, generally 1625, 1730 or 1830	Not critical, generally 1625, 1730 or 1830
Row crop tractor tyre tread width	330 – 360	na	na
Tractor track width for out of crop work	Not critical, generally 1625, 1730 or 1830	Not critical, generally 1625, 1730 or 1830	Not critical, generally 1625, 1730 or 1830
Non-row crop tractor tyre tread width	460 – 600 530 common	460 – 600 530 common	460 – 600 530 common
Harvester track width	2200 – 2640	2200 – 2600	3000 – 4000
Harvester tyre tread width	300 – 750	400 – 750	700 – 800

It is clear that changes are needed for controlled traffic to work, but the key decision is what track width to use as the base. A track width of 2.4 – 2.6 m offers some advantages. Most potato, carrot and onion harvesters have track widths of 2.2 – 2.4 m, although there are exceptions. The challenge is that most potato harvesters are single row, and potato harvester track configurations are not symmetrical, with an out-rigger wheel required for stability. While it may be physically possible to side-shift the digging front to the centre row of 3 rows over a 2.4 m span, there are issues of maintaining tracking and stability on sloping land. A change to European style twin row harvesters would be a positive move, but then we are still left with a 2.4 m track width for a 1.6 – 1.7 m harvest width. Changing the digging width to 2.4 m would be a positive move, but that is a major engineering re-design issue. There may be other options that involve pre-digging and windrowing all three rows into one and still using a single row harvester. A UK manufacturer has recently released a 3 row straddle potato harvester with a 2.7 m digging width which may have potential.

Top pull carrot harvesters are another issue. They generally harvest only one or two rows at a time and the row spacings are narrower than potatoes. Increased moves to self-propelled carrot and potato harvesters compound the problem, as a number of these are of tricycle design. One model leaves tyre tracks over 65% of the width of the machine on a single pass. Moving across the paddock two rows at a time, the entire paddock is subject to multiple wheel passes.

There is the option of a completely different track width (e.g. 2 or 2.5 m) which would then require a complete re-think of crop growing systems. There is no commonality between current tractor track widths and the track widths on any harvesters, regardless of the crop.

A consideration in most vegetable growing areas, and particularly in Tasmania, will be the overall width of tractor and machinery combinations for road travel. Many growers transport equipment on public roads. Vehicles exceeding 3.5 m total width on highways, and 3.2 m on minor roads, require at least one escort vehicle. A significant amount of travel occurs on minor roads. The road transport issue lends some support for a 2 – 2.5 m track width standard.

Soil Erosion and Drainage

Almost all vegetable cropping in Tasmania occurs on undulating land, particularly in the north-west and north-east. Slopes of 10 – 20% are common, with isolated parts of paddocks up to 35%. Even though the crop growth zones under controlled traffic would have much better infiltration, soil erosion in the traffic lanes remains a serious risk, particularly at the interface of the compacted traffic lane and the friable crop bed. A technique that is used to control erosion in fine tilth seedbeds is ripper mulching, in which straw is placed in lines ripped along the contour. This technique has been further adapted with the development of a prototype machine to apply straw down the furrow. This may have potential for reducing wheel track erosion under controlled traffic. There is also scope for the construction of up-slope cut-off drains to divert overland flow, although this could be a significant capital investment on many farms.

Many paddocks used for vegetable production in Tasmania have complex slope profiles, resulting in areas within paddocks that accumulate run-off. It may be necessary to install strategic drainage, and maybe grassed waterways, to ensure that traffic lanes remain firm and trafficable in wet conditions.

Farm and Operational Logistics

Vegetable farms in Tasmania tend to grow a more diverse range of crops and operate on smaller contracts compared to other production areas. Paddocks often have irregular shapes, with many being dissected by drainage lines or having boundaries dictated by dams, creeks or other features. Slope may be an issue, not only from an erosion perspective, but also for maintaining accuracy of traffic, particularly in wet conditions. Although GPS will obviously assist directional tracking, it is still important to maintain traction on the wheel track to keep the equipment on track.

Another issue regarding farm logistics will be the use of headlands. Headlands are usually planted across the slope and harvested first to allow room to turn harvesters at the end of the row and for parking trucks. Such an arrangement is inconsistent with the objectives of controlled traffic. It may be possible to sow headlands to grass, but land is valuable and up to 5% of a paddock area could be devoted to permanent headlands under such a strategy. The alternative would be to crop the headlands anyway, and just accept that they will not be managed under a controlled traffic system.

THE DESIRE TO CHANGE

Technical challenges to the introduction of controlled traffic in the vegetable industry are considerable, but all within the bounds of possibility if there is the will to change and the benefits are recognised as worth pursuing. The processing vegetable industry has come under significant economic pressure in recent times due to rising input costs, particularly fuel, and the availability of cheap imports of processed product. If controlled traffic can offer sufficient economic and sustainability advantages to offset some of these pressures, then there will be interest.

WHAT WILL IT TAKE?

Change will require a considerable degree of co-operation. Since most crops are grown under contract, the role of fresh vegetable packers, vegetable processors and extractives companies will be critical. Each company provides a range of services to its growers, and so is in a position of influence in relation to future directions.

The wide spread use of contractors in Tasmania, particularly for harvest operations, suggests that contractors will be central to any change process. An important part of the overall picture will be identifying the advantages for the contractor. Improved soil sustainability, yield and water use efficiency, ease of operations, direct drilling and options for permanent drip irrigation are all advantages that will accrue to the grower. Will the benefits of reduced power requirements for root harvest machinery offset the cost of machinery modifications for the contractor? And where are the benefits for contractors who harvest cereals, pyrethrum and poppies?

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Controlled Traffic Farming Systems in the Mackay Sugar Industry

Brad Hussey

INTRODUCTION

In recent years growers in the sugar industry have been making a move to controlled traffic farming. This move has been necessary as traditionally sugarcane has been grown on 1.5 m row spacing. Cane is harvested one row at a time with all harvesting equipment passing over each row. Harvesting equipment has a wheel or track spacing of 1.83 m to 1.88 m which is not matched to the row spacing.

THE NEED FOR CHANGE

This miss-match of wheel to row spacing leads to a large area of the field being compacted during the harvesting operation by heavy harvesting equipment. Due to the high summer rainfall fields are often wet when harvested leading to perfect conditions for soil compaction.

Mackay is warm and wet compared to the south with 1600 mm of rain falling mostly in the summer months. The soils used for sugarcane production vary widely from sands to clays but the most common soils are sandy duplex soil.

Sugarcane yields are also considerably higher than many other crops with district average yields in the 80 to 100 t/ha range. Individual blocks can have yields in excess of 150 t/ha. To remove these high yields from the field requires a large amount of infield traffic.

This traffic is mostly unconstrained and almost never guided with GPS guidance. This miss-match of wheel spacing and unconstrained traffic often results in 80% of the field being trafficked.

THE NEW FARMING SYSTEM

The move to a control traffic farming system has been a part of a larger change to a New Farming System. The new system is based on controlled-traffic system at 1.8 m with permanent beds. Soybeans are grown in the beds to break the sugarcane monoculture and cane is then direct drilled into the beds using dual-row double-disc-opener planters to reduce the amount of tillage required. These planters plant 2 rows of cane at 500 mm apart into the bed which is about 1 m wide.

BENEFIT OF THE NEW SYSTEM

- The sugarcane monoculture has been broken by the fallow legume
- The amount of tillage required has been significantly reduced
- The amount for fuel used has been reduced
- The compacted area has been reduced from 80% to 30%

PROGRESS TO DATE

To date over 1000 ha of sugarcane has been planted to the new farming system in the Mackay district and this area is increasing each year. To allow the new system to develop new equipment has been developed and tractors have been fitted with GPS steering systems. While all of the components of the new farming system are sound, the new system has not resulted in yield increases to date but savings have been made in time and fuel usage.

CONCLUSIONS

The area of sugarcane farmed using a controlled-traffic farming system is increasing. Cane growers are not just adopting controlled-traffic but a whole new farming system. By adopting these systems growers have been able to reduce input cost and reduce the area of the field compacted. But to date these changes have not lead to significant yield improvements

Delivery of Networked GPS Corrections for Machinery Guidance

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Abstract: The Department of Sustainability and Environment (DSE) in Victoria has developed a Global Positioning System (GPS) Continually Operating Reference Station (CORS) infrastructure called GPSnet™. Recently GPSnet has been enhanced with two real-time GPS correction services: VICpos and MELBpos. These services supply Differential GPS (DGPS) and Networked Real-Time Kinematic (NRTK) corrections that are suitable for applications such as machine guidance. VICpos DGPS corrections deliver sub-metre results Victoria wide, while MELBpos NRTK is a high accuracy centimetre positioning service for the Melbourne and environs. Real-time data streams are made available over the Internet for access by fixed or mobile devices.

This paper briefly describes GPSnet CORS architecture which is designed to provide robust NRTK positioning services. Current plans to construct additional GPSnet infrastructure to improve the high accuracy service delivery in regional areas of Victoria is discussed. A novel methodology for obtaining high accuracy positioning from the Internet as an alternative to using a mobile phone connection in rural areas is also presented.

Key Words: MELBpos, VICpos, GPSnet, Precision Agriculture, NRTK, Virtual Base Station, GNSS Internet Radio

INTRODUCTION

Spatial Information Infrastructure (SII), an agency within the Department of Sustainability and Environment (DSE) in Victoria, has been involved with the development of Global Positioning System (GPS) Continually Operating Reference Stations (CORS) infrastructure called *GPSnet™* [1] since the mid 1990's. Initially GPSnet was designed for the more traditional purposes of surveying, mapping and geodetic control. However, the vast improvement in positional accuracy obtained from Differential (DGPS) and Real-Time Kinematic (RTK) services has lead to a proliferation of new GPS applications that now demand instantaneous, robust, high accuracy results.

To meet the stringent requirements of emerging applications such as precise machine guidance, GPSnet has been enhanced to stream real-time correction data over the Internet (Millner *et al.* 2004). Two services: VICpos the DGPS sub-metre positioning service available anywhere in Victoria and MELBpos a high accuracy Networked Real-Time Kinematic (NRTK) service which is valid over Melbourne and environs, offer a mix of data streams for a growing variety of uses. Generally real-time users access the Internet positioning services from a mobile phone with General Packet Radio Service (GPRS) Internet data services installed. However, a mobile Internet connection from the GPRS network is not

[1] GPSnet™ is registered in and by the State of Victoria as a business name (from April 2000 in 3-year intervals) and is also a registered trademark (from 17 January 2000 in ten-year intervals).

always a practical solution, particularly in rural and remote areas where mobile coverage is often sparse.

This paper presents the methodology for setting up a local radio re-broadcast from a fixed line Internet connection where the mobile phone coverage is limited or non-existent. The investigation focuses primarily on a Very Small Aperture Terminal (VSAT) geostationary satellite service as the fixed Internet connection in combination with a local Ultra High Frequency (UHF) or Very High Frequency (VHF) radio re-broadcast. A brief introduction to the CORS architecture required to generate NRTK corrections and the current plans to extend the high accuracy CORS network in Victoria's western districts will also be discussed.

CONTINUALLY OPERATING REFERENCE STATION (CORS) NETWORKS

CORS networks were first established in the early 1990's by the National Geodetic Survey to cover the United States and its territories. CORS networks have rapidly proliferated throughout the world by the virtue of a universal attraction for reliable and authoritative position information.

The Australian Regional Geodetic Network (ARGN) is a network of 15 sites that define the Geocentric Datum of Australia (GDA), the fundamental framework for all national spatial information. Cooperative jurisdictional sub-networks supplement the ARGN: GPSnet in Victoria, SunPoz in Queensland and SYDNet in New South Wales. The vast size of the Australian continent creates a huge economic and technical challenge for national real-time centimetre positioning services based on CORS networks. These challenges need to be addressed however as there is increasing demand from many user groups to provide national real-time coverage from CORS infrastructure. The eventual aim of Victoria's cooperative GPSnet infrastructure is to provide real-time centimetre solutions state wide.

ADVANTAGES OF CORS NETWORK INFRASTRUCTURE

The most apparent advantage of CORS infrastructure is that it saves a user time, effort and money by eliminating the need to purchase, operate and maintain their own private reference station equipment. Denham *et al*. (2006) describes in detail the benefits offered to precision agriculture from properly configured CORS networks such as GPSnet. Properly configured CORS networks can achieve greater accuracy over larger coverage areas compared to a single private reference station: *pass-to-pass and year-to-year.*

Not so apparent is the computing complexity required to allow the same pass-to-pass and year-to-year accuracy to be constant from farm-to-farm, nation wide. GPSnet coordinates are computed relative to the nation's fundamental CORS GPS network—the ARGN (Ramm *et al.* 2004). Undistorted national coordinates permit generation of NRTK solutions at 1-centimetre horizontal accuracy. For example homogenous results based on national coordinates are essential for machinery contactors that rely on consistent correction data around the whole country.

One difficulty with the existing Australian CORS infrastructure is the density of spacing required to achieve centimetre positions in real-time. The question of how to increase accuracy from infrequently spaced CORS sites is an active topic for our leading geodetic researchers at the Cooperative Research Centre for Spatial Information (CRS-SI). In addition, Hale *et al*. (2006) introduces the topical concept of a CORS management model that will put together arrangements such that CORS networks in Australia can be expanded in a unified and sustainable way to optimise use and maximise benefits.

GPSNET ARCHITECTURE

GPSnet architecture has evolved in development since 1995. Given that GPS correction services can provide high accuracy, the main issues relating to the architecture development are not related to accuracy but to robustness measured through performance, integrity and continuity. Architecture specifications include performance requirements for computing hardware, software and communication equipment and the management tools necessary to support continuous GPSnet operations. For details see Vicmap Position – GPSnet Product Description: www.land.vic.gov.au

GPSNET REFERENCE STATION SITES AND TELECOMMUNICATIONS

GPSnet sites require high-grade geodetic receivers, firmly mounted and housed securely with an unimpeded view of the sky. Sites are carefully selected to avoid signal multipath and spurious radio frequency interference. Backup power with surge protection and data storage is included. Equipment is now being progressively upgraded to be compatible with Global Navigation Satellite System (GNSS) such as modernised GPS (L2C and L5), GLONASS (Russian Federation) and Galileo (European Satellite Navigation System) signals.

Generally each locality has different telecommunications for remote operation and data transfer. The preferred option is a high bandwidth, low latency Digital Subscriber Lines (DSL ADSL, Wireless, or Satellite) that permits direct TCP/IP configuration and remote management. Data is streamed in real-time to a central processing centre over a secure Virtual Private Network (VPN). The VPN is flexible enough to incorporate hosted connectivity and facility management. For example additional cooperative sites can be added and managed under a GPSnet Host Agreement (see www.land.vic.gov.au/Gpsnet) regardless of their location with communication and facility costs kept to a minimum.

CENTRALISED PROCESSING CENTRE

The centralised server cluster processing facility was designed by engineers from Trimble Navigation, currently located at Barwon Water, Geelong. The overriding principle is to provide physical redundancy for each main processing function, operated in a modular way with duplication of server hardware. The server cluster consists of two servers for each main purpose: control of reference station connectivity, network processing and user access via a web-browser interface. Remote management, accounting and archiving are also included.

INTERNET CONNECTIONS FOR NTRIP

Users can access the GPSnet servers in real-time or for processing back in the office after the fieldwork is completed. The web interface (see www.GPSnet.com.au) is designed for any type of Internet connection, although latency and reliability, not necessarily bandwidth are the determining factors. Internet enabled phones include General Packet Radio System (GPRS) for Global System for Mobiles (GSM) phones or the equivalent but soon to be defunct Code Divisional Multiple Access (CDMAx1). Third generation wireless (3G) and WiFi *Broadband* services should become more widespread. Internet connections such as ADSL, dialup and VSAT Satellite provide plenty of choice for fixed line or office connections. The current trend for the inclusion of wireless Subscriber Identification Module (SIM) card slots within GPS equipment (especially for surveying applications) provides a complete integrated solution. Generally, mobile Internet is subject to limitations such as coverage area, particularly in rural and remote areas of Victoria. It is intended that the local re-broadcast model presented in Section 2 can overcome user access restrictions from limited mobile coverage.

While the data flow using CORS networks, to a central server cluster and the mobile Internet may appear complex at first, it follows international conventions and can be set-up easily within a GNSS Internet Radio Client or by a GPS distributor. Key to linking CORS networks and users is NTRIP which stands for Networked Transport of RTCM via Internet Protocol. NRTIP was developed to enable the streaming of DGPS or Networked RTK correction data via the Internet. All the user needs is the GNSS Internet Radio Client application for a mobile device, (Phone, Personal Digital Assistant, Pocket PC or Win CE) or PC/Laptop. NTRIP software, GNSS Internet Radio and other tools are available to download for free: (refer to http://igs.ifag.de).

PERFORMANCE MONITORING AND RESEARCH ACTIVITIES

Real-time users understand the importance of signal availability, reliability and integrity. In the case of time-critical applications such as precise machine guidance that operate continuously in demanding environments, reliably of the GPS corrections can be the most important consideration. To reduce the likelihood of catastrophic failures GPSnet architecture includes several quality control processes and redundancies. For example, measures to detect system faults and tools to provide alerts regarding maintenance and other issues. Earlier, SII and University of Melbourne developed the “GQC” quality control program for post-processed data files. Currently, Real-Time Quality Control (RTQC) is a research activity with the CRC-SI. The recent addition of a mobile phone text message service module into the RTQC software will provide system notifications, warnings and operation advice to active users in the field is another example.

NETWORKED REAL-TIME KINEMATIC (NRTK) GPS CORRECTIONS

Results from VICpos and MELBpos have been rigorously tested with industry and academia (Hale *et al.* 2005) with very favourable results. Gordini (2006) found 1-centimetre solutions at 95% confidence when testing MELBpos NRTK and encouraging results at the centimetre level even when the nominal 70 kilometre base-line limits were extended to larger network triangles. For many interested participants, scientific results and terminology can be detailed and quite daunting. What are the actual benefits of Networked Real-time Kinematic (NRTK) over Real-time Kinematic (RTK) and how does NRTK work?

Stand-alone GPS positions without corrections are typically accurate to about 20m with precision close to 5m in ideal environments (*GPS Guide for Users*. DSE 2005). Many circumstances are far from ideal and signal multipath, the reflection of satellite signals bouncing off nearby objects like trees or buildings, is the most common cause of unwanted errors. At worst signal multipath can introduce 100's of metres in error! Purpose built GPS equipment account for multipath in signal processing and antenna design. Differential (DGPS) processing introduces a correction to the satellite code ranges. Based on a known point (reference station) the user's position can be computed to less than 1m with appropriate equipment and practice, due to the reduced effect of atmospheric delays on the satellite ranges (*GPS Handbook*. DSE 2006).

Real-time Kinematic (RTK) goes further by providing satellite carrier phase corrections usually on both L_1 and L_2 GPS frequencies. If the true L_1 carrier phase wavelength ambiguity is determined the position solution can be *fixed* and tracking at a centimetre resolution is possible. Yet RTK suffers from two major limitations: solution extent and correction reception. A fixed centimetre position solution is valid up to distances of about 15 – 20km from the reference station. After this distance the atmospheric effects become more difficult to resolve and a fixed centimetre solution can easily deteriorate to a *float* solution at the decimetre level. Transmission of the RTK corrections from the reference station by UHF/VHF radio frequencies can reach about 20–30km depending on conditions and use of repeater radio systems.

NRTK overcomes the extent and reception issues associated with RTK and provides a number of added benefits. By streaming GPS observation data from individual reference stations to a centralised server, a reference network is created that models GPS ionospheric and tropospheric errors and satellite orbit biases. Technically these biases can be estimated using double difference combinations with code and phase observations on both L_1 and L_2 frequencies or by rigorous physical models for the estimation of all the biases in real-time (Gordini 2006). Regardless of technique the user receives a more reliable correction model based on their location within the network. Virtual Reference Station (VRS) is a network RTK approach developed by Trimble Terrasat (Vollath *et al*. 2001) which generates a "virtual reference station" to imitate a real reference station close to the users' position. In this way increasing the 20km RTK extent to 70km for NRTK.

NRTK corrections are distributed over the Internet (Section 1.33) and when a user has Internet access the RTK radio reception issue shifts from being one of radio range to that of Internet reliability. A combination of *anywhere* Internet coverage and re-distribution with a local radio is presented in Section 2 to address the dilemma of Internet reliability where mobile Internet availability is sparse or problematic.

The NRTK approach also benefits from economies of scale. Total coverage area compounds as additional sites are added to the network. For instance, 6 triangles worked together increase the total coverage area by 118% when compared to the same non-networked individual sites (Denham *et al.* 2006). For example the MELBpos correction service has 7-sites networked together that equates to a coverage area of 14,410 km^2. By adding 2 more proposed sites at Whittlesea (WHIT) and Kyneton (KYNE) the total coverage area will more than double to 29,150 km^2. Further benefits are evident by virtue of continual connectivity and network processing, as each site can be scrutinised for performance and the antenna position monitored for movement.

EXPANSION GPSNET INFRASTRUCTURE IN THE WESTERN DISTRICTS OF VICTORIA

GPSnet consists of 23 collaborative CORS sites (June 2006) that are spaced at approximately 200km intervals across rural and regional Victoria (VICpos) and 70km spacing across Greater Melbourne area (MELBpos). The high accuracy service in the Melbourne and environs relies on the closer spacing to ensure a fixed solution, with centimetre results.

Figure 1 displays the current status and future plans for GPSnet infrastructure. The high accuracy network generating the MELBpos service is expanding to the west by constructing additional reference stations at Ararat (ARAR) and St Arnaud (STAR). Beulah (BEUL) will contribute to the network when data is streamed via VSAT through a VPN tunnel to the processing centre. Extra stations are planned at Cressy or further west towards Hamilton, depending on research outcomes for results using larger network triangles. Additional sites such as Murrayville (MURR) have strong collaborative support for their inclusion with GPSnet.

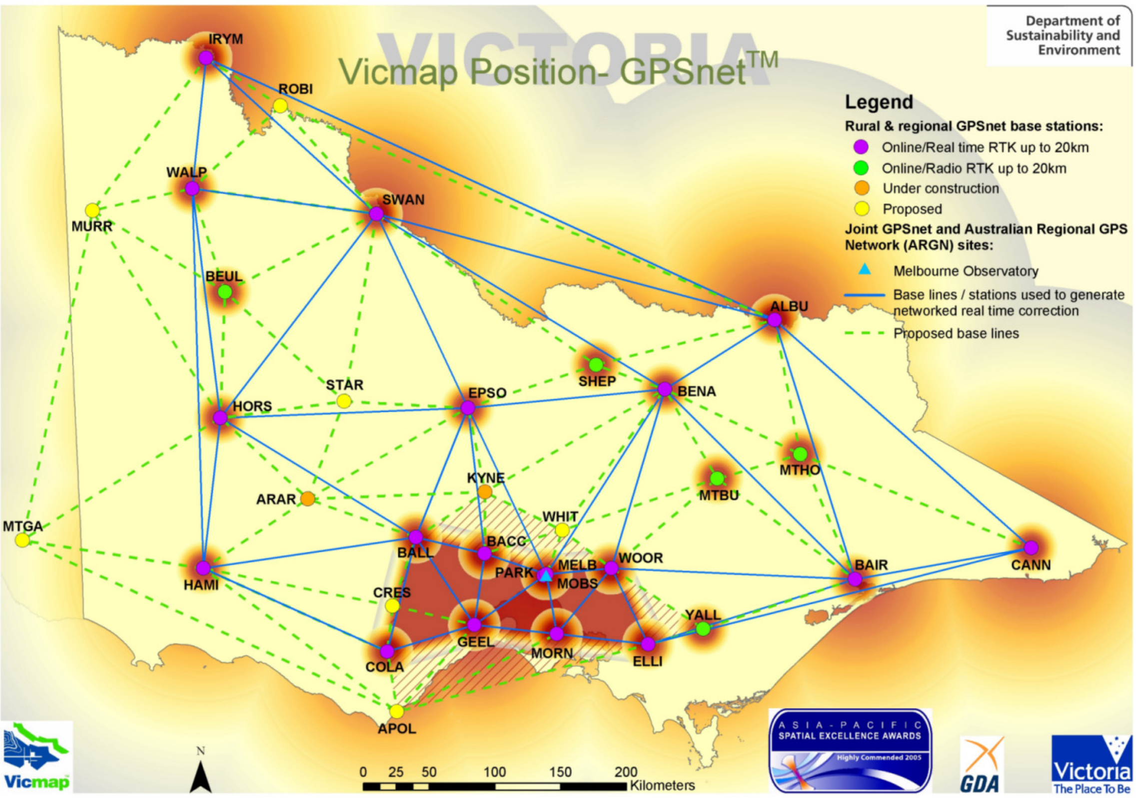


Figure 1. Vicmap Position GPSnet infrastructure

METHODOLGY FOR NRTK DELIVERY: LOCAL RE-BROACAST MODEL

Background

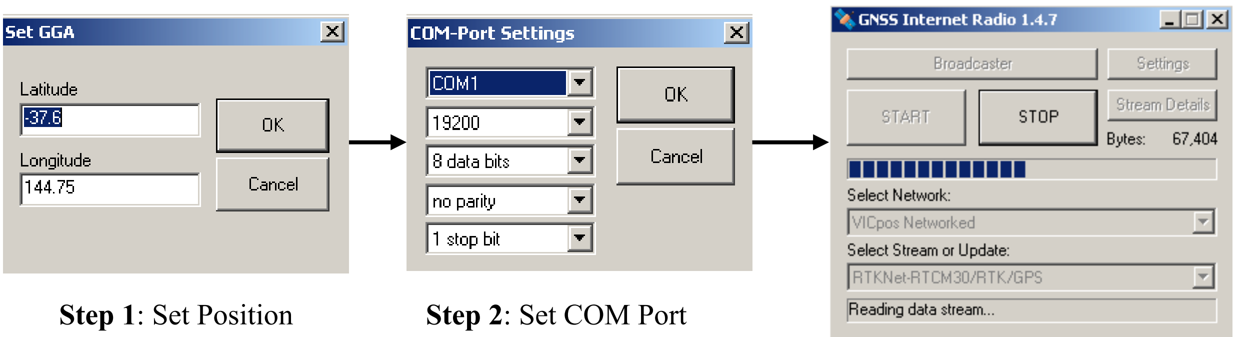
Investigations into a new method for delivery of Internet based NRTK corrections was motivated by the need to supply services for precise machine guidance in rural and regional areas of Victoria. For the most part, high accuracy users in metropolitan areas have access to reliable wireless Internet connections through reasonable GSM/GPRS mobile phone coverage. Distribution of GPS corrections via NTRIP standard over regions where mobile phone coverage is problematic inspired a novel alternative approach. Moreover, advanced GPS equipment designed for surveying includes internal GSM SIM modules, which allows for *plug-and-play* configuration. Less evident is the inclusion by GPS/GNSS manufacturers of GPRS or *Bluetooth* wireless capability with other GPS equipment used in machine guidance. Usually the interfaces available are based on cable (DB9 pin) connections suitable for input from a UHF/VHF radio. Mobile phone with direct cable input is possible assuming coverage is available in the working area. However, such a mobile device with delicate connections may not be durable enough to withstand continual vibrations from heavy machinery operations.

The study was focussed on a two way fixed Internet connection that could be operated anywhere, in combination with a suitable UHF/VHF radio for local transmission of NRTK corrections. VSAT geostationary satellite from NewSat Networks fulfilled the first requirement; while RTK modem/radios from Leica, Micronics, and Trimble were used for on site NRTK re-broadcasts.

GNSS Internet Radio – NRTIP Client application

The GNSS Internet Radio was developed in Europe to stream NTRIP data files over the Internet (Section 1.3.3). In this regard the term "radio" implies the similarity to playing music files (MP3) through the Internet and should not be confused with a local UHF/VHF radio that transmits the corrections to the roving GPS equipment.

The free GNSS Internet Radio application installs readily on a regular PC, with several output options. Figure 2 shows the streamed Bytes for VICpos Networked file based on Latitude –37.5, Longitude 144.75 that is output to a computer COM1 Port. Essentially, the GNSS Internet Radio software transforms the computer into a virtual GPS receiver sending out NRTK corrections from a Com Port, as would a real operational GPS reference receiver!



Step 1: Set Position **Step 2**: Set COM Port **Step 3**: Stream Data

Figure 2. Sequence for GNSS Internet Radio streaming NRTK from a PC COM Port.

SYSTEM DIAGRAMS

The concept to turn a computer with a reliable Internet connection into a virtual GPS reference station receiver by the use of free software and then re-broadcast NRTK corrections over a local radio is illustrated in Figures 3 and 4.

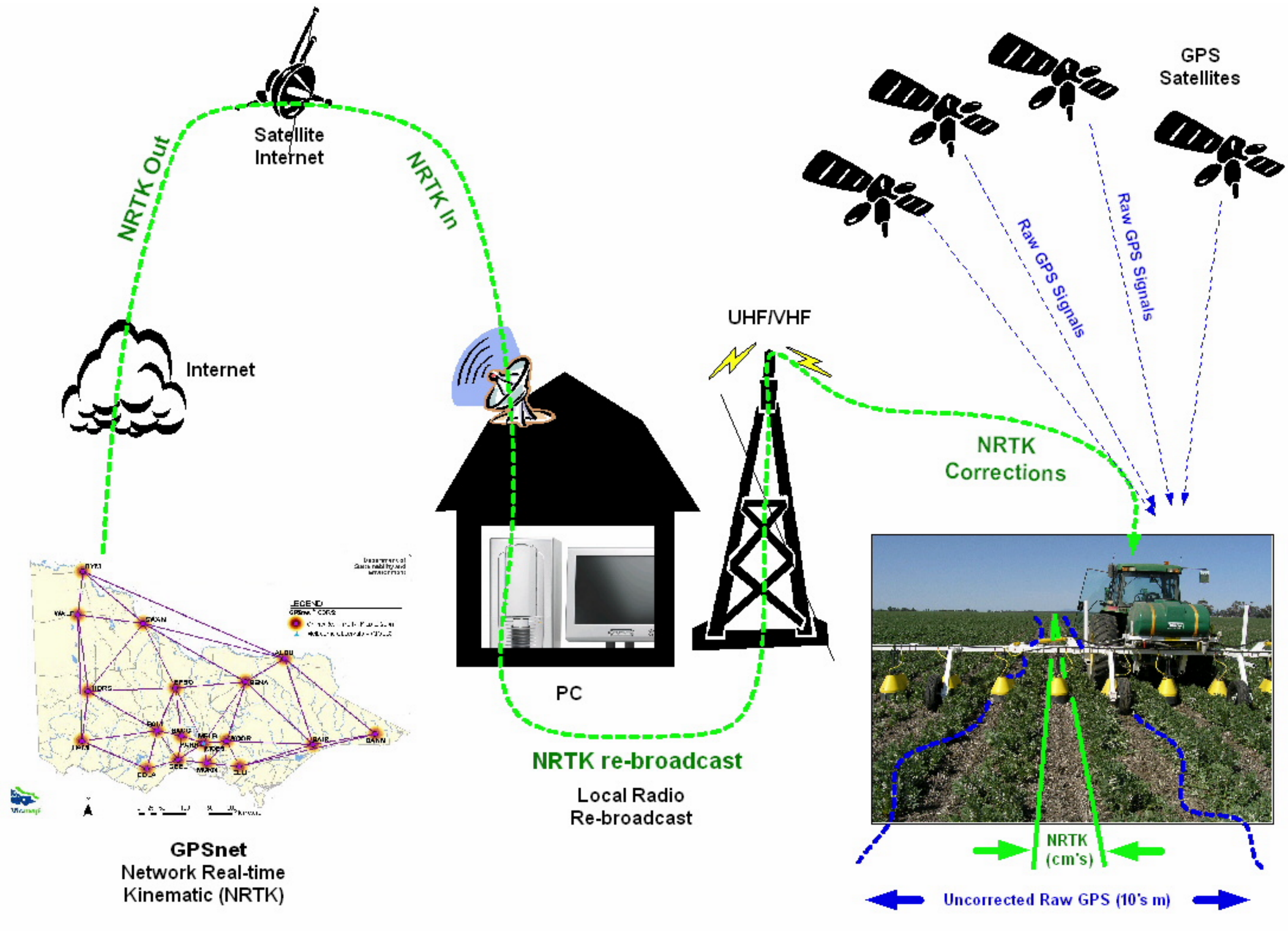


Figure 3. Schematic illustration of system data flow for the re-broadcast model

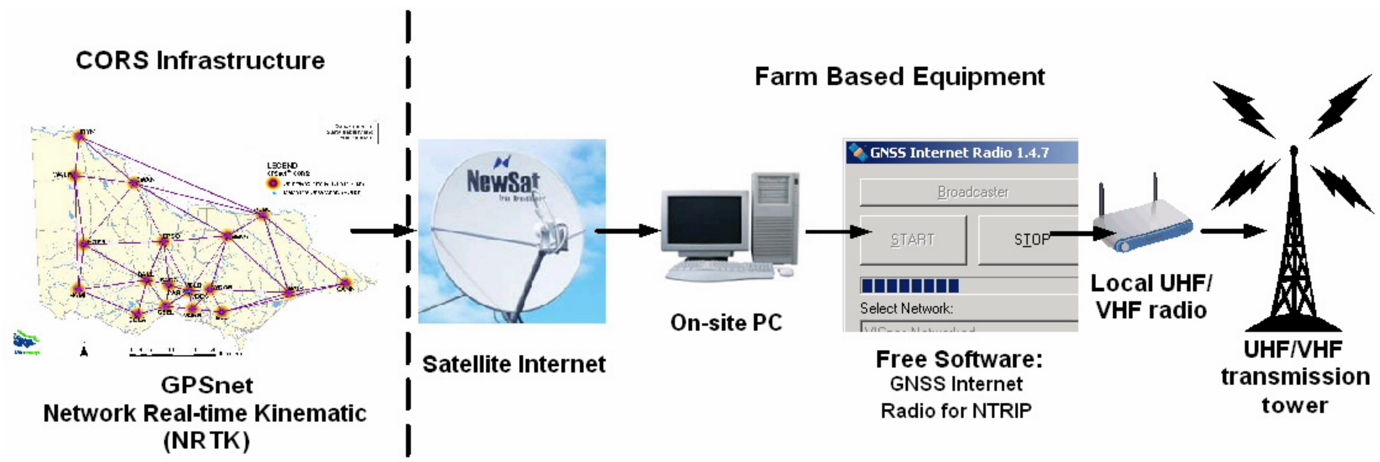


Figure 4. Modular system components of the re-broadcast model

The modular components that transform a PC into a virtual GPS reference receiver include the following: GPSnet infrastructure properly configured to generate NRTK corrections at the user location. A reliable Internet connection at the location, VSAT is good a choice for remote areas. PC to load up free software that connects to GPSnet services to stream correction data out the PC COM Port. Local UHF/VHF radio that connects into the back of the PC COM Port and re-broadcasts the NRTK corrections out to be received by a GPS application in the field.

RESEARCH AND RESULTS

Proof-of-concept tests have now been performed to verify that a radio re-broadcast solution is feasible for delivery of NRTK corrections. The major system level components used for a radio re-broadcasting NRTK solution include the following:

- VICpos and MELBpos correction services
- Internet Service Provider (ISP)
- Personal computer acting as Virtual Reference Station and running GNSS Internet Radio for delivery NRTK corrections via NTRIP
- Pair of UHF/VHF data radio modems
- Dual frequency GPS receiver

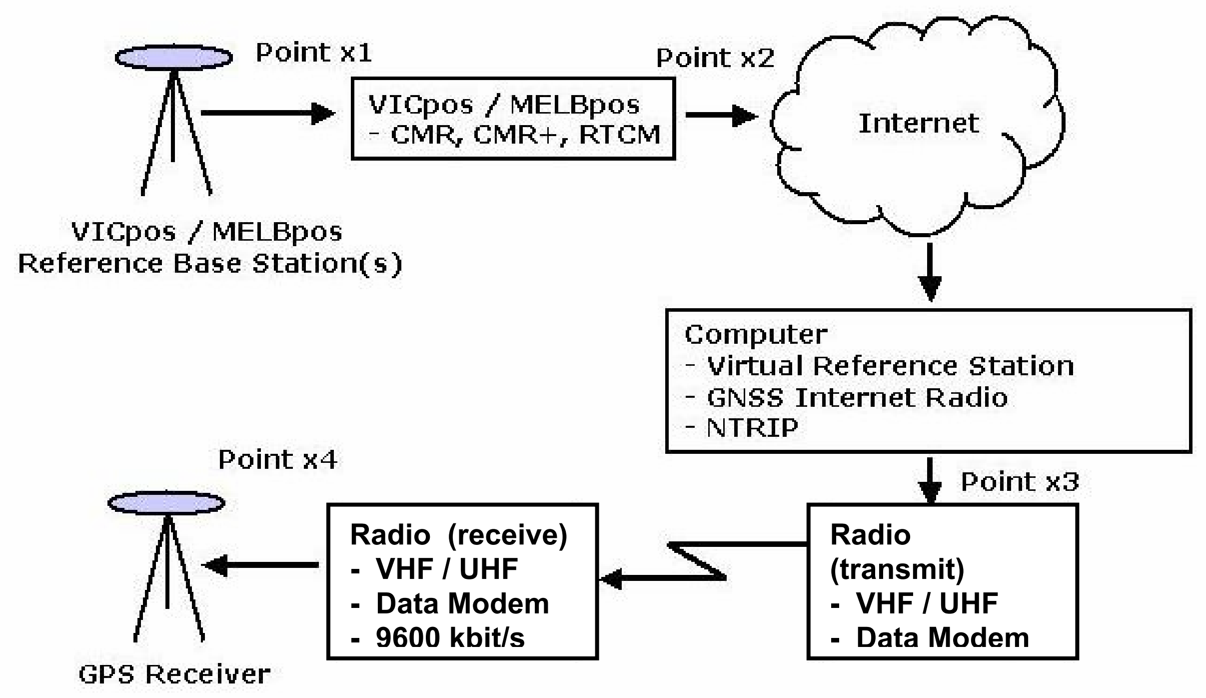


Figure 5. Generic test system

Tests were conducted using VICpos for both single base (RTK) and network based (NRTK) solutions. The transmission interval of correctional data packets sent from the central server cluster was configurable and varied between 1 second and 5 seconds. The size of the correctional data packet is dependent on the format desired by the GPS receiver (CMR, CMR+, RTCM2.3, 3.0). Typically the packet is only a few hundred bytes long.

A number of ISPs were used in the trial including a narrowband dialup connection, an ADSL broadband connection, and a 256/256kbps satellite link provided by NewSat. The size of a correctional data packet delivered by VICpos is relatively small; subsequently it is not the physical bandwidth that affects delivery of an NTRIP packet to a VRS, but the traffic congestion and quality of service. These two characteristics are variable, non-deterministic and can affect the latency and interval rate of data packets arriving at the VRS. Consequently statistical data was captured on packet latencies and interval rates observed between the VRS and VICpos server (labelled Point x2 and Point x3 in Diagram 5). It is intended to use this data to form a correlation between packet latency, interval rates and positional accuracy during the next test phase.

The VRS used GNSS Internet Radio (NTRIP) application software to stream the correctional data, over the Internet to a data radio modem. The connection between the PC and the radio was via a standard DB9 serial cable configured at 9600 kbit/s. Two types of data radio modems were used in this trial; a pair of Micronics VHF radios configured to operate at 9600 kbit/s half duplex and a pair of Trimble SNB900 radios. For the purpose of this test it was assumed that the radio link added no adverse effects to the delivery of correctional data packets to the GPS receiver. Three different GPS receivers were tested including a Trimble R8, Trimble 5700, and a Leica GPS1200. All three receivers proved capable of obtaining NRTK initialisation and providing a fixed position solution to sub-decimetre accuracy.

PACKET DELIVERY MEASUREMENTS

Traffic congestion, network throughput and quality of service are the key criteria of the Internet that impact on the ability to deliver NRTK correctional data to a GPS receiver. Latency is an important factor in broadcasting GPS corrections. Latency that exceeds more than 1-second can affect the accuracy on the ground particularly for dynamic applications such as precise machine guidance. Two metrics were captured to characterise the delivery of correctional data packets over Internet: the packet latency and the packet interval.

Round Trip Time (RTT) of data packets were measured as an indicator of latency and the timestamp of two consecutive packets were recorded to calculate the variation of the packet interval. Both these characteristics influence the accuracy of a NRTK measurement when using radio re-broadcasting via the Internet. Ideally when using NRTK in conjunction with Internet radio re-broadcasting, a user should strive to minimise packet latency and have a steady and consistent packet interval rate. The following packet delivery measurements summarise the observations made with three different Internet Service Providers. The VICpos server was configured to send correctional data packets at an interval of 1 per second and a 500-packet sample was observed at the VRS.

Measurement / ISP	**Dial Up Narrowband**	**ADSL Broadband**	**Satellite Broadband**
Packet Latency – Minimum	130 ms	40 ms	640 ms
Packet Latency – Maximum	181 ms	110 ms	1562 ms
Packet Latency – Average	136 ms	41 ms	800 ms
Packet Interval – Minimum	0.270 s	0.220 s	0.746 s
Packet Interval - Maximum	3.424 s	2.300 s	1.237 s
Packet Interval - Average	1.001 s	1.005 s	0.998 s

Table 1. Packet Latency and Packet Interval Comparisons

DISCUSSION

The progression from a concept to the completion of the initial testing phase has been a significant step to demonstrate the viability of a local re-broadcast delivery model for NRTK corrections. Already, testing has identified that it is not necessarily physical bandwidth that influences delivery of an NTRIP packet to a VRS, but the Internet traffic congestion and quality of service. To this end a more complete understanding of the time delays in the system as a whole is very important.

Measurement and determination of time delays will form part of the next round of tests in order to from a correlation between packet latency, interval rates and positional accuracy. Latency tests will take part on known ground marks located at Beremboke near Geelong, Victoria.

Use of a mobile VSAT service from NewSat, with latency techniques being developed as part of the research component, will assist to identify the Committed Information Rate (CIR) required for the most efficient NRTK transmission and reception. Contemporaneous configuration of the VICpos server processing interval at 1, 2, 3 or 5 seconds will also be monitored to optimise the NRTK output stream. When using NRTK in conjunction with Internet radio re-broadcasting, the application must receive packets with minimal latency with a reliable and consistent packet interval rate.

Importantly, availability of mobile VSAT services will facilitate links with other research activities. Such as testing the latency of GSM/GPRS corrections at Beremboke and research associated with long base-line NRTK for network triangles larger than the normally accepted VRS base-line length of 70 km's.

The NRTK re-broadcast model now provides a favourable backdrop for increased end-user involvement. Further testing on dynamic machine guidance applications will expand appreciation of pass-to-pass relative precision and assessment of year-to-year accuracy under varying operational conditions.

CONCLUSION

This paper has briefly described CORS architecture developed to generate Networked Real-time Kinematic (NRTK) corrections from Victoria's GPSnet infrastructure. A brief background on NRTK and explanations of the benefits of networked RTK approach over single reference station RTK followed. Advanced survey equipment integrated with GSM/GPRS wireless Internet capabilities have been successfully trialed using MELBpos NRTK with real-time results reported by enthusiastic participants at 1-centimetre accuracy. Fortunately, most metropolitan users have a choice of equipment and telecommunications infrastructure to set up high accuracy applications. In the regional areas, users are challenged by more difficult circumstances including sparse telecommunications coverage and legacy equipment, designed with ports for serial cable not internal wireless Internet capability. The need to provide high accuracy positioning services in rural parts of Victoria motivated the investigation into a practical NRTK delivery system. The concept of transforming a PC loaded with free software and a reliable Internet connection into a virtual reference station GPS receiver was proposed for the task.

The model based on a combination of ubiquitous Internet connection like VSAT and a local radio re-broadcast was validated. Initial tests identified correction packet latency and packet consistency as significant factors that will impact on performance. In the near future the research component will attempt to correlate packet metrics with positional accuracy. Meanwhile the active participants provided support and encouragement for adoption of the re-broadcast model. The system has proved to be a viable and effective alternative to mobile wireless connectivity, currently the most popular means of access to NRTK correction data from GPSnet infrastructure.

AKNOWLEDGEMENTS

The authors wish to acknowledge all those who have participated in the supply of equipment and services to assist with testing and research activities. In particular Andrew Whitlock from Department or Primary Industries (DPI) Victoria, Stuart Dasler (NewSat Networks) John Koles (MICRONICS GPS), Bernie Edmonds (CR Kennedy) and Paul Standen, Paul Andrews (Ultimate Positioning).

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Applications for 2 cm Autosteer

Matt McCallum, Ag. Consulting Co., Ardrossan

AUTOSTEER IDEAS AND INNOVATIONS

The potential benefits of autosteer to farming are only limited by your imagination. Here is a brief list of ideas and innovations using gps that are currently being implemented by farmers and/or investigated by researchers.

Inter row sowing (outlined below – precision sowing)

- Relay cropping – sowing one crop inter row into an existing crop e.g. summer feed or crop into winter cereal
- Precision spraying – using shrouds and other techniques to only target crops rows with fungicides and insecticides (good for IPM and cost savings). Using drop nozzles to spray products like Treflan down in between stubbles to reduce tie up.
- Wide row cropping – use expensive grass herbicides (Axial, Kerb, high rates of Select) on the crop row and knockdown herbicides (Roundup, Sprayseed, Basta) on the inter row.
- Variable rate spraying and top dressing – targeting ryegrass "hot spots" with high rates of Avadex with direct injection systems. Using a "N sensor" for variable rate urea and fungicide application based on the size of the crop canopy

PRECISION SOWING

The advent of 2 cm autosteer in agriculture is exciting. It allows farmers to sow crops with a high level of precision never thought possible before gps. Research and farmer experience is proving that precision sowing can improve your cropping system and make you money by having the ability to sow crops inter row or at/near the row of last years crop.

The benefits of inter row sowing are:

- increased yield of wheat-on-wheat due to less soil borne disease on the inter row (Table 1)
- better establishment of canola and cereals into cereal stubble
- increased harvestability of lentils by using standing cereal as a trellis
- ability to handle high biomass stubbles and reduce stubble clumping (hay stacks)
- leave more stubble standing and increase the efficacy of soil applied herbicides

Table 1. Wheat-on-wheat yields in inter row sowing experiments 04/05

Site	Sowing row	Yield t/ha	% increase	Disease effect
Sandilands SA 2004	Inter row In row	4.11 3.88 (lsd 5% = 0.21)	6%	Take-all
Tammworth NSW 2004	Inter row In row	2.51 2.30 (lsd 5% na)	9%	Crown rot
Sandilands SA 2005	Inter row In row	3.74 3.42 (lsd 5% = 0.31)	9%	CCN and Take-all
Hart SA 2005	Inter row In row	2.99 2.77 (lsd 5% = 0.13)	8%	None
Buckleboo SA 2005	Inter row In row	2.82 2.79 (no sig. diff.)	None	None

The benefits of sowing on/near last years sowing row:

- increased ability to establish a crop under marginal moisture conditions in a knife point / press wheel system
- more even seed bed with dry sowing by running your tyne in last years loose soil in the seed furrow and not having to penetrate hard ground
- potentially recapturing previous years residual nutrition e.g. N and P

NIGHTSPRAYING

The ability to spray at night has proven to be useful when:

- there are not enough hours in the day during busy periods e.g. sowing
- conditions are too windy during the day
- conditions are hot and dry for summer weed control

A number of herbicides were tested by Ag. Consulting Co. and the YP Alkaline Soils Group to compare the efficacy of these products at night. Key results and observations were:

- Group A (Targa®, Select®): OK at night, except Targa® had reduced efficacy once under frost conditions at night at Ardossan in 2002
- Group B (Midas®, OnDuty®, Ally®, Hussar®, Oust®, Atlantis®): OK at night, except Midas® had reduced efficacy under frost conditions at night at Ardossan in 2002
- Group C (Lexone®): OK at night, although symptoms of herbicide action may be delayed
- Group L (SpraySeed®). OK at night, although symptoms of herbicide action may be delayed.
- Group M (Roundup Max®). OK at night, although symptoms of herbicide action may be delayed.
- Group F (Sniper®, Brodal®): OK at night
- Group I (2,4-D amine): OK at night
- Group G (Goal®, Affinity®): Bit of a mystery? Not recommended at night due to reduced efficacy in some cases under good spraying conditions.

ACKNOWLEDGMENTS

Bill Long, Danny LeFeuvre, Nathan Rennie of Ag Consulting Co
YP Alkaline Soils Group
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Advanced Cropping Systems with Controlled Traffic. A Nuffield Scholar's Experience

Mark Branson, B.AppSc (Agric) NSch – Farmer

BACKGROUND INFORMATION:

Property: 1200 Ha Owned at Stockport and Giles Corner, Lower North of S.A.
Rainfall: 425 to 500mm, Predominately winter rainfall.
Paddock Sizes: From 20ha to 70ha.
Crops Grown: (80%). Durum and Bread Wheats, Malting and Feed Barleys, Canola, Faba Beans, and Field Peas.
Sheep (20%).
Self-replacing merino flock, Hazeldene bloodline, Old ewes put over Poll Dorset Ram – 1st cross lambs.

CONTROLLED TRAFFIC – MATCHING OPERATING WIDTHS

- Started on my farm by matching tractor tracks with boomspray to spray Fungicides on Beans in 1997 when I started tramlining.
- Used DGPS guidance first in 2002 when purchasing a KEE ZYNX controller to an Omnilite 132 5Hz DGPS receiver.
- With the purchase of a new airseeder I matched all in crop machinery to track on 2.2m wheel spacings, with the airseeder 1/3 the width of the boomspray and urea boom.

KEE TRIMBLE – RTK AUTOSTEER ON JD 8200 TRACTOR

- +/- 2cm Repeatable Accuracy.
- Base Station on the tallest most central hill on the farm. Powered by Solar Panels and Deep Cell Batteries.
- DGPS Receiver (Duel Frequency).
- Bigfoot – 3 Gyros, 3 Accelerometers that keep the YAW, ROLL, and PITCH adjustments in order. Guaranteed to keep you straight on uneven rolling ground.
- Uses 2 VHS radios to communicate between the base station and the tractor.
- Accurate to 10km, but VHS signal travels 35km.

AUTOSTEER IN CONTROLLED TRAFFIC – THE OPPORTUNITIES

Canopy Management
- Later N Applications
- Later Fungicides
- Use of Growth Regulators

Night Spraying
- Ability to sow and spray when wet.
- Complimentary to Precision Agriculture
- Easier driving – Less fatigue

CONTROLLED TRAFFIC - THE BENEFITS

- Improved soil health through reducing compaction.
- Decreasing crop inputs by 5 to 8%.
- Decreasing diesel usage by up to 25%
- Increasing crop yields by 5 to 15%
- Grain quality increases by having better soil structure

NUFFIELD SCHOLARSHIP

"Using Precision and Conservation Agriculture to Improve Farm Profits and the Environment"

Last year Mark completed a Nuffield Scholarship spending 18 weeks travelling the world looking at where Australia fits into world agriculture, Precision agriculture, High input farming, and Conservation agriculture involving No-till and Controlled traffic. This scholarship was sponsored by GRDC. The countries travelled included New Zealand, USA, Canada, UK, Belgium, Scotland and France.

WHAT DID I LEARN?

- Agriculture land throughout the world is extremely variable.
- Environmental issues caused by agriculture need addressing.
- We need to become farmers of Carbon.

Carbon -

- Increases water holding capacity and use efficiency.
- Decreases soil erosion.
- Increases infiltration, which reduces runoff.
- Decreases soil compaction.
- Increases soil tilth and structures.
- Decreases fertilizer inputs.
- Increases nutrient cycling and storage.
- Increases absorption of pesticides.
- Increased capacity to handle manure and other wastes.

Solution: No-till, growing high carbon crops, and stubble retention.

We need to remove compaction from our soils.

Compaction -

- Decreases yields by 5% to 15% depending on soil type.
- Decreases water infiltration
- Decreases nutrient uptake by the roots.
- Decreases carbon cycling in the soil.
- Increases soil erosion.
- Increases the chance for nutrient loss from the land.
- Increases the chance of waterlogging.

Solution: Controlled traffic.

CONTROLLED TRAFFIC AROUND THE WORLD

In the UK the are into tramlining instead of CT. They use 4 wheel steer sprayers in their system, both self-propelled and trailers to reduce crop damage on the corners.

At Silsoe Research Centre I saw a tillage machine, which uses a camera set-up to visually cultivate between green wheat rows and saw potential in this technology to use in CT systems in inner row spraying or other inner row weed control. This was called the ROBOCROP Vision Guidance System.

I saw a RTK CT system at Clay Mitchells farm in Iowa, USA where he strip crops Corn and Soybeans using the sun's angle to give his Corn a 20% yield advantage. He also runs a self-propelled sprayer, which uses auto section cut-off on 35 sections at RTK accuracy.
In North America I saw many types of crop dividers on sprayers, which are used in spraying summer crops.

In the USA I saw very good contract sprayer systems.

PRECISION AGRICULTURE IS A REALITY

Phosphorus: If adequate, place in the soil at replacement rates derived from the previous years yield maps.

Nitrogen: Use management zones to determine yield expectations within the paddock, and in season sensors to variable rate according to how the canopy is looking at the time of application.

Nitrogen Budgeting: A major problem in working out how much is coming from the soil through mineralization.

Solution.
- Plant Root Simulation Probes (PRS ®)
- NVDI scanning N-Rich strips and farmer paddock practice to allow the plants to tell the N recommendation.

Profits can fall short if any nutrient is short.

REMOTE SENSING

Aerial Imagery: Multi and Hyper spectral cameras measuring and mapping different bands of information taken from aircraft.

Satellite: EADS Astrium's Farmstar from France.

- Measures: Chlorophyll and Leaf Area Index (LAI).
- Agronomic Models: Plant population, Biomass, N status of the crop.
- Recommendation Maps: Tiller density, Lodging risk, N application maps.
  A powerful remote sensing and agronomy package.

GROUND N SENSORS:

Yarra N Sensor – Old

- Measures biomass and Chlorophyll.
- Uses ambient light as it's light source.
- It is used for post N, Fungicides, Plant Growth Regulators, and Defoliants.

- It increases the harvestability of the crop through evening up maturity.
- Profits in Germany = A$90/ha.
- Estimated profits in Australia (using Yarra's model) = A$28/ha.

Yarra N Sensor – New 2006 model.
- Uses its own light source.
- Uses a windows interface.
- Uses wireless instead of cables.

Greenseeker ® - Measures NVDI.

Model RT100
- Used to work out a standard N rate for a paddock or zone.
- Need to put down a N rich strip to compare standard paddock N, and a area where N is not limiting.
- Need to work out algorithms for Australia, work being done in WA and NSW.
- Excellent agronomic work has been done out of Oklahoma State University.

Model RT200
- 6 Greenseeker sensors on a boom used to average NVDI across boom.
- Uses its own light source.
- Has good agronomics in Oklahoma, USA.
- Virginia, USA and Canada have research projects looking into developing algorithms for their growing areas.

Crop Circle ® - Measures NVDI and other crop reflectance indexes.
- Has its own patented light source, both NIR and Visible, mimicking natural light.
- 3 models – Yellow/NIR, Orange/NIR, Red/NIR.
- Single sensor at the moment.
- Are developing an on-the-go N rate package (release 2007) and 8 sensor, GPS offset, mapping system at the moment.

Other Precision Ag. Sensors.
- On the go pH sensors for liming, - Verris, - Aust. Centre for P.A.
- On the go protein sensor for N budgeting, - Zeltex AccuHarvest sensor.
- Electronic Conductivity sensors for soil mapping, - EM38, - Verris, - GEOCARTA.

CONCLUSION

The Nuffield Scholarship was a wonderful experience that will stay with me forever.

Australia is a world leader in controlled traffic work and adoption but there is still work to be done in making the soil benefits better defined, and in steering implements in undulating country to inner row sow.

Satellite Imagery and Yield Mapping on CTF farms – What's Next?

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INTRODUCTION

With CTF and tractor guidance providing enormous improvement in farming systems, many of our clients were asking "what is the next step/leap"? As part of our GRDC funded project, ***CTF Solutions*** evaluated other new technology to increase dryland grain production profitability and sustainability.

After 4 years of research, with 50 co-operators across Australia, successful new technologies include **topography mapping (from 2cm RTK GPS), yield map interpretation, and high resolution satellite imagery**. Other technologies (EM mapping, VRT, PA management zones) were much less successful.

TOPOGRAPHY MAPPING

Topography mapping is basically the collection of height/elevation data using RTK GPS (the same system that is used for guiding tractors). The intense field data collection is made easier by using a 4WD. Once collected ***CTF Solutions*** analyses the data using a GIS to produce contour maps, elevation maps and slope maps.

The maps are then used to identify problem areas and design layouts for drainage, waterlogging and erosion control. They can be overlayed with other data such as imagery, soils, yield maps or farming operations.

The picture below (Figure 1) shows 10cm contour lines overlaying high resolution (1m pixel) satellite imagery. Areas of poor drainage are shown in dark colours, which are reflected by the topography lines. Drainage works costing $5,000 are generating an extra $50,000 production each year.

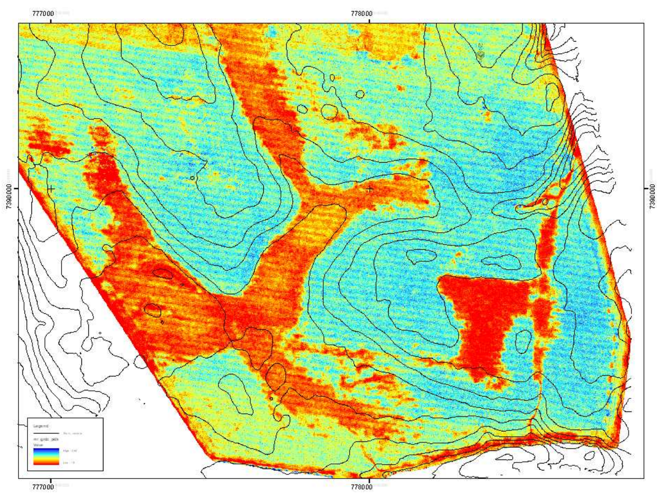


Figure 1

YIELD MAPPING

Yield maps have been around for some time. But only a few grain growers are collecting yield data and even fewer are making any sense of it. Because CTF and 2cm guidance ensures that the header comb is always full, the quality of yield maps is maximised.

The yield data below (Figure 2) is from round and round harvesting – not CTF. The darker areas are an artefact of the harvesting, not the actual yield. This is difficult to remove from the data, and any further analysis is flawed.

Figure 2

Figure 3 (below) is yield data from a CTF system with guidance. The even spacing of the data ensures its integrity, and any further analysis is valid.

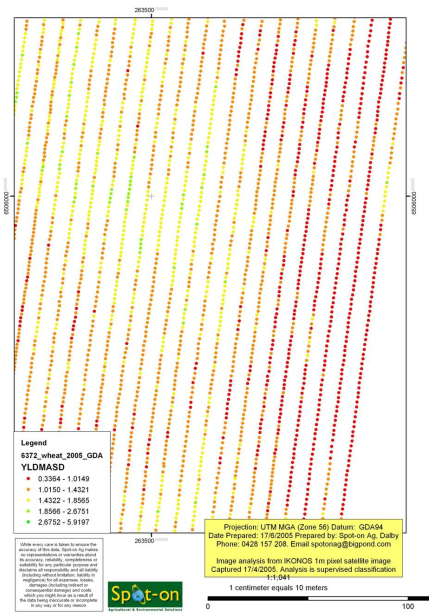


Figure 3

CTF Solutions has developed techniques to overlay yield maps from a number of years to produce **'yield stability' maps**. This helps identify where the most yield variation is, and to understand what is causing the variation. We also know now that there is significant value in properly evaluating your yield maps every season, rather than just filing them for a rainy day!

The yield stability analysis (Figure 4) highlights a significant problem in the bottom part of this paddock. The darker areas are yielding approximately half as much as the lighter areas in the top half of the paddock (3 years of data).

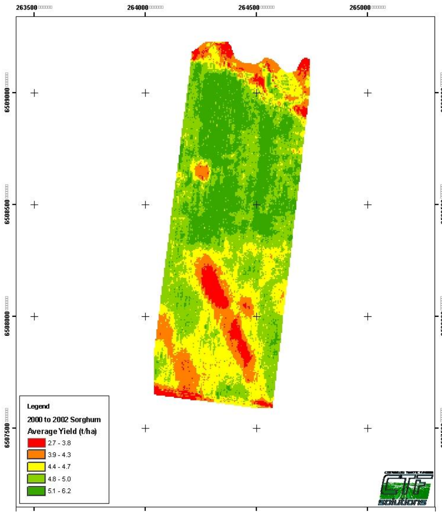
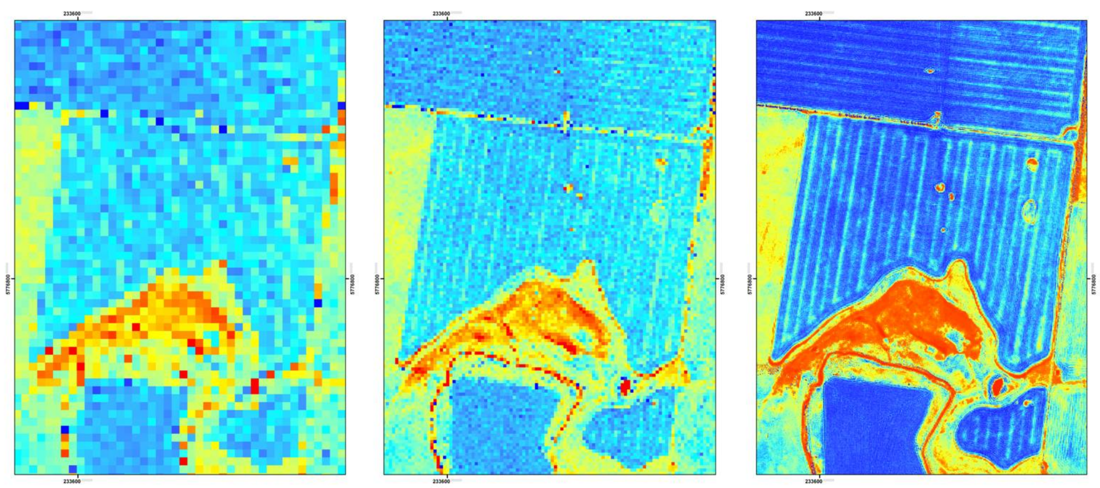


Figure 4

HIGH RESOLUTION SATELLITE IMAGERY

The **best new tool** that we have identified is **high-resolution satellite** (or aerial) **imagery**. A pixel size (the smallest 'piece' of the imagery on the ground) of 1m to 2m is needed to see detail. ***CTF Solutions*** has captured over 500,000ha of high-resolution satellite imagery over grain, cotton, sugar and horticultural farms across Australia. The imagery shows every bit of detail of the crop, and farmer responses have proved its value. The imagery is also spatially accurate, meaning you can go to any point in the image using a cheap GPS unit. This makes ground-truthing of the data simple.

The images below (Figure 5) represent different pixel sizes. You can clearly see responses when high-resolution (1m pixel) is used, and the detail identifies causes. The striping is a result of missed fertiliser.



25m pixel 10m pixel 1m pixel

Figure 5

The image below (Figure 6) shows an area of pest outbreak in a crop of canola. After ground-truthing, an analysis has been conducted to separate the paddock into affected (lighter colour) and non affected areas (darker colour).

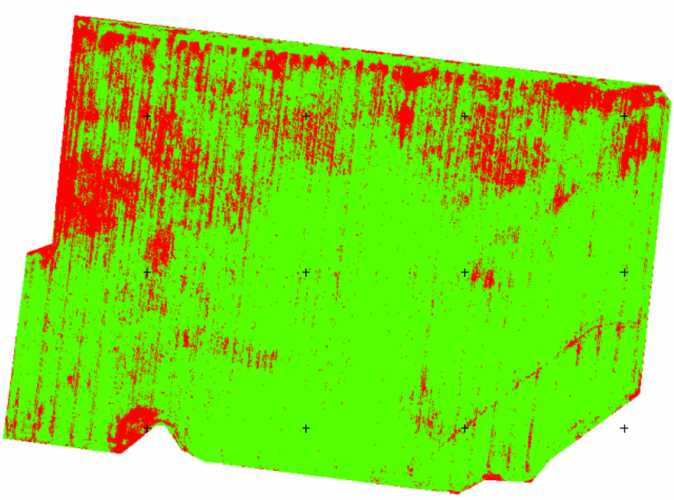


Figure 6

The image below (Figure 7) shows an analysed image and ground truthing information. The areas of good growth (higher NDVI) have higher tiller density and hand harvested yield, than the areas of poor growth (lower NDVI)

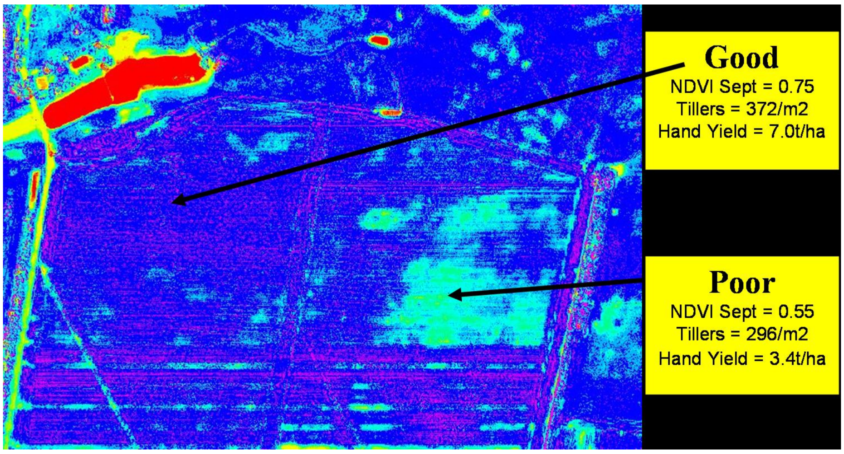


Figure 7

CONCLUSION

New technology such as RTK GPS has taken agriculture a long way in a short time. RTK can obtain detailed topography maps at a small cost. This can dramatically improve your CTF layouts and help manage water logging, drainage and erosion. There are additional pieces of new technology to further refine and fine tune production in CTF systems. The variability at a micro scale (i.e. less than a planter width) has been largely managed by CTF due to the removal of compaction. The next priority is to manage variability across paddocks and farms with the help of imagery and yield mapping. These tools have been shown effective to do this.

POSTER PRESENTATIONS

Uses of Satellite Imagery in Controlled Traffic Farming

Shona Chisholm, Geoimage Pty Ltd

High resolution satellite imagery is captured all over the world by GeoEye's IKONOS satellite and DigitalGlobe's Quickbird satellite. From these satellites, we receive images with resolutions down to 0.6m of detail on the earth. Satellites also capture in the near infra-red wavelengths, not visible to the human eye, which allows for assessment of crop condition, otherwise undetectable from the ground perspective.

Satellite imagery is a useful tool in developing and maintaining controlled traffic farming systems. With enough detail to identify individual trees, and even wheel tracks within paddocks, imagery is useful for basic farm planning, area measurement and vegetation identification. Combined with analysis techniques, crop health and changes in vigour can be identified easily.

IKONOS imagery is supplied on a per sq km basis over the area you require, and can be formatted for use in all types of farming and mapping software. Processing involves mosaicking of individual swathes of images, orthorectification to increase positional accuracy, and other analysis techniques such as NDVI.

Normalised Difference Vegetation Index is an algorithm using the near infra-red band of the satellite to highlight the photosynthesizing capacity of the crop, thus identifying any irregularities within a paddock or farm. NDVI can pick up such anomalies as crop disease, water-logging or areas that might require more nutrients. Images can be captured on a regular basis, eg. annually, to monitor change and improvement within the pasture.

The benefits of satellite imagery in property planning and crop monitoring can often far outweigh the initial cost outlay.

Managing Rough and Deep Controlled Traffic Tracks in Southern Queensland and Northern NSW

Brooke Phelps, Conservation Farmers Inc

Summary: The adoption of controlled traffic farming for a majority of farmers has been an extremely positive experience, however as a result of the self mulching shrink, swell properties of the Vertosol soils in southern QLD and northern NSW, there are some farmers who have experienced problems with rough and deep controlled traffic tracks (CT tracks).

There is no ideal way to manage these, and there is much debate as to whether the rough and deep CT tracks are really an issue with the practice or a product of design and layout. Regardless, CFI has been conducting some case studies which highlight the costs and benefits of numerous different options that a variety of farmers have been implementing.

For some soil types there is an option of simply waiting for the soil to naturally repair themselves with the natural wetting and drying cycles. In the interim, learn to live with the tracks by slowing the tractor speed and/or plant the tracks with a guidance row in the centre. Anther option is to alternating spray tracks so that all tracks are used equally. This significantly reduces the incidence of some tracks being deeper and rougher than others. A farmer in southern Queensland has found that by keeping his weight of machinery to a minimum, he has significantly reduced the need to renovate his CT tracks.

The third option is to renovate the tracks either as a separate operation or as part of the planting operation. It has been found that renovation is better achieved directly after planting when the soil water profile is low. However, many farmers have found that attachments to the planter can do a reasonable job at planting time when soil moisture is higher.

A less appealing but amicable option is to cultivate. A more appealing option than a full cultivation is to work the area around the CT tracks only. There are many machinery options available whereby most farmers would have access to or still own old pre-no tillage machines. One option being explored by a NSW farmer is the use of a leading tyne ripper used over the CT tracks. This reduces the incidence and size of clods being brought to the soil surface, which often pose a new problem after ripping or heavy cultivation.

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