

Zero-Till Farming Systems

Investigation of Zero-Till Farming Systems (ZT)
in high rainfall cropping zones (HRZ), and its
impact on soil biology and nutrient cycling



by Stephen Ball

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Foreword

Over the last fifty years, the major increases in yields for crops sown in Southern Australia and overall profitability have come about due mainly to the changes in agronomy practises and management techniques and different crops. These include;

1. Ley Farming. A rotation of legume pastures and cereals, where the legume produces very good pasture productivity for livestock and nitrogen for the following cereal.
2. Better Rotations. Utilizing Grain Legumes in rotation as a cash crop and a Nitrogen source.
3. Semi Dwarf Varieties. To increase efficiencies by putting more nutrients into the grain yield rather than vegetative growth.
4. Grass Selective Herbicides. Allow control of grasses in pastures, but more importantly the control of these grasses in crops.
5. Canola. The introduction of Canola gave another income source in the rotation as well as benefits in rotation.
6. Nitrogen Fertilizer. Allowed farmers to have multiply cereal & oilseed crops in a row and still be able give them enough nitrogen to produce good yields.
7. Export Hay. As another option for a profit stream and as an integrated weed management tool.
8. Adoption of Minimum Tillage and No-Till. The use of single pass sowing and residue retention to lower costs and produce better yields in drier years.
9. Adoption of speciality crops such as Lentils.
10. There have been other impacts such as the strategic use of Fungicides.

As the terms of trade continue to reduce, the farming community is looking for the “Next Big Thing”. At best, tradition breeding programs for wheat and other grains give us on average only 0.2 % yield increase per annum. Areas where the improvement can come from include; Genetically Modified Crops (GM’s), Zero Tillage Farming Systems (ZT) and Controlled Traffic Farming (CTF).

The components of zero-till when used as a system have big benefits ranging from water use efficiencies and nutrient availability, through to creating a well functioning soil biota.

Over time the farmer can achieve an increase in yields, with a decrease in some inputs such as fertiliser and chemicals. The right machinery, set up correctly can also reduce seeding rates, due to higher germination percentages and lower fuel consumption.

Farmer bodies, government, scientists and agriculture researchers will need to ensure that as farmer innovators take up zero-till, the new trial programs that are funded and managed through bodies like Grains Research and Development Corporation (GRDC) are done so within the zero-till framework. The next group of farmers, the early adopters, will need and demand information that has been done in trials, such as the National Variety Trials (NVT) with an emphasis on zero-till to give them clear information and direction about what is achievable and how to implement them.

There is still a place for longer term trials compared to the current thought of just three years. For most farmers to change from one farming system to another, takes a large amount of conviction and usually an equally large amount of capital. For these farmers to see zero-till working over time, gives them confidence to move ahead, particularly when given a long term view.

This research paper has been funded/ sponsored by GRDC who in turn are funded by government allocations and farmer levies. They funded a Nuffield scholarship to “Investigate zero-till farming systems in high rainfall cropping zones (HRZ) and its impact on soil biology and nutrient cycling”. Its aim is to lay out the current sources of information in a logical sequence to better arm farmers who want to implement zero-till farming systems in their business.

Acknowledgements

It has certainly been an opportunity of life time to be awarded a Nuffield Scholarship. I feel it is a continuation of the process of lifelong learning and there are many people who have helped. I have completed two circuits around the globe and an extra trip to Argentina. All up there were 36 flights to 10 countries and some of these twice.

My first thoughts of Nuffield were when I worked for an older scholar and I also have a family friend who is a scholar and they inspired me with their management of not only their farm but their broader outlook past the immediate district, so thank you to Guy & Sue Wheal and Kim Kelly who planted the seed.

Another important influence was Tim Reeves who I met at Roseworthy who always made me think outside the square and made me look at Agriculture with global perspective.

Next thing I knew there was a phone call from the South Australian President, Andrew Johnson who encouraged me to apply. After two interviews, I was going to be a 2010 scholar.

I spent six weeks travelling around the world with seven other scholars on our Global Focus Program, thank you, you were excellent and I hope we have become lifelong friends.

On our travels for the Global Focus and Study Tour, we have met a lot of fantastic people and some excellent businesses, that have willingly shared their experiences and opened their homes to us, I thank you kindly. Without exception all of the farmers we met, had the same hopes, aspirations and concerns as us.

There are a couple of people I would like to thank for their support and encouragement. I met Nikki at Roseworthy over the odd BBQ and beer and we now have four wonderful children, Kasey, Megan, Sam and Henry. They saw the opportunity which was presented to me and willingly gave up their husband and father for nearly 5 months. They only asked for a small favour in return. We caught up in New Zealand for a week skiing.



Photo 1 – Ready to Hit the Slopes

I would also like to thank Bussy McInerney who leased our farm for the year which allowed me to gain the most from my starting year of the Nuffield scholarship and which also allowed Nikki to accompany me on my Study Trip.

As I am a farmer by choice and not by birth, my own parents Mick & Daphne, gave me lots of support to follow my quest to be a farmer. Nikki's parents Don and Bev gave us the opportunity to be involved in their farm business and now they help in our farm business. A big thank you to all of them.

Finally I would to thank two organisations. Firstly, my sponsor the Grains Research and Development Corporation (GRDC) who along with Nuffield saw the potential in me and funded my scholarship. Secondly to Nuffield, it is an organisation like no other giving farmers from around the globe the opportunity to be involved in the largest farmer network in the world and the huge benefits this brings.

Abbreviations

AAPRESID	Argentinean No-Till Association
AMF	Arbuscular Mycorrhizal Fungi
CA	Conservation Agriculture
CAP	Common Agricultural Policy
CFFA	Canadian Food Fibre & Forestry
CIMMYT	International Maize & Wheat Improvement Centre
CT	Conventional Tillage
CTF	Controlled Traffic Farming
GRDC	Grains Research & Development Corporation
GSR	Growing Season Rainfall
HRZ	High Rainfall Zone
MT	Minimum Tillage
NTA	No-Till Alliance
NT	No-Till
SANTFA	South Australian No-Till Farmers Association
SOM	Soil Organic Matter
SA	South Australia
USDA	United States Department of Agriculture.
UN-FAO	United Nations Food & Agricultural Organization
UV	Ultra Violet
WA	Western Australia
ZT	Zero-Tillage

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Executive Summary

“Residue is King”

To continually be in the vanguard of efficiency and profitability, Australian farmers need to adopt new technology and management practices. Currently Zero-Till, Genetically Modified Crops and Controlled Traffic Farming are valuable tools that are available to them.

This report looks at zero-till farming systems as a whole and then breaks it down into its manageable components, so farmers can identify those areas in their farming business where this management option can be implemented. Having said this, the whole system needs to be implemented for any benefit to be realised.

A+B+C = Healthy Soil

A = Absence of Soil Tillage

Tillage has been around for an exceptionally long time, but according to Faulkner “No one has ever advanced a scientific reason for ploughing.” To achieve the aim of no soil disturbance, there are a number methods; direct sowing with a disc seeder or broadcasting of crop seeds, and direct placing of planting material into the soil (Theodor Friedrich, 2008). For most farmers the use of disc seeders will be the preferred method and farmers should aim for no or absolutely minimal disturbance. Do not destroy what you and your soil biota are building.

B = Biodiversity

One of the ways to create biodiversity is through sound crop rotations. They can include annual crops which are classified as;

- Cool season grasses and broadleaf’s e.g. Wheat & Beans.
- Warm season grasses and broadleaf’s e.g. Maize or Soyabeans.
- Perennial crops e.g. Lucerne & Sulla.

As well as annuals there are perennial crops that can be used, for example Lucerne and livestock can be integrated, but need careful monitoring in order to keep permanent soil cover. Whilst it would be good to introduce warm season crops into the rotation, most of the HRZ’s in SA & WA have a mediterranean climate with no or limited summer rainfall. With current cultivars, this would only allow them to be grown on stored moisture and hope for some rain to finish off the crop and then some grain will be harvested. There are some new cultivars which are cold tolerant and can be planted at a soil temperature of 10°C. Every situation and

farm is different and determining the type of crops and their sequence can be a complex process.

C = Cover on the Soil

This is the lynch pin. Aim to retain all of your stubble / residue to keep 100% soil cover. You are giving this back to feed the soil biota. This residue feeds the whole system. If the soil fertility is to improve under zero-till, it is imperative to increase its organic matter through retention of all biomass which is the residue that is left on the surface combined with root structures decaying in the soil. As well as having physical benefits to the soil, for example lowering erosion, the residue feeds soil organisms known as Biota. The biota carries out a wide range of processes that are important for the maintenance of soil “health” and fertility in both natural and managed agricultural soils.

The job that farmers require from their macro- and micro-organisms in the soil biota is to help;

- Improve the soil structure e.g. Glomalin from Arbuscular Mycorrhizal Fungi's.(AMF's)
- Organic matter turnover and movement through the soil profile, with soil ameliorants transported through the soil profile. e.g. earthworms and their castings.
- Nutrient cycling, principally nitrogen, phosphorous & sulphur.
- Disease incidence & suppression e.g. fungal feeding nematodes.
- Agrochemical degradation e.g. glyphosate binding bacteria.

Research Area

Scientists, agricultural researchers and research farm managers were interviewed across 3 continents with them contributing to the body of knowledge in the report. Also across these continents, innovative farmers were visited to see how they have implemented zero-till. Also a very large 3 day congress was attended in Argentina as a guest of the Argentinean No-Till Association (AAPRESID).

Disc Seeders

Most of the disc seeders that are currently available in Australia are cost prohibitive to the majority of small to medium farmers. In South America there is a large range of disc seeders manufactured, particularly in Argentina and Brazil that are far more affordable. With some

input from Australia farmers, the machines can be made to our specifications. A number of companies were interested in our input e.g. Avec, Bertini and Semeato.

These and others were all double or triple disc units and can handle in excess of 10 t/ha of stubble. So to retain all stubble and get through this residue, a disc seeder is the only realistic option. Other benefits include;

- Superior seed and fertilizer placement.
- Increase timeliness of sowing.
- Reduced fuel consumption

Recommendations

- Adopt the Zero-Till system
- Obtain a quality double disc machine that has;
 - a. No soil disturbance when in use.
 - b. Seed firming mechanism, either a wheel or Keeton finger
 - c. Closer unit that fills the trench with soft soil and some residue
 - d. Realistic price so smaller farmers can access the technology to move to ZT.
- Small / Medium size farmers can look towards South America to find suitably priced machines. They are slowly being imported into Australia.
- Look upon all residue as precious and must be retained to form a permanent cover on the soil and as feed source for the biota.
- Use as diverse a rotation as possible. Try to utilise cool and warm season crops. Get some cold tolerant maize cultivars from Argentina or Chile.
- Use organic manures to increase SOM and as a very good source of both nitrogen, phosphorous and to a lesser degree potassium.
- Re-inoculate soils with worm species particularly the Anecic type as this will help with soil ameliorants being moved through the profile and their burrows allow for increased water infiltration. Also the Endogeic type actually eats soil and move nutrients through the profile. This is of particular importance for phosphorous which is relatively immobile in the soil.

Introduction

“No one has ever advanced a scientific reason for plowing.”

Edward Faulkner from Plowman's Folly (1943)

As a professional food and fibre producer, who is constantly looking to be more economically and environmentally sustainable my choice of study topic for my Nuffield Scholarship has provided me with the opportunity to look at zero-till farming systems in detail. This will impact positively on our business as zero-till farming has shown to be the next positive step forward in sustainable farming systems. Wattle Vale Farm is a medium / small family run business in the heart of the South Australia's High Rainfall Cropping Zone as designated by GRDC.

For the last 13 years all of the cropping enterprise has been carried out using no-till (NT) techniques with knife points and press wheels. As much stubble as possible is retained, but in good years there is too much residue to handle. Then the stubble is broken down by mechanical means, such as slashing or prickle chaining or livestock grazing. Other methods employed are baling the straw or as a last resort, burning. There have been very good gains in productivity, but in the last five years these have plateaued with no noticeable improvements.

After hosting many international key note speakers for the SANTFA Annual Conference, they had a common message. To keep improving the soil, it was imperative to look at zero-till. By shifting from knife points to discs they stated that the soil structure will improve by itself through retaining all of the residue, and feeding the biota. This will in turn improve the overall soil health and lead to increased yields with fewer inputs.

A Nuffield scholarship was a great opportunity to find out if zero-till was the answer to ***“Where next?”*** and ***“What is the Next Key Driver?”***

What transpired was an expedition over 4 continents, with some wonderful visits to leading edge farmers, top rate scientists and researchers. Also machinery manufacturers were called upon, mainly in South America. The result of this journey is the firm commitment that zero-till is the way forward and it is an option a lot of farmers will take up over the next 5-10 years.

Objectives

The objective of the study was to investigate where the next leap in productivity was going to come from.

Firstly the area of particular interest was zero-tillage systems, which is not only about using disc machines but the whole system where all biomass, stubble and residues are retained and a diverse rotation is put into practice. To complement this systems approach, an investigation of what is occurring in this residue layer and in the soil beneath it, in terms of nutrient cycling and soil biology was undertaken.

Secondly to seek out the best disc machines that not only work under varying conditions, but are also available at a realistic price so that small to medium size farmers can purchase them and thus utilize the zero-till system.

Thirdly, an investigation into new crops that could be utilized across high rainfall cropping zones in southern Australia. In particular, those which are suited to a Mediterranean climate, which could increase the diversity of our rotations.

Current farming systems and the need to change

Throughout the Southern and Western Australian cropping zones the main farming system for crop production is no-till. This system is based around some residue retention and seeding via a tyned implement with knife points. In some years where the residue burden is too great to be able to be handled at seeding, it is removed by baling and burning or “walk out the paddock” by allowing livestock to graze over summer and autumn. In the rest of the world, mainly North and South America this is still considered a tillage practice with low benefits to the soil. Some farmers have been practicing no-till, Australian style, for around 15 years and have been retaining the residue. They have used slashing, rolling or harrowing to break it up into small enough pieces to allow seeding to occur with little or no blockages. These farmers have felt they have reached a plateau in the system with no added yields and improvement in soil structure and soil health.

Juca Sã from Brazil has been instrumental in the movement to zero-till in Southern Brazil. He has shown what is happening in the zero-till system through the years of its initial and transition phases and then through the consolidation and finally at maintenance phase.

Table 1 Evolution of Zero-Till From 0 to 20 Years

Evolution of a continuous zero-till system			
Initial phase	Transition phase	Consolidation phase	Maintenance phase
<ul style="list-style-type: none"> • Rebuild Aggregates • Low OM • Low crop residues • Reestablish microbial biomass • > N 	<ul style="list-style-type: none"> • Increase soil density • Start incr. of crop residue • Start incr. in OM • Start incr. P • Imob. N \geq Min. 	<ul style="list-style-type: none"> • High CR • High C • > CEC • > H₂O • Imob. N < Min. • > Nutrient Cycling 	<ul style="list-style-type: none"> • High accum of crop res. • Continuous N and C Flux • Very high C • > H₂O • > High Nut. Cycling • Less N and P use
0-5	5-10	10-20	> 20
Time (years)			
(Sã, 2004)			

Juca believes that our no-till systems will never leave the transition phase and therefore not receive the major benefits which occur later in the evolution. (Sa, 2004). He states “That we should dispense with a tyne and knife point to a system which abstains from tillage and retains all residue coupled with diverse rotations.”

The Zero-Till (ZT) system

This system is one that incorporates the use of no or minimal disturbance disc seeders with diverse rotations and continuous soil cover through retaining the entire residue on the soil surface and most times including controlled traffic farming (CTF).

According to the United Nations Food & Agricultural Organization (UN-FAO), zero-till or conservation agriculture will have all of the above and can integrate other features such as perennial plants, inclusion of allelopathic and smother crops such as canola or saia oats, all to increase the biomass in the soil and feed the good macro and micro organisms in the soil.

For the zero-till system to be successful Rolf Derpsch a world expert in this type of farming system and cover crops, says all of the components of zero-till must be implemented together and if you miss one component then the system will break down. We have learned that almost all advantages of the no-till system come from the permanent cover of the soil and only a few from not tilling the soil (Derpsch, 2008). He likens it to a three legged stool with the legs named A,B & C. The three legs are stable but when one is removed it quickly topples. They stand for

A = Absence of Soil Tillage: No Mechanical Soil Disturbance.

B = Biodiversity: Crop Rotation / Cover Crops or Integrating Livestock & Farming.

C = Cover of the soil: Permanent Cover with Crop Residues.

A + B + C = Healthy Soils

A = Absence of Soil Tillage and Disturbance

Farming has been traditionally carried out with the use of such implements as the mouldboard plough, offset discs, cultivators and harrows. Farmers in this cycle of farming believe that to obtain a uniform and loose seedbed, which is weed-free, it was and still is necessary to till the soil.

Even the No-Till seeding method has negatives. No-till seeding is carried out using a tined implement with knife points with row spacing of 250-300mm. These points are generally 12-15mm wide with tungsten facing. The soil has some cultivation particularly below the level of the seed and there is still quite a large amount of soil throw.

Dwayne Beck, Rolf Derpsch & Carlos Crovetto believe this to be cultivation and don't see how it can be called no-till.

When the seeding system uses any plough, cultivator or even knife point seeders, a number of negative impacts have been found on the soil and conditions in it.

1. During the tillage operation there is an infusion of higher levels of oxygen. This results in a rapid decomposition of soil organic matter (SOM). This continues for a short time after tillage / seeding which gives a large flush of available nutrients to the plant, at a particular time when the plant only requires a limited amount.
2. The populations of larger organisms such as earthworms and arthropods are quickly decimated by physical damage to the organism itself and also damaging its habitat / burrow means they will not reproduce.

3. The action of the cultivating machine slices and dices delicate macro and micro organisms such as fine thread like fungi and worms. This results in the soil being dominated by the smallest organisms like single cell bacteria. (Blank, 2007)
4. The soil structure is damaged. Soil structure can become coarse, massive and platy on some soils, whilst there may be an increase in soil strength, water infiltration, retention and availability all decrease. On other soils tillage breaks down the soil structure into a fine powder so the soil is easily eroded by wind and water. These soils become waterlogged easily and become less fertile; less responsive to fertilizers and then a lot of energy needs to be expended to remediate them. (Benites, 2003)
5. The implements used for tillage often lead to the development of a hardpan, which is a horizontal compaction zone which is created by the smearing action at the bottom of the plough / seeder that reduces root growth and water infiltration into the lower levels of the soil profile.
6. Under tillage, the soils can become water logged, compacted and possibly anaerobic where there is a lack of oxygen. In most cases this leads to a decrease in beneficial micro organisms and leads to a large increase in different organisms, many of which are pathogenic (disease causing) bacteria and fungi e.g. Pythium and Phytophthora root rots.
7. As the soil with a hardpan has more water added from either rainfall or irrigation, the level of the water in the small area of the profile continues to rise up towards the surface, the area of aerobic conditions decrease and anaerobic area increases. This lowers the physical space available for living roots to live in. Dr Kim Coder states “The consequence of having smaller volumes of space for roots to grow means that roots and their resources are subject to much greater fluctuation in water, heat loading and mechanical damage. Drought and heat stress can quickly damage roots in this small layer of oxygenated soil.” Some weeds which typically have shallow roots systems and shorter life cycles can out compete the crops that we sow. (Coder, 2000)

With the above reasons and more it is clear there is no reason to continually till the soil. At a field day in England, here is a condensed version of the conversation between two farmers.

Farmer 1 “I have to plough the soil to control weeds.”

Farmer 2 “How long have you been ploughing.”

Farmer 1 “25 years.”

Farmer 2 “If you still have the same weeds, you are a slow learner.” (Ball, 2010)

The excuse for ploughing is no longer valid. This particular farmer was using it as an excuse to continue the way he had been farming for 25 years. The other pointed out that in five years of Zero-till he had overcome the problem weeds because the grass weed seeds needed to be buried to germinate and he kept them on the surface.

B = Biodiversity

In agricultural cropping systems it is relatively hard to achieve diversity in any one year but it can be achieved by planting a different crop each year. In previous years and even today a number of farmers plant one cool season grass crop such as wheat and then a cool season broadleaf crop such as canola, the two crop sequence. This system has fallen down mainly in WA, as there was no real diversity. There was only 1 year to control broadleaf weeds in the wheat crop and the equivalent for the canola weeds. They put too much pressure on the chemicals and in a short period of time, the system soon collapsed as the weeds became resistant to the chemicals. Canola also has some allelopathic properties, which it produces to stop competitors. This unfortunately stops some micro-organisms in the soil from thriving. A major one is Arbuscular Mycorrhizal Fungi(AMF), and we now know these AMF have a major role to play in our soils.

Stacked rotations are being used to overcome some of these problems and help create a better system. Two crops of each type are grown in sequence. It enables weeds to be controlled and also disease issues are better accounted for in this system. A rotation may incorporate legumes and oilseeds for broadleaves and cereals such as wheat, barley & maize. It would be very good to find a warm season crop that could be grown in Mediterranean climates. It will be discussed later. The rotation currently used on Wattle Vale farm, is;

Beans - Canola- Durum - Wheat - Vetch - Canola - Wheat - Cereal Crop or Hay

Within these crop rotations it is also ideal to have crops with different rooting systems to take advantage of nutrient and moisture differences in the soil profile.

All situations and rotations are different but some guiding principles can be helpful and Dwayne Beck has given his Top 10 List.

1. Reduced and no-till systems favour the inclusion of alternative crops. Tilled systems may not.

2. A two season interval between growing a given crop or crop type is preferred. Some broadleaf crops require more time.
3. Chemical fallow is not as effective at breaking weed, disease, and insect cycles as is black fallow, green fallow or production of a properly chosen crop.
4. Rotations should be sequenced to make it easy to prevent volunteer plants of the previous crop from becoming a weed problem.
5. Producers with livestock enterprises find it less difficult to introduce diversity into rotations.
 - a. Use of forage or flexible forage/grain crops and green fallow enhance the ability to tailor rotational intensity.
6. Crops destined for direct human food use pose the highest risk and offer the highest potential returns.
7. The desire to increase diversity and intensity needs to be balanced with profitability.
8. Soil moisture storage is affected by surface residue amounts, inter-crop period, snow catch ability of residue, rooting depth characteristics, soil characteristics, precipitation patterns, and other factors.
9. Seedbed conditions at the desired seeding time can be controlled through use of crops with differing characteristics in regard to residue colour, level, distribution and architecture.
10. Rotations that are not consistent in either crop sequence or crop interval guard against pest species shifts and minimize the probability of developing resistant, tolerant or adapted pest species.

C = Cover on the Soil

Almost all of the advantages of the zero-till system come from the permanent cover on the soil surface. This really is the key to the system. Carlos Crovetto states “The grain is for man and the stubble is for the soil”. (Crovetto, 2006) The retention of 100% of the residue and use of disc seeders goes hand in hand. To be able to keep the entire residue from the previous year’s crop you need to use a disc seeder otherwise to be able to get through with a traditional tyned seeder you may have to compromise by either removing some as baled straw or feeding livestock to lessen the load. This results in not maintaining 100% cover and having also tilled the ground and undone the micro- and macro-organisms good work.

The benefits to the soil include:

1. Erosion Control

In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer protects the soil from the physical impact of rain and wind thereby allowing the soil to regenerate. According to Kris Nichols, she believes that a 10 tonne residue will result in 1mm of new soil. This has particular reference to Australian soils where most are extremely old and weathered. Not only can farmers stop erosion of our soils, but they can rebuild them. (Nichols, 2008)

2. Water Infiltration & Water-holding Capacity

By having the residue on the surface, the speed of water over the surface is dramatically slowed and this gives it more time to infiltrate. Also as more organisms inhabit the soil they create micro- and macro-pores leading from the soil surface down to the subsoil and allowing rapid water infiltration in case of heavy rainfall events. Water holding capacity is increased as the SOM levels increase. This is enabled as the specific density of the soil decreases and pore spaces increase which allows more water to be held in the soil profile. This water is then available for the plant roots. According to Patriquin, 2003, the rough rule of thumb is for every 1% increase in SOM, the water holding capacity increase by 50%. (Patriquin, 2003). It will take time but Australian farmers can take the path to capturing more of the rainfall we do get and keeping it in the soil as available moisture for our crops.

3. Soil Temperature & Lower Evaporation

By keeping the residue on the surface, there is a big benefit for farmers to lower soil temperature by almost half when compared to a soil with no cover. Durceu Gassen from Brazil showed that a soil with no residue cover over summer had a temperature of 53.5⁰C, where as one covered with maize residue had a temperature of only 25.5⁰C. This has a double benefit in that microbial activity becomes extremely slow at temperatures above 30⁰C. The other benefit is that the residue cover also lowers evaporation which means there is more plant available moisture. It has a stabilising effect on both temperature and soil moisture. These reasons alone should be enough to see Australian farmers take up Zero-till, with much of our farming carried out in low rainfall areas.

The combination of lowering evaporation and increasing both water infiltration and water holding capacity means that we can have a direct action to increase yields across Southern Australia. I feel the French-Schulze model will need to be changed. According to French & Schulze we should be able to grow 20 kilograms of wheat for every millimetre of rainfall in

the growing season after evaporation is subtracted. This can be seen below in equation 1 & 2 using data from the Gilbert Valley in SA with a growing season rainfall (GSR) of 400mm. If all the residue is retained, we can reduce evaporation by 20%. This gives more water available for plant growth and this is shown in equation 3.

$$\text{Eq1} \quad \text{Yield Potential} = (\text{GSR} - \text{Evaporation}) \times 20\text{kg}$$

$$\text{Eq2} \quad 5800 \text{ kgs} = (400 - 110 \text{ mm}) \times 20\text{kg}$$

$$\text{Eq3} \quad 6240 \text{ kgs} = (400 - 88\text{mm}) \times 20\text{kg}$$

In a simplistic way, this shows that by reducing the evaporation alone we could result in an increase in yield by approximately ½ tonne. If the amount of extra water available through increasing water holding capacity is also considered, the increase in potential will be above this ½ tonne. We can see the logic in this solution already, if we look to the humble veggie garden; it is common to put pea straw on to lower evaporation and help smother weeds and this has been done for many years.

4. Weed Barriers

Over time as the system progresses more residue accumulates, this has a positive effect on weeds and weed seeds. The residue acts like a mulch in the veggie garden and smothers weeds trying to grow, thus making the plants more competitive. By not cultivating the soil some weed seeds will fail to germinate as they need darkness or contact with the soil to start life. This keeps the weed seeds on the surface and over time they are broken down by UV light.

5. Feed the Soil Biota

As cover is the third leg on the stool, biota forms the core of that particular leg. The biota is the living fraction of the soil. Over time with total residue retention the numbers of soil organisms increase, both in total number and diversity. The residue and soil interface becomes a habitat for a number of organisms, from earthworms and larger insects down to soil borne fungi and bacteria.

Due to the fact that no mechanical implements are used that destroy the "nests" and channels built by micro-organisms, higher biological activity occurs under the zero-till system. Additionally, micro-organisms do not die because of famine under this system (as is the case

under bare soils in conventional tillage) because they will always find organic substances at the surface to supply them with food.

Finally, the more favourable soil moisture and temperature conditions under zero-till also have a positive effect on micro-organisms of the soil. For these reasons more earthworms, arthropods, (acarina, collembola, insects), more micro-organisms (rhizobia, bacteria, actinomycetes), and also more fungi and mycorrhiza are found under no-tillage as under conventional tillage (Kemper and Derpsch, 1981; Kronen, 1984; Voss and Sidiras, 1985). Despite the fact that chemicals are used to kill weeds, higher biological activity occurs under zero-till, an indicator of a healthier soil.

The biota carries out a wide range of processes that are important for the maintenance of soil “health” and fertility in both natural and managed agricultural soils. The job that farmers want from their macro and micro-organisms in the soil biota is to;

1. Help with soil structure e.g. Glomalin from Arbuscular Mycorrhizal Fungi's (AMF's)
2. Improve organic matter turnover and movement through the soil profile e.g. Earthworms and their castings.
3. Increase nutrient cycling e.g. nitrogen, phosphorous & sulphur.
4. Suppress disease and reduce the effects of these diseases e.g. fungal feeding nematodes.
5. Help with agrochemical degradation e.g. Glyphosate binding bacteria.

Help with Soil Structure

One particular organism that inhabits the top layers of the soil profile is AMF's. They are the world's biggest organism where, for example, one individual fungi can cover a square kilometre under forests. They are ancient microorganisms that evolved with plants to aid in acquiring nutrients and they produce glomalin. This is a sticky substance secreted by the fungal hyphae that funnel nutrients and water to the plant roots. It acts like little globs of chewing gum on strings or strands of plant roots and fungal hyphae. Into this sticky “string bag” fall the sand, silt and clay particles that make up the soil – along with plant debris and other carbon containing organic matter. The sand, silt and clay stick to the glomalin, starting aggregate formation, a major step in soil creation. (S.F.Wright, 2004)

On the surface of soil aggregates, glomalin forms a lattice-like waxy coating to keep water from flowing rapidly into the aggregate and washing everything, including the carbon away.

As the builder of the formation “bag” for soil, glomalin is vital globally to soil building, productivity and sustainability, as well as to carbon storage. An interesting note from Kris Nichols is that she uses glomalin measurements to gauge which farming or rangeland practices work best for storing carbon. Since glomalin levels can reflect how much carbon each practice is storing, they could be used in conjunction with carbon trading programs. She has found that both tilling the soil and leaving land idle, such as in fallow, which is common in our climate decrease glomalin levels by destroying hyphal fungi networks. The networks need live roots and do better in undisturbed soil.

When glomalin binds with iron or other heavy metals, it can keep carbon from decomposing for up to 100 years. Even without heavy metals, glomalin stores carbon in the inner recesses of soil where only slow acting microbes live. This carbon in organic matter is also saved like a slow release fertilizer for later use by plants and hyphae. Over all the AMF's and their product glomalin help build significant resilience in the soils. (Nichols, 2008)

Organic Matter Turnover and Movement through the Soil Profile

The earthworms and other macrofauna such as termites and dung beetles are very important biological agents that fragment organic residues and cause a large surface area to be exposed for decomposition. These organisms macerate the mulch, incorporate it into the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure and its porosity. They also help with the formation of soil aggregates and soil pores. Through these soil pores the organic matter and other organic and inorganic materials can be moved through the soil profile. With the aim of zero-till to not till the soil, this is one of the ways farmers can transport these to mix throughout the soil. Lime, gypsum and manures / compost are examples of soil ameliorants which are spread on the surface, but are needed and are best utilised further down in the profile. This process carried out by the living component of a soil or the soil biota, can be regarded as “biological tillage”.

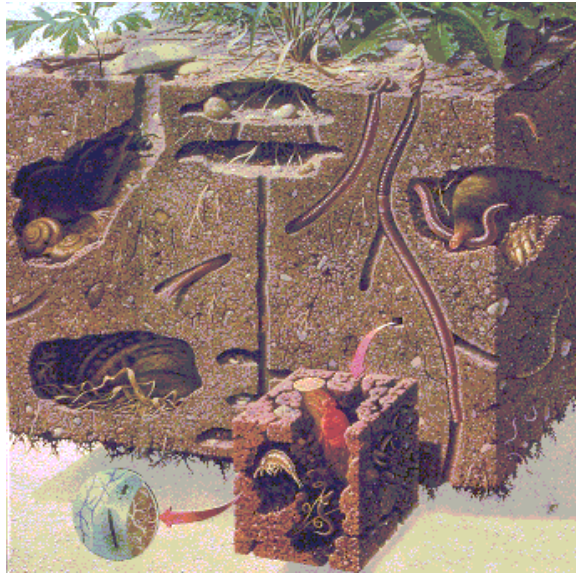


Photo 2 Biological Tillage by Macro-organisms

In most cases these tillers are big organisms that burrow through the soil looking for their food. Earthworms “glaze” the passageway they create with a nutrient rich and microbial active slime layer that greatly enhances water holding capacity and soil structure. Earthworms and many soil arthropods also shed organic matter, grazing on the microorganisms present, and then excreting the nutrients in a plant available form. Together, all these small channels and pores serve as reservoirs and a transportation network for air, water, nutrients, roots and organisms. According to Danny Blank, water use efficiency has increased by as much as 50% in some regions of Australia by reintroducing absent soil biology. This means that the same amount of crop could be grown with half the amount of water. (Blank, 2007) Dwayne Beck reintroduced Night Crawlers (Anecic Earthworms) to the research centre paddocks and has been very happy with the results



Photo 3 Roots following Earthworm Burrows

There are a number of different Earthworms and they all live differently so their positive effects are also varied. In Australia there are about 2000 species of earthworms and they range from tiny 2-3mm long worms through to the giant Gippsland worms at 2-3metres long. They all fall into 3 classifications i.e.: Epigeic (surface dweller), Endogeic (criss-cross burrows in the top surface layer), Anecic (deep vertical burrowing). (Mingin, 2010)

Epigeic worms live in the top soil, and duff layer on the soil surface. These small, deeply pigmented worms have a poor burrowing ability, preferring instead an environment of loose organic litter or loose topsoil rich in organic matter to deeper soils. Epigeic species feed in organic surface debris. They are the ones found in most worm farms and which need a lot of residue to live. And like the Anecic worms are easy prey for insects and bigger predators like birds living in the mulch layer.

Endogeic worms build complex lateral burrow systems through all layers of the upper mineral soil. These worms rarely come to the surface; instead spending their lives in these burrow systems where they feed on decayed organic matter and bits of mineral soil. They are the only category of worm which actually eats significant volumes of soil and not strictly the organic component.



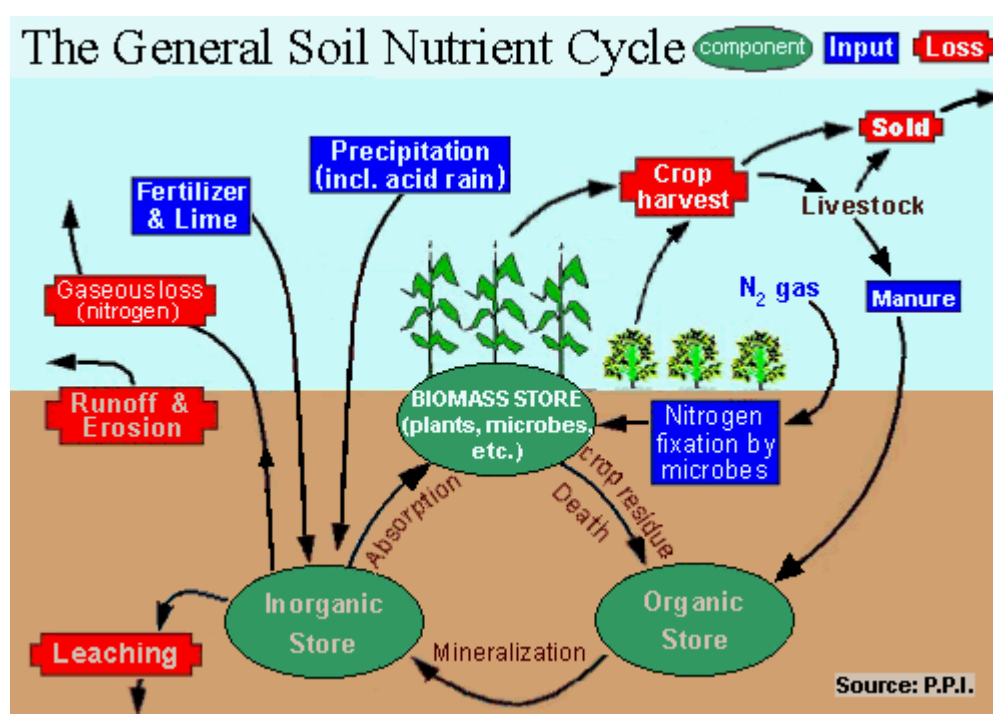
Photo 4 Endogeic Worms in Action (Rolf Derpsch)

Anecic worms like the common Night Crawler build permanent, vertical burrows that extend from the soil surface down through the upper mineral soil layer. It is not unusual for their burrows to reach a depth of six feet or more. These worm species coat their burrows with mucous which stabilizes the burrow so it does not collapse, and build little mounds (called middens) of stone and castings outside the burrow opening. Anecic worms are able to

recognize their own burrows, even in an environment where there are hundreds of other burrows present and return to these burrows each day. (Mingin, 2010)

The Anecic species feed in decaying surface litter, so come to the soil surface regularly, which leaves them exposed to predators. They have developed a spoon shaped tail that bristles with little retractable hairs, called setae, with which to grip the burrow wall and avoid being easily pulled out. They also tend to be very large worms. These worms have a long generation time and each only has one burrow. In the absence of this burrow, Anecic worms will neither breed nor grow. By utilizing a disc machine with very minimal disturbance less of these burrows will be destroyed.

Nutrient Cycling



Nutrient cycling is very important in all systems, but particularly so in cropping systems where we are trying to maximize the efficiency of the nutrients used.

Soil organisms, including micro-organisms, use soil organic matter as food. As they break down the organic matter, any excess nutrients (nitrogen, phosphorus and sulphur) are released into the soil in forms that plants can use. This release process is called mineralization. The waste products produced by micro-organisms are also soil organic matter. This waste material is less decomposable than the original plant and animal material, but it can be used by a large number of organisms. By breaking down carbon structures and

rebuilding new ones or storing the carbon into their own biomass, soil biota plays the most important role in nutrient cycling processes and, thus, in the ability of a soil to provide the crop with sufficient nutrients to harvest a healthy product. The organic matter content, especially the more stable humus, increases the capacity to store water and store (sequester) carbon from the atmosphere. (Bot, 2005)

The ability of soil to hold nutrients, is often measured by what is called Cation exchange capacity (CEC)—a measure of a soil's negative charge (usually in clays and organic matter). Rarely are soil organisms mentioned with regards to nutrient retention, however, in a healthy soil, vast reserves of important plant nutrients are stored within the bodies of bacteria, fungi and other soil organisms. Bacteria have the highest concentration of nitrogen of all other organisms both macro and micro. Fungi are typically the second most concentrated in nitrogen. (Blank, 2007).

Along with nitrogen they contain other critical plant nutrients—high levels of phosphorus, potassium, sulphur, magnesium, calcium, etc. Decomposition happens almost exclusively by these two sets of organisms, which in turn store nutrients from the decomposed organic matter in their own bodies, immobilizing nutrients, and thereby reducing leaching. Another example is calcium, which is held incredibly tightly by fungal hyphae in the soil. Without healthy fungal biomass, calcium is easily leached through soils. The presence of decaying organic matter in soil, broken down leaves roots, dead organisms, etc, along with diverse populations of bacteria and fungi is the key to immobilizing and storing nutrients in the soil. These nutrient-rich organisms then become the basis for the critical cycling of nutrients for our crops.

As mentioned above, fungi and bacteria have considerably more nitrogen in their bodies than other organisms. The carbon to nitrogen ratio for bacteria is around 5:1 and for fungi is 20:1. Nutrient cycling happens when other sets of soil organisms (primarily protozoa, bacterial and fungal feeding nematodes, micro arthropods, and earthworms) are present to consume the nutrient-rich bacteria and fungi and release nutrients in plant-available forms. A healthy soil contains diverse species and huge populations of protozoa, beneficial nematodes, micro arthropods, and earthworms. For example, one gram of healthy soil can contain 1 million protozoa. These protozoa, with a C:N ratio of 30:1, consume bacteria. Because the protozoa need less nitrogen, the excess is excreted in the form of ammonium ions. The ammonium ions are held more tightly to the soil particles than are nitrate ions, the most common (and

leachable) form of nitrogen in commercial fertilizers. This predator-prey relationship between protozoa and bacteria can account for 40 to 80% of nitrogen in plants. (FAO - Soil Bulletin, 2002). Bacterial and fungal-feeding nematodes do a similar job. They consume vast quantities and have been found to turn over approximately 50 – 100 kg/ha/year. These nematodes are beneficial, unlike their close relative Cereal Cyst Nematodes (CCN), contributing immensely to plant available nitrogen.

These interactions and countless exchanges of nutrients between soil organisms occur in root zones of plants where the highest concentrations of organisms exist (because root exudates provide food for the bacteria and fungi which in turn attract their predators—protozoa, nematodes, micro arthropods and earthworms). Nutrient cycling by these predators also occurs with other valuable plant nutrients such as potassium, phosphorus, calcium, sulphur and magnesium, resulting in a less leachable form than what is usually applied in synthetic fertilizers.

Humus or humified organic matter is the remaining part of organic matter that has been used and transformed by many different soil organisms. These fractions of the organic matter in the soil are left over when decomposers have scavenged all they can from the residue and from their bodies when consumed by predators because chemically it is too complex to be used by most organisms. It is a relatively stable component formed by humic substances, including humic acids, fulvic acids, humatmelanic acids and humins. (Bot, 2005) It is probably the most widely distributed organic carbon-containing material in agricultural soils. It has many functions which are listed below;

1. Improved fertilizer efficiency.
2. Longer life of Nitrogen for example urea performs for 60-80 days longer.
3. Improved nutrient uptake, particularly phosphorous and calcium.
4. Stimulation of beneficial soil life.
5. Provides magnified nutrition for reduced disease, insect and frost impact.
6. Humates “buffer” plants from excess sodium
7. Organic humates are a catalyst for increasing soil carbon levels

Other soil organisms are also involved in more direct forms of nutrient cycling. Nitrogen-fixing bacteria, *Rhizobium* sp., convert atmospheric nitrogen into a usable plant form as they colonize the roots of legumes. Mycorrhizal fungi colonize root systems as mentioned before with staple grain crops as wheat, barley, maize and sorghum. In so doing, these specialized

fungi cycle nutrients by secreting enzymes that solubilize calcium phosphate and pump the phosphorus directly to the plants, thus making an otherwise unavailable nutrient now available to plants. (S.F.Wright, 2004)

With the retained residue and increase over time of organic matter, there is a dynamic nutrient release over the whole season rather than peaks. (Jack Desbiolles 2010) In a tilled system with regards to nitrogen, there is normally a large spike in autumn after the first rains and subsequent cultivation and/or seeding pass with high disturbance. This is due to high amounts of oxidation occurring after tillage where there is a large increase of respiration and turnover by soil organisms. The new system follows the crops needs much more than the traditional and unnecessary spikes.

Disease Incidence & Suppression

Root disease can be a major restriction to plant production and therefore yield of grain or hay. The cause of this disease is that current practices have allowed a pathogenic organism to become dominant. (Better Soils Technical Committee, 1998) After the Zero-till system has been employed for a number of years there is evidence that the soil can become “suppressive”. This is when the level of predator organisms has increased and keep the pests and diseases in check that were previously causing yield losses. A number of cases of this disease suppressive soils have been found on a number of the continents where zero-till has been used for a number of years. A couple of the diseases that have been suppressed are Rhizoctonia and Take-all. This suppression seems to come from the fact that those organisms are being predated by beneficial organisms and that under the zero-till the plants are more healthy and are able to tolerate some pressure from disease. (Roget, 1998)

Agrochemical Degradation

In some instances, with the build up of microbial action, agrochemical degradation has increased such as with glyphosate. “Agricultural chemicals are broken down in a similar way to organic matter where microorganisms produce the appropriate enzymes to degrade the compound. More complex structures degrade more slowly either because fewer microorganisms in the soil produce enzymes capable of degrading them or because of the inaccessibility to microbes” (Department of Agriculture Victoria, 2011). When agricultural chemicals are degraded, the microorganisms responsible obtain carbon (energy) from the chemical allowing these microorganisms to grow and multiply. Microorganisms capable of degrading a particular chemical grow and multiply until there is a higher proportion of them

in the soil relative to other species. This can result in this community of microorganisms in the soil adapting to the point where the chemical can be broken down more rapidly than it would have previously. This can be a problem when rapid degradation of a chemical may reduce its effectiveness against pests.

The Result of ZT

After starting either a zero-till or conservation agriculture system one of the most important immediate nutrient effects is the potential of the residue cover to restrict N availability. Residues with a high C to N ratio, such as wheat, maize, barley, sorghum, and ryegrass, commonly induce N immobilization in soil surface strata during decomposition, although the magnitude of this effect is dependent on residue quantity and quality, as well as the mineral status of the soil. (Bolliger, 2009)

Table 2 : Zero-Till Wheat Yield at Melton Mowbray, England

Based on Long Term Average Paddock with 10 t/ha History

Year 1	8.75 t/ha
2	7.5 t/ha
3	6.5 – 7.5 t/ha
4	8.0 t/ha
5	8.5 – 9.5 t/ha
6	Back to 10 T/ha

(Reynolds, 2007)

The N immobilization process is most intense during the first years of zero-till but after 5 or more years it gradually diminishes due to the increased surface concentration of SOM acting as an N source and thereby effectively counteracting N limitations induced by residues. (Sa, 2004) One way to help with this process is to use those crops in the rotation with a lower C:N ratio such as beans, peas and other legumes. A stacked rotation of some of these crops in the first few years would be beneficial, particularly if you intended to grow a crop like hard wheat where extra nitrogen would be needed above normal application levels.

The residues of legumes have a higher nitrogen component and are closer to C:N ratio of the biota and are therefore broken down more quickly making the nitrogen available sooner. In tillage-based systems, mineralization is "boom and bust". Booms occur after tillage with busts following shortly after and therefore requiring a big nitrogen application. According to Juca Sa, after the transition phase of zero-till systems, the nitrogen is being cycled at a more even

rate which then levels out the amount of nitrogen available to the plant throughout the season. (Sa, 2004)

The ideal soil that is healthy has the right amounts of nutrients but also has those available to the plant roots and other organisms such as Arbuscular Mycorrhizal Fungi (AMF). This ideal soil would be one that does not limit productive capacity. (Better Soils Technical Committee, 1998).

The major benefit that farmers will see by implementing the zero-till farming system will be an increase in yields, water use efficiencies and soil biota activity. The whole system package will need to be implemented as shown by Ken Sayre and Bram Govaerts from CIMMYT.

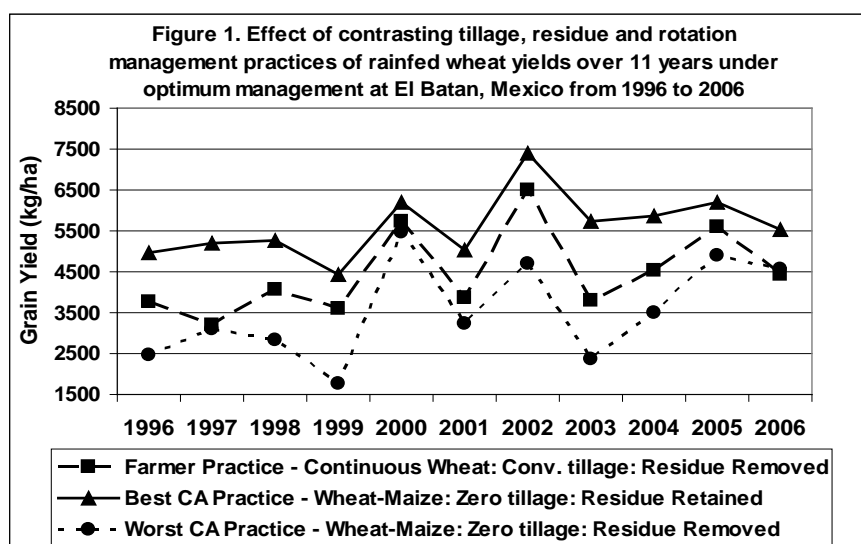
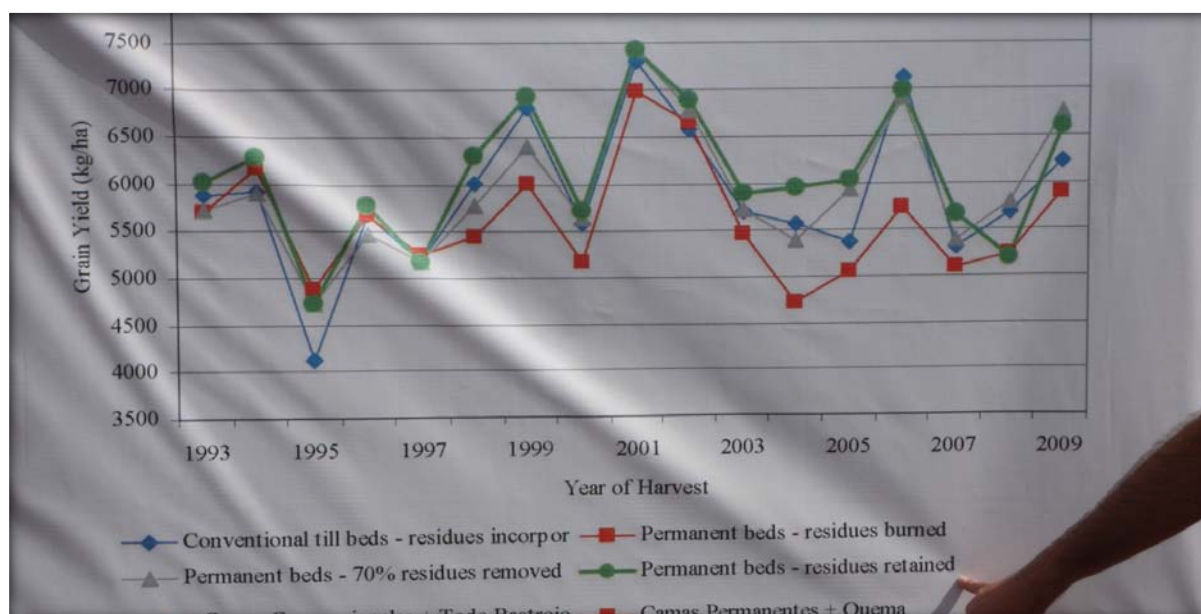


Figure 2. Comparison of different farming system with residue retained or not. (Govaerts 2010)



Summary of Soil Characteristics

In essence, farming systems that do not use tillage, maintain biodiversity and soil cover have a large impact. The soil physically will be changed by;

1. Lowering or even stopping erosion.
2. Increase total soil in 'A' horizon i.e. making new soil.
3. Increasing water infiltration.
4. Increased soil moisture holding capacity.
5. Improved aggregate strength.
6. Improved structure.
7. Improved temperature buffering.

The soil will also have more suitable and beneficial chemical properties with an increase in;

1. Organic matter and therefore organic carbon.
2. Nitrogen in all forms.
3. Phosphorous.
4. Potassium.
5. Calcium and Magnesium.
6. pH.
7. Aluminium saturation.
8. CEC (Cation Exchange Capacity).

And the soil biology will be a lot richer and more diverse with an increase in;

1. Earthworms.
2. Arthropods.
3. Fungal feeding Nematodes and Protozoa.
4. Fungi.
5. Mycorrhiza.
6. Cellulose degradation.
7. Microbial Biomass

Why disc machines?

There are a few reasons as to why farmers are opting to use disc seeders and most of these relate to the retention of the entire residue and this has been discussed in previous chapters.

Other reason for using the disc machines include;

- Seed and fertilizer placement.
- Increase timeliness of sowing.
- Fuel consumption is reduced.

Seed and Fertiliser Placement.

A benefit of disc machines over the tyned openers is that they have a very consistent seed placement characteristic with discs tending to have exacting depth gauge wheels. When these depth wheels are on the sides of the discs, they don't allow them to dig any deeper and maintain an even depth of seeding for each of the individual disc assemblies independent of each other. Furthermore, in the disc seeders which have no chamfer on the discs for the angle of attack, the whole assembly does not throw soil over into the next furrow like most tyned and some single disc assemblies.

Most assemblies have a parallelogram which keeps the disc in contact with the soil at most times. A walking beam does an even better job as it maintains consistent down pressure over all of the assemblies components. When a seed singulation unit is added, like a vacuum planter, the depth of seeding and the distribution along the row is very accurate.

Increase timeliness of sowing.

To get the best result from tyned machines, the working speed in most cases is around 8 km/hr. Disc seeders are able to get very good results at speeds of up to 15 km/hr. This can dramatically increase the area that can be seeded per day. This gets the crop into the ground at the optimum seeding dates which add to increased grain yield at the end of the season. In studies for timeliness of sowing in the Mid North High Rainfall Zone trials, in 19 of the last 20 years those wheat crops sown on or before May 10th yielded on average 0.5 – 0.75 t/ha more than those sown later in the month and further into June. A negative of this practice could be that farmers get their crop in too close together and have a weather event such a frost or a very hot day with excessive wind can devastate all of a particular crop that was sown very quickly, rather than spacing them out. According to Mick Faulkner, “The other 19 years more than make up for it.” (Faulkner, 2010)

Fuel consumption is reduced.

By using disc seeders in the Zero-till system fuel usage is dramatically reduced. A study by Sorrenson showed a decrease in fuel consumption of 66% compared with conventional tillage and the seeding operation and a 15% reduction when compared to the use of knife points and No-Till. (Christini Pieri, 2002)

Problems / Limitations with Current Disc Machines

A number of the current disc machines that are available on the market, have different problems in that they have:

1. Trouble coping with our high clay content soils, particularly when wet.
2. Too much soil disturbance.
3. High maintenance and servicing.
4. Not enough down pressure to engage properly.
5. Unable to cut residue and cause hair-pinning.

High Clay Content Soils.

According to J. Desbiolles, 73% of farmers who participated in a survey stated that had problems with sticky soils where they have had clogged seed boot outlets, soil accumulation around the moving parts of the disc e.g. depth gauge &/or press wheels, overloading of scrapers and high drag forces causing stalling of the disc rotation. These can then result in irregular and poor seed placement, furrow bulldozing and delays in the seeding program. In most cases these same farmers have learnt to wait an extra day to start sowing again. They quickly catch up with the hectares that can be sown in a day with increased sowing speed afforded by disc seeders. (Mike Ashworth, 2010)



Photo 5 – Trial Site at Riverton Showing Problems with Sticky Clay Soils and Not Cutting

Too Much Soil Disturbance

A few of the machines that have come on the market have had a problem of maintenance issues. Of particular concern are the number of bearings that not only need regular greasing (on some assemblies they have 5 greasing point for 5 bearings multiplied by number of rows eg. $40 \times 5 = 200$), but also require changing on a regular interval. One farmer at Alma in SA used to spend two hours a day servicing and replacing bearings. This machine did not last very long on the property.

Some current machines can create too much disturbance, but this can be helpful to those who want to incorporate some herbicides at seeding (IBS). This is a trade off with burying some of the residue and some weed seeds at the same time. The other problem is that when soil is cultivated respiration and oxidisation occurs and lot of valuable plant nutrients are burnt off and therefore not be available later when the plant needs them as discussed earlier.

Down Pressure to Engage Properly

Another problem has occurred when farmers were switching over Zero-till from Conventional-Tillage, and when after the years of heavy cultivation and traffic the soils are extremely hard and the disc machines do not have enough weight or down pressure. On the other side of the coin some farmers have found problems when changing from No-Till utilizing knife points, to Zero-till with discs as the soil was too soft and there was not enough resistance to help cut the residue and had hair pinning. Mixing of the straw and soil/mud also created a lot of build up that the scrapers could not handle. According to Dwayne Beck, single disc machines have the most problems with hair pinning as they do not have any scissor action to cut through the stubble which the double discs do, particularly the offset models.

Ideal Disc Machine

According to Erbach the requirements for machine performance criteria are;

1. The need for a device to effectively cut residue.
2. Uniform penetration of the soil.
3. Sufficient tilling in the seed zone to obtain good soil-to-seed contact.
4. Uniform seeding depth.
5. Adequate covering of the seed.
6. Proper soil firming over the seed.
7. The capacity to follow land contours.

To fill these criteria I have a basic set of requirements that the seeder should have;

1. A double offset disc of two differing sizes.
2. Have a small seed firmer wheel. (Not a press wheel)
3. The depth wheel/gauge needs to be independent of any furrow closer i.e. put on front discs.
4. The depth wheel needs to hold the soil in place as the blade pulls from the soil.
5. Furrow closer e.g. Star or cast wheel.

In addition to this, Dwayne Beck has given some comments regarding the assembly attachment style:

1. The JD and similar machines have radial attachments, which mean the angle of attack is correct for only one spot in its travel.
2. The parallel (or parallelogram) linkage has the proper angle of attack as long as the frame of the implement is parallel to the soil surface (very level fields).
3. The walking beam attachment has the proper angle of attack at almost all times.

Innovations in Disc Machines

1. *Walking Beams*

The benefit of this method of attaching the assembly as shown in the picture allows the discs and closing mechanism to be truly ground following. The double disc assembly is connected to the walking beam and the beam then attaches to the main frame. In the model from Avec, all of the down pressure came from an air over hydraulic system for dampening and keeping each unit independent.



Photo 6 – Walking Beam Design on Avec Seeder

Pulling depth control wheel rather than pushing. With a large number double disc units, the depth control wheels are connected at the rear behind the discs. This system creates a pushing motion and a separating force pulling the depth control wheels away from the discs. Trends in the new designs incorporate a forward fixing point. The force generated by pulling rather than pushing the depth control wheels keeps them tight against the disc which reduces strain and fatigue on the steel. It can also help with cutting action applied to the residue.



Photo 7 – Pulling Spoke Depth Wheels with Seed Firming Wheel

2. Spoke design for depth wheels

Current designs of the depth control wheels are solid externally with a cavity in behind and this can fill with soil, mud and also residue. The preferable option now is to have spoke design which allows for this residue to escape and not build up.

3. Opening radial arm for depth wheel

The unit which pulls the depth wheels also can be fitted with pivot points that allows for them to pivot out of the way making it easier to change bearings or even the discs.

4. Seed firming wheels

They follow in behind the discs, running along the bottom of the furrow. These innovations along with the soil closure wheels, have taken the place of press wheels. The firming wheels are different, as they only act by pushing the seed into the soil at the bottom of the slot, not by compacted the soil around the seed and the above soil like press wheel. The germination percentage is lot better as the plant shoot does not have to emerge through hard and compacted soil.



Photo 8– Seed Firming Wheel in Centre

5. Soil closure wheels

These are made in a variety of design, but all have similar job to do. They work with the seed firming wheels to create an ideal germination and growth environment. They back fill the slot created by the discs, but not with a lot of pressure. This helps in the fact that once the seed germinates it has only soft friable soil and light residue to push through. The soil does not cap over like some traditional press wheels.

New Crops

Low soil temperature maize

Maize would be an ideal crop to grow in the Southern HRZ as it is a warm season grass that produces a large amount of biomass and would give us a very good opportunity to control current weeds and pests of the cool season crops, but the current varieties of maize / corn in Australia have a temperature requirement at planting to enable germination. The soil temperature needs to be 15⁰C and rising. For the bulk of the HRZ area with a Mediterranean climate this does not occur until mid October and by this time the soil profile is drying out and little follow up rain.

There are now some varieties in South America that have been bred and selected to be able to be sown when the soil temperature is only 10⁰C. This occurs in the Lower North of South Australia in early August. This opportunity will not give the farmers a double crop for the year, but they will be able to plant it as the crop for that year. The maize will be planted on a full profile of water and rain for another two months. Farmers can cut this for hay / silage or let it go through to maturity and reap the grain.

Sulla – Hedysarum coronarium

Sulla is an exciting new biennial forage legume suited to neutral – alkaline soils ideal for short pasture rotations in both mixed farming and livestock production systems. Sulla has a high yield potential and is highly palatable with excellent forage and fodder quality and outstanding animal performance. It can grow to almost 200cm. It also has the added advantage of potentially fixing high levels of nitrogen. Unlike lucerne, Sulla is non-bloating and has reputed anthelmintic qualities which may reduce worm burdens. (Woollard, 2010)



Photo 9 – Sulla Cut for Hay / Silage

Recommendations

There are a number of recommendations but the most important one is to;

- Adopt the Zero-till system
- Obtain a quality double disc machine that has;
 - a. No soil disturbance when in use.
 - b. Seed firming mechanism, either a wheel or Keeton finger
 - c. Closer unit that fills the trench with soft soil and some residue
 - d. Realistic price so smaller farmers can access the technology to move to ZT.
- Small / Medium size farmers can look towards South America to find suitably priced machines. They are slowly being imported into Australia.
- Look upon all residue as precious and must be retained to form a permanent cover on the soil and as feed source for the biota.
- Use as diverse a rotation as possible. Try to utilise cool and warm season crops.
- Use organic manures to increase SOM and as a very good source of both Nitrogen, Phosphorous and to a lesser degree Potassium.
- Re-inoculate soils with worm species particularly the Anecic type as this will help with soil ameliorants being moved through the profile and their burrows allow for increased water infiltration. Also the Endogeic type that actually eat soil and move nutrients through the profile. This is of particular importance for phosphorous which is relatively immobile in the soil.
- Make use of our own waste or other peoples waste, such as animal manures.

Appendices

Whilst on the Global Focus Program, Contemporary Scholars Conference and the Study Trip, a number of very interesting topics were discussed or seen. Following is some of those.

Vertical or Circular Integration

- The most successful businesses visited were those that made use of all their products and by products. The Alvis Bros Company for example ran three dairies, one of which is organic. All the milk is used in the cheese factory and then sold through a number of supermarket chains and their farm shop. The whey is utilised in a company piggery. The animal waste from both the piggery and dairies is spread on the land. The Alvis Bros also has a half share in a contracting business which does their entire paddock work and also contracts out to other farms as well.
- Fazenda Frankanna is a business in Brazil run by Richard Dijkstra. It is another which makes very good use of its waste products. They have a 400 sow piggery and 400 cow dairy. All of the effluent is screened and the solid's are removed and composted then spread over the paddocks. The liquid then goes through two methane digesters which then powers the dairy and piggeries heating needs. Once the water leaves the digesters, it is 99.5% pure. All of the water is used to irrigate a fair proportion of the farm. This farm land was worth between \$12,500 to \$15,000 per hectare, which is very similar to land in the Gilbert Valley around Riverton. Wattle Vale Farm produces one crop per year whereas Fazenda produces five different crops in two years, such a hay, grain and cover crops.
- Bart Ruth in Nebraska is another successful farmer who utilises other farmers waste. He farms next to a 5000 cow dairy. The dairy is only interested in the cows and milking. They don't want to do anything outside of those two operations. Bart gets all of their solid waste and liquid. Each year he gets enough water to irrigate 300 hectares which equates to an addition 250mm of precipitation. He also gets slurry to inject into 70 hectares. He had to buy the centre pivots, but pays none of the pumping costs.

Rural Message to Urban Dwellers

- Whilst touring through the USA and Canada, we saw a great number of signs promoting agriculture, whether it was a sign to say "Everyday a Kansas farmer feeds

250 people” or a billboard showing family line up on the lounge watching television. Above them the slogan said “A typical hog raising family”.

- Alvis Bros regularly catered for school groups of children who visited their farms. They also had teaching materials for the teacher and schools to utilise and were instrumental in developing and promoting this in schools.
- The Datterra Coffee Company in Brazil again had school groups through but also included a camp for the students from schools and universities to study flora and fauna on their farms. 20% of their farm was dedicated to natural and regenerated Cerrado (Open Savannah and Closed Woodland)
- A speaker at the No-Till on the Plains Farmer Group had a “lumberjack” forest farmer as a guest speaker. He spoke passionately about the need for farms of all types and need to promote agriculture to the next generation who will be getting a slightly stilted view from environmentalist groups etc. He set up “Adopt a Farmer” firstly in Washington State, then right across the country.

Commonality of Terms

- Around the world there are a large number of farmers, researchers and scientists involved in farming or farming systems work. In each country or state / province different terms are used to signify the same farming system. For example in Australia, no-till describes the use of tined implements with knife points and press wheels. Where as in Brazil and Argentina the term no-till means using only disc seeders with no disturbance. In Australia we call this zero-till.

Extra Recommendations

- Find ways to utilise waste products of our own or other farmers such as piggeries and poultry facilities
- Work with media. To give the different networks footage of modern farming practices such as zero-till to use as file footage. This would replace those old videos of farmers cultivating their land in a dusty paddock
- Work with key farmer groups and others around the world to get some uniformity of farming system terminology eg for Minimum Tillage, No Tillage and Zero Tillage.
- Look for integration opportunities within the farming business to move from commodity to edible product.
- Look to lease / buy land with high rainfall (700mm+) or irrigation.

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Plain English Compendium Summary

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Objectives	To investigate Zero-Till Farming Systems (ZT) in high rainfall cropping zones (HRZ), and its impact on soil biology and nutrient cycling.”
Background	Farmers are looking at different technologies, management practices and new crops to enable them to keep ahead of negative terms of trade and find the next “big thing” has enhances productivity and increases their efficiencies to improve profitability.
Research	The research took place over a period of six months during the first half of 2010. The countries visited were England, Wales, Canada, USA, Mexico, Brazil, Argentina, Uruguay, Chile and Australia. Throughout these countries, information was sought from farmers, scientists and researchers into Zero-till. Producer groups such AAPRESID and No-Till on the Plains were also contacted. A lot of machinery manufacturers were interviewed and their machines inspected in the factory, sales yards and working in the paddocks
Outcomes	Farmers in countries around the world are employing the techniques of ZT and using disc seeders and full residue retention. The benefits they are getting are huge. Australian farmers need to embrace ZT. Currently in Australia there are a few disc machines being manufactured but they come with a high price tag. There are a lot of machines available overseas that are a lot cheaper in comparison, and these would allow small to medium sized farmers to access this technology.
Implications	It is clear that ZT should be implemented across the HRZ cropping areas, where farmers have the ability to produce large amounts of biomass each year. This should be all retained to feed the soil biota. This practice will enable them to get better efficiencies from fertilizer and water. Where practical the substitution of inorganic with organic fertilizers such as compost and manures will help speed up the process to get a healthy fully functioning soil that requires less man made nutrients to achieve better yields