A Nuffield Farming Scholarships Trust Report

Award sponsored by

AHDB

Success with No-till - under any conditions

Russell B McKenzie

July 2015

NUFFIELD UK

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

TRAVEL AWARDS

"Nuffield" travel awards give a unique opportunity to stand back from your day to day occupation and to study a subject of interest to you. Academic qualifications are not essential but you will need to persuade the Selection Committee that you have the qualities to make the best use of an opportunity that is given to only a few – approximately 20 each year.

Awards are open to those who work in farming, growing, forestry, or otherwise in the countryside, and sometimes to those working in ancillary industries, or are in a position to influence those who do. You must be resident in the UK. The normal age range is 25 to 45 but at least one younger candidate each year will receive an Award. You must have spent at least 2 years working in a relevant industry in the UK. Pre- and post-graduate students are not eligible for an Award to support their studies.

The Nuffield Arden Award is unique in that there is no age restriction and the subject is set by the Selection Committee. An Arden Award is offered every 2 years.

Full details of all Awards can be seen on the Trust's website: www.nuffieldscholar.org. Application forms can be downloaded and only online submission is accepted.

Closing date for completed applications is the 31st July each year.

A Nuffield (UK) Farming Scholarships Trust Report

Date of report: July/2015

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Success with No-till under any conditions
Scholar	Russell B McKenzie
Sponsor	Agriculture and Horticulture Development Board
Objectives of Study Tour	To understand the parameters to succeed with No-tillage and how the best No-till farmers benefit from the system in both the driest and wettest of climates.
Countries Visited	Australia, New Zealand, USA, Brazil, Argentina, Czech Republic, UK
Messages	Greater stability in long term crop performance is obtained through successful adoption of No-tillage in varying climates No-till confers ability to traffic and absorb water better in wet periods, balanced with improved retention in drier times. Compaction should not be ignored, but dealt with in a variety of methods. Organic matter is the central cog for a living, working soil in a balanced rotation. No-tillage must be thought of as a system, not just a machine. Patience!

CONTENTS

DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor AHDB, or of any other sponsoring body. The views and content of my report –written as a farmer - are from a practical perspective based upon my travels across the world and a selection of the most inspiring people I have met.

CONTACT DETAILS

Russell McKenzie

Howson's Lodge
Old Weston
Huntingdon
Cambs PE28 5LS

07768 904989

russ@tebbits.co.uk

Nuffield Farming Scholars are available to speak to NFU Branches, Agricultural Discussion Groups and similar organisations

Published by The Nuffield Farming Scholarships Trust
Southill Farmhouse, Staple Fitzpaine, Taunton TA3 5SH
Tel : 01460 234012
email : director@nuffieldscholar.org
www.nuffieldscholar.org

1.0. Introduction

I have to thank my late father for priming my interest in agriculture from a very young age. Although not from a farming background he would always take me to see tractors and combines working and I guess my interest was ignited from the tender age of 4 and now, at 41, that passion and the desire is still burning. The only regret I have is he never had the opportunity to see me graduate or follow my dreams of pursuing a career in farm management and that has driven me on to be the best I can be. I have always been determined that farming was going to be my chosen career and progressed through Writtle College, gaining a BSc in Agriculture. I was fortunate to get a trainee Manager position with Albanwise, farming in Norfolk where Brian Reynolds became my early mentor and is still an inspiration to me to this day.

Figure 1. Me, Russell McKenzie on my travels in the Mato Grosso-Brazil.

I live in Cambridgeshire in the village of Old Weston where I am responsible for the management of 750 hectares of arable land for the family farm of D J Tebbit and John Sheard Farms. Logistics can sometimes be a bit of an issue as we are spread out over 17 miles and have 4 separate units! Our cropping is dominated by wheat, oil seed rape and spring beans, but latterly it has become interspersed with winter and spring barley as we look to lengthen our rotation to combat the growing threat of blackgrass.

I am happily married with 2 wonderful children and outside of work when I am not analysing trials data I am a keen sports fan and have spent a lifetime of suffering following the England cricket team, albeit with a few highlights along the way!

Having spent several years thinking about undertaking a Nuffield Farming Scholarship I am indebted to my wife, Ellie, for encouraging me to go for it. It has been the most incredibly rewarding experience to explore the world and learn from the best farmers in different countries. There is an expression “don’t believe the hype” but, in the context of a Nuffield Farming Scholarship, **do** believe it, as the experience is everything it promises to be and has certainly exceeded my expectations!

2.0. Background to my study topic

My first experiences of direct drilling were with a John Deere drill back in the late 1990s where it was used primarily for planting wheat after break crops across the three farms for the company I worked for in Norfolk at the time. It was clear back then there was huge potential for direct drilling to deliver excellent seed placement and better establishment in some of the very difficult clay pits we had within some fields, and at a fraction of the cost of our other methods.

Back in those early days of my career I could see the potential for No-tillage, but purely as an opportunity to make cost savings as part of a large enterprise; but one of the things I have learnt is that cost saving is a bi-product, an added bonus if you like, as there are so many more benefits to true No-tillage.

We have used a tine-based direct drill on the home block with considerable success and that started me thinking: can less really mean more? Is it really possible to step off the cultivations conveyor belt and let your soil do the work for you? In the dry autumn of 2011 I could see we were able to get crops established far better with direct drilling than where we had cultivated. The old school mantra of "you need to get air in the soil" doesn't make sense to me if preserving moisture is important. In 2011, although there was some moisture in the soil, it quickly evaporated in anything cultivated to depth from the middle of August onwards, but the surface tilth was generally in excellent condition and I took the opportunity to experiment!

… cost saving is a bi-product, an added bonus if you like, as there are so many more benefits to true No-tillage.

One of the more variable and difficult fields on the farm presented us with the chance to do a split field trial for a second wheat crop. Half was ploughed and the other direct drilled. Although the field ploughed and worked down well, moisture was lost fairly quickly. When it came to drilling some weeks later and with little rain since, the wheat in the direct drilled half established well due to improved moisture retention. The other half was patchy and required significant rainfall (some 3 weeks later) to complete establishment.

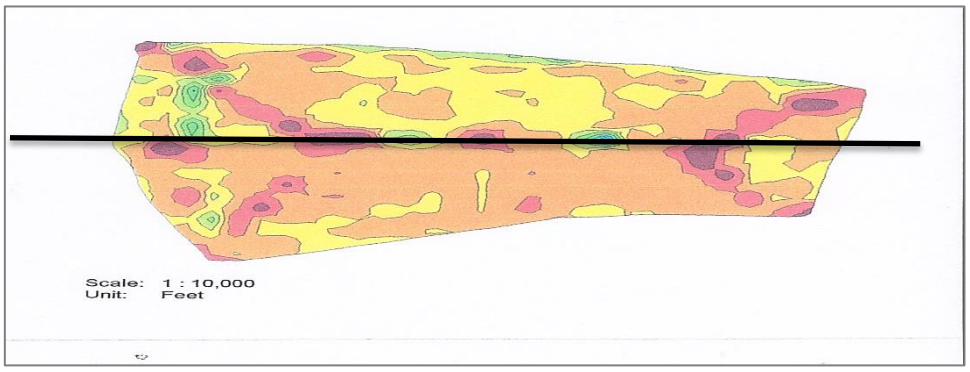


Figure 2. Yield map of the field, direct drilled area above the black line, ploughed below (Red-orange=worst performing areas, Yellow-green=best performing areas)

My observation of better establishment in the direct drilled area was validated when the yield map was returned and we saw a 0.75 tonnes per hectare yield increase over the ploughed area.

Better establishment, better yields and reduced time and cost were some of the many plusses we experienced up to 2011. Then the autumn of 2012 struck!!

We experienced a wet spring that year and the ground conditions in the autumn were equally as difficult. Cultivating wet soils was tricky but, once again, by the following harvest direct drilling came out on a par with anything that had been cultivated, and sometimes better.

It was after harvest 2013 that the inspiration came for what I wanted to research during a Nuffield Farming Scholarship study tour. It was obvious that on our heavy clay soils, with the right attention to detail, direct drilling could be suitable and help maintain crop performance. But not just this: it was the fact that it could be successful in achieving crop establishment - both when moisture was limited or when it was very wet. I realised I wanted to find out more and learn from the best who had been using No-tillage long term and I wanted answers about how do the best succeed in the driest regions, and equally, make it work when one has large amounts of rainfall.

It was obvious that on our heavy clay soils, with the right attention to detail, direct drilling could be suitable and help maintain crop performance. But not just this: it was the fact that it could be successful in achieving crop establishment - both when moisture was limited or when it was very wet.

At the same time I tried to maintain a degree of rationality about my research, especially in terms of wet conditions, on the basis that there aren't many systems that work well in torrential rain! But I've maintained an underlying belief that a system that could help mitigate or reduce the reliance upon the weather for establishing crops was surely the way forward.

I have certainly experienced a growing concern over recent years that our seasons are getting more unpredictable. Couple this with appropriate soil management and it felt clear to me that reducing cultivations was the only realistic way we were going to be able to achieve that goal. I hoped my Nuffield Farming research would provide me with the answers.

3.0. My study tour: which countries and why?

To really understand what makes No-tillage successful in both dry and wet conditions I felt it was crucial to explore the issues from all angles, which meant looking at very low rainfall and high rainfall areas and how they coped. I really wanted to understand not only how different growers combatted the fluctuations in weather, but what benefits they achieved through No-tillage.

Australia: March 2014. I travelled up through the Victoria region and into the Clare Valley where I met a host of different farmers who have no choice but to make No-tillage successful to preserve their future - due to complications with erosion and moisture retention. I came back, adamant that I was never going to complain about moisture ever again as some of the people I met were so grateful for every drop they received. I was very lucky to meet a brilliant researcher at the University of South Australia, whose research on every conceivable No-tillage tool was so beneficial to my studies.

UK and Europe: April 2014. I also completed some visits to the Czech Republic and visited some UK farmers to gain a wider perspective on how farms in the UK view No-tillage and specifically what is realistic in terms of cropping and limitations to the system.

USA: June 2014. I ventured to the United States where I covered a variety of different conditions from North Carolina through to the baking summers in Kansas and Texas, circling round to North and South Dakota and finishing off in Philadelphia. I met a number of growers in each region and also encountered some excellent research facilities that were utilising cover crops under testing conditions.

Australia: November 2014. There were areas I still considered I needed to cover, so on my return to Western Australia, I met a number of growers who enjoyed varying degrees of rainfall. To better understand the principles of managing weed resistance in No-tillage I visited AHRI at the University of WA. I then travelled to Tasmania to get a better appreciation of how they cope with significantly more rainfall.

New Zealand: November 2014. Having heard and seen so much about the Cross Slot drill system, and coupled with New Zealand's climate being so similar to the UK's, it was the nearest comparable country I could find where No-tillage was being practised successfully. An extended tour of the South Island and parts of the North Island helped me understand more about how and why No-tillage can work in near-maritime climates.

Brazil: January/February 2015. Brazil was a country that I had on my radar to study how early adoption of No-tillage had developed. I travelled though the Mato Grosso, Minais Gerais and Goias States meeting some brilliantly attentive growers who embraced the system early on and impressed me with their striking attention to detail in making the system work. Brazil is so vast and 3 weeks almost didn't do it justice, but the trip was rounded off brilliantly when, in Tapejara in the deep southern state of the Rio Grande do Sul, I visited probably the best No-tillage farmer I had met anywhere on my travels. The farms were a fraction of the size of those in the Matto Grosso, but this

grower and his wonderful crops were a shining example of excellence, knowledge and understanding, illustrating that size isn't everything.

Argentina: February 2015. South American countries are so big, that long hours of travelling is the end result of trying to see them. Even though I travelled through the Buenos Aires, Entre Rios and Santa Fe provinces, I only scratched the surface! I was able to meet and have some great discussions with farmers on some very difficult soils, where No-tillage allows them to optimise crop production. This rounded off my travels perfectly with some terrific farm visits to well established, committed No-tillage practitioners.

I have been so fortunate to meet some truly outstanding and inspirational people in different parts of the world and consequently found that the margins between the good and the very best are so fine, but so pivotal. It is almost impossible to visit everywhere in what afterwards seems very little time and there is always that person you discover you should have met after you have left a country!

.. the margins between the good and the very best are so fine, but so pivotal.

But certainly what I have discovered and learnt over my 12 weeks of travel has helped reinforce and redefine the shape of the way we should be farming at home and in the future.

4.0. Why consider adopting No-tillage?

The momentum in UK agriculture to understand and adopt No-tillage methods has gathered pace at a staggering rate, with a desire to change and improve on farm practices that I have not seen since the introduction of strobilurin fungicides in the mid 1990s (before there was widespread resistance) changed the face of wheat disease control overnight

When I was in North Dakota, the inspirational Jay Fuhrer of NRCS (National Resource Conservation Service) put everything into the perfect context for me when discussing cultivations and relating it to the dust bowl era, which had severe effects upon the loss of topsoil. Jay considered that many farms were, at best, maintaining their soils, and were certainly not improving them by cultivations and, in the worst case scenarios, they were degrading them without actually realising it was happening. This prompted a comprehensive change amongst farmers in North Dakota to focus on the health of their soil and move into less invasive crop establishment techniques.

Figure 2. A reminder from Jay Fuhrer's father of the effects of the dust bowl in 1935

There is a natural inbuilt fear that breaking from traditional practice can expose a business to greater risk and although there may be a desire to understand and preserve our soils better this is tempered by a huge resistance to change. It is the brave early adopters unafraid of change who have benefited most from their forward vision in respect of No-tillage. Luis Sabbatini, who I met in Argentina, had neighbours who laughed at his "craziness" when he started with No-tillage, but within 3 years they were all following suit as the benefits and crop performance he was achieving became apparent.

So why has it not happened on such a large scale in the UK?

Figure 3. Meeting Argentinian No-till pioneer Luis Sabbatini

4.1. Blighted by history - and a vision for the future

When I embarked on my study on how we can successfully utilise No-till in our variable climate I was immediately drawn to thinking: why did the curve not progress from when it was first introduced in the 1970s?

Back then (when I would still have been in nappies) the system functioned upon the wide use of Paraquat coupled with stubble burning and certainly less residue than we have now. Although initially things worked very well, grass weeds became a massive issue and this, coupled with poorly established crops and water logged fields in places, unfairly earned direct drilling a bad name and few ventured towards it again.

But at least in part, the fundamental issue that contributed to its downfall back in that era, was the effective dependence upon chemicals and stubble burning to alleviate weed problems, alongside production driven imbalances in rotations and a heavy reliance upon autumn cropping. The primary focus then was on cost reduction, something I consider to be an added bonus amongst all the other benefits that come with direct drilling.

But even back in this era, there were echoes of why the cultivations conveyor belt can be so difficult to get off. To quote Harry Allen (1981):

> *"The ideal soil condition for direct drilling is a firm, level surface with continuous cracking to depth. Deep cultivation is not the answer; it will loosen the soil excessively and allow it to compact again very easily."*

This quote demonstrates that the principles behind direct drilling have been understood for some time, but only now are we starting to unlock its true potential as we enter a new era of understanding.

There are now new imperatives. Experts from the University of Sheffield are warning of potentially only 100 harvests left in our soils if we continue with our current intensive cultivations, so how we manage our soils has never been under so much scrutiny. If we really are entering a period of change, then the answers are there from some of the best practitioners across the globe whom I have been fortunate to meet. We must manage our soil practices better and keep up with the pace of food production that is required to feed a growing global population.

Experts from the University of Sheffield are warning of potentially only 100 harvests left in our soils if we continue with our current intensive cultivations.

Relating this anecdote back to Jay Fuhrer's observations in regard to the lack of improvement in soils, then we are potentially at a crossroads in learning how to farm better and smarter with our prime asset, the soil. One thing is certain, they aren't making any more of it, so we need to look after what we've got, and when it comes to crop establishment, perhaps less really can mean more.

4.2. 2015: International Year of Soils

What could be more appropriate for my chosen subject than this being the year of the soils, with worldwide reiteration that we are fortunate to have this incredible asset, that can't preserve itself and needs a helping hand?

I was staggered in Australia to come across improvements from direct seeding in what appeared to be easy working soils and this illustrated how detrimental intensive cultivation can be, regardless of soil type. I visited Australian Scholar Bob Nixon who is based in Kalannie, north east of Perth, who has been using No-tillage for a number of years. We were able to compare a No-tilled field to a neighbour's that had been under regular annual cultivation.

This demonstrated the value of long term No-tillage and how even on these marginal soil types, it was blatantly obvious when you compared the wheat crops in the two fields that Bob's was far more even and looked like it had better potential to produce more yield.

But to be able to look after our soils better we have to be better at managing our soil carbon, which with straw removal, even in low yielding wheat zones in Australia can be like waving goodbye to two tonnes per hectare of organic carbon over a four year period, which is difficult to replace. But one element that influences decisions here is our wonderful weather in the UK!

4.3. What has been happening with our weather in the UK?

In seasons that appear to becoming increasingly variable, direct drilling could feature on farm to help mitigate against the swing in weather conditions. I have noticed over recent seasons that our

early spring period in March appears to be getting drier and, in the autumn, September appears to be moving towards being a month with little rain until October - when the tap gets turned on. Having faced a very wet October in 2000 and again in 2012 it is easy to focus on those wet seasons as being the benchmark for what we should plan for, but I am equally concerned about the drier periods which seem to be longer than they used to be. This is where No-tillage must be a better option to buffer against swings in weather from wet to dry and vice versa.

Figure 4. Better aggregation by No-tillage (left) vs. cultivated soil (right)

Below is a summary of the weather data from the Cambridge meteorological station, focussing on the key periods for crop establishment in February-May and September-November over the past three and a half decades. I have included 1974 as a reference point as it was the year in which I was born!

Period	Annual Average Rainfall	Feb-March Average	Sep-Nov Average	Most frequent Wet/dry Feb-March	Most frequent Wet/dry Sep-Nov
1974	628 mms	96.5 mms	285 mms		
1980-1989	571 mms	167 mms	167 mms	May/Feb	Oct/Sep
1990-1999	530 mms	140 mms	142 mms	Apr/Feb	Oct/Oct
2000-2009	558 mms	161 mms	161 mms	May/Mar	Nov/Sep
2010-2014	514 mms	135 mms	135 mms	Feb/Apr	Oct/Sept
Average	543 mms	151 mms	155 mms		

Source: Meteorological station, Cambridge

What the above table doesn't illustrate is the point of distribution for rainfall events. I have observed prolonged periods of dry followed by a very heavy rainfall event when soils appear to get drier and, initially, the capacity to absorb water is reduced. This isn't a problem unique to our country and it was something I also discovered in Brazil, where although they receive huge volumes

of rain - 1400-1600 mms annually - several growers I met found their total levels were reducing by at least 200 mms annually and that the drier periods were getting longer and hotter. Sometimes the rainfall events I witnessed in Brazil and America after prolonged periods of drought were extreme; for example a hailstorm that had shredded corn crops. The ability of the soil to retain moisture, even in what would appear to be a very moisture-rich, but aggressive climate like Brazil's is still a key factor, not only in crop establishment, but also for the ability of the crop to have sufficient moisture for growth during drier periods.

The data in the table above shows that consistently over the past 2-3 years it has been noticeable how dry September has become, coupled with a very wet October, and this has certainly been the case for the past 3 autumns, backed up by the rainfall figures for these months. Also, when in conjunction with the key spring establishment period of March, which for 2 seasons running has also been very dry, sometimes extending into April, this gives further credence as to why direct drilling, with the ability to successfully establish crops without drying seedbeds through exposure to air by cultivations in the spring and the autumn, is a more astute choice of operation.

4.4. Is the future of crop establishment already here?

In the quest to find the right answers to my questions with regard to how to make No-tillage successful on difficult soil types and in testing conditions, I have been left in little doubt that it is the future for crop farming. But not the immediate future: some of the people I have been fortunate to meet have met their challenges head on, adapted their techniques, have been blessed with patience, and felt safe in the knowledge that the system would work but that it isn't an overnight instant fix. Impatience and expecting instant rewards are among the biggest handicaps when adopting No-till.

The template below illustrates the process of progress when transitioning to a No-tillage system

	Initial Phase	Transition Phase	Consolidation Phase	Maintenance Phase
Time (years)	1-5	5-10	10-20	20+
Point A	Rebuild Aggregates	Increase in Organic Matter	High Organic Matter	Continuous Nitrogen & Carbon Flux
Point B	Low Organic Matter	Increase in Crop residues	High Crop residues	High Nutrient cycling
Point C	Low Crop Residues	Increase in Carbon & Phosphorus	Greater Cation-exchange capacity	Less Nitrogen & Phosphorus usage
Point D	Additional Nitrogen required	Immobilization of Nitrogen	Nutrient Cycling	Better water retention

Source: Ashworth, Desbiolles and Tola (2010)

There is no situation where instant changes can reap rapid results, but a good starting point is seeing how some of the seasoned No-tillers manage their varying conditions, and appreciating what it was they learnt that has improved their ability to farm in difficult climates.

5.0. The quest for inspiration

5.1. Succeeding with No-till in the dry

I am firmly of the belief that No-tillage's potential to produce a higher establishment percentage in the most marginal conditions is a major factor in preferring the system over traditional cultivations.

Australia was one of my first choices for getting to understand how farmers succeed with No-tillage in one of the driest and hottest climates. I met Chris Drum, who farms at Rupannyup in the Wimmera region.

Figure 5. Chris Drum, a truly inspirational farmer and mentor for younger members of Vic No-till

Amongst many of the things I discussed with Chris, one of my initial questions was about when he started No-tillage and the reasons behind why the decision was taken. One of his answers was: the Melbourne dust storm in 1982 which saw over 1mm of top soil lost to wind erosion, which equated

to around 15 tonnes per hectare. There was a recurring joke amongst some of the farms with regard to replacing the fence lines round the field boundaries as the wind erosion would be so severe that the soil blown from the field would collect at the end of the field and cover what was the original barbed wire fence. It was so deep, that instead of digging the fence out, they would just place another one on top of where the soil had landed. The power of the wind on these exposed plains could be so severe that after a severe drought in 2005 Chris and several other farmers I had met knew things had to change and No-tillage became widely adopted.

Chris was deeply passionate about how he farmed his land and his concern over the forces of nature, with its strong winds, prompted his move to No-tillage. He was also fanatical about his stubble height. He wanted to maintain the height at 10-15 cms so it acted like a large form of comb/windbreak to buffer the effects of wind erosion. This was difficult to achieve with crops like chick peas in the rotation as they have to be harvested so close to the ground. But it was a vital component in his efforts to protect against the forces of nature. The lengths to which he would go to preserve stubble height meant that he modified the trailing wheels on his seeder so they did not follow in the same lines as the tractor wheels, resulting in the stubble springing back up rather than being squashed down.

Figure 6. An example of the row spacing illustrating wheat stubble and, in between, the bean stubble from the previous harvest.

I was surprised at the level of uptake for RTK (Real time kinetics) with GPS guidance amongst a lot of the growers I met. This was down to the importance of inter-row planting for a host of different reasons. Initially in relation to what Chris had mentioned, it allowed them to retain their stubble height and to act as the aforementioned wind break, but it also meant they could plant accurately with the 2cm pass-to-pass guidance. Another key feature mentioned by all these growers when drilling conditions were very dry, was to adjust the location of drilling away from directly between the previous crop rows. Sowing closer to the original seed row and more specifically as close to the root ball of the previous crop's stubble as possible could be more optimal due to better moisture retention in the old root zone.

Figure 7. Losing topsoil from wind erosion in cultivated ground in Tasmania

Wet conditions are always a concern but, equally, drying soils can make life increasing difficult as well. A lot of the growers who were using CTF (Controlled Traffic Farming) reported significantly less trafficking (up to 40%) and yield increases of 25-30%.

Residue retention was viewed as a vital component in helping protect the soils in these regions to mitigate the drying impact of the strong sun. Growers like Chris wanted to, in his words, "*Harvest every drop of moisture I can*". The further down the line of No-tillage he progressed the more he saw improved water retention capabilities and less pooling. The common theme amongst all these growers was that they were achieving far more reliable harvest performances due to No-tillage levelling out the dips and hollows, allowing for prolonged moisture availability in the most testing of conditions.

In Brazil and Argentina, although they can receive large amounts of rainfall, the drier periods are just as testing for crop survival. In places like the Mato Grosso where three crops are grown in a calendar year, young crops can be particularly susceptible to moisture stress. A recurring theme with many growers across different countries was the value they place on residue maximisation and retention. Bernardo Romano was a fantastic example; he placed high emphasis on getting as much residue as he could.

His residue levels were quite astonishing. Even though when I visited him, they had experienced a dry period there was still significant moisture left in the soil.

Figure 8. Impressive levels of crop residue retention in Argentina

As a heavy clay land farmer, sometimes it can be difficult to appreciate how to adopt techniques from the other side of the world. This, however, shouldn't be seen as a barrier and I went to visit an excellent No-till farmer in the UK whose "can-do" attitude exemplified why the hurdles to No-tillage aren't as high as some may think.

Simon Cowell farms on some of the most difficult clay soil in Essex you can imagine and, in his own words, spring cropping was virtually impossible. They used to cultivate, beating soils into submission with power harrows, but still did not achieve reliable establishment. The key thing with his current approach is flexibility. Simon does not allow himself to be tied to or dictated by a set pattern. A great example of this was when we were looking at his spring crop establishment. Simon has the choice between disc and tine drills and can utilise whichever one he considers is the most appropriate for the conditions. When using a disc drill on his heavy land in the spring the consequences associated with poor slot closure can be catastrophic. He stressed how vital it was, especially in the spring in drying conditions, to ensure any open slots were covered as drying winds can soon completely dry out the seed zone hampering germination and crop development. But being aware of these pitfalls Simon would run a very light harrow over the surface to bring loose soil back over the open slots and from what he had experienced it made all the difference between success and failure. Flexibility and being prepared to do that little bit extra was a very important factor in his decision making.

Simon would run a very light harrow over the surface to bring loose soil back over the open slots and from what he had experienced it made all the difference between success and failure.

A tine based system used in the wrong conditions can compromise moisture retention and a lot of growers I came across valued the disc based approach to reducing the impact of moisture loss at seeding; none more so than the team at Cross Slot in New Zealand.

I had been following the progress and surge of interest in these drills that was developing in the UK, and wanted to see for myself what the key messages were from the pioneers behind this excellent system. But is it really possible to establish crops in very dry conditions?

Bill Ritchie emphasised the critical value of pore space between soil particles and the influence it can have upon seed germination. Even when soils are close to reaching permanent wilting point, the relative humidity (in unmoved soils) can still be close to 100% although at this point the soil could be considered too dry to sustain seed germination. It is vitally important to comprehend how the importance of organic matter or a mulch on the surface will help to slow down the process of moisture evaporation and, as Baker (2007) commented, the humidity within the mulch layer will be much higher than the atmosphere above it.

Figure 9. With Bill Ritchie (l) and John Baker (r) of Cross Slot New Zealand

It is with this in mind that the differences between undisturbed No-tillage and cultivated soils can be drawn. Cultivated soils have larger pore space and the loss of moisture from the upper zones is far more rapid due to the poorer capillary action of the soil. Unmoved soils in comparison potentially have far better capillary movement to the surface from depth. In drying periods and over time this action becomes far more effective.

Figure 10. An example of the capillary action in a drying soil at the base of a No-till corn crop in Argentina

The significance of this shouldn't be underestimated, according to the farmers I encountered in the Wimmera and Mallee regions and several growers in Argentina. They felt that under No-tillage their crops could withstand drier periods for at least a further 7 days compared to crops in cultivated soils. This could potentially be hugely significant for crops as they approach flowering and grain fill, as well as at establishment.

Key Points:

- Residue retention
- Inter-row or close row planting
- Improved pore space helps with water availability
- Stubble height for wind erosion protection
- Slot closure vital in dry conditions

5.1. Succeeding with No-tillage in high rainfall areas

It is fairly obvious that excessively wet periods prevent most establishment systems from being used and perhaps there are occasions when they shouldn't be.

Simon Cowell has a simple rule of thumb for wet autumn conditions, developed because he has some poorly drained areas within some fields that prove difficult to establish in a wet autumn. They move to a spring crop. It is something that I agree with as my experience is that, for some areas, as the autumn drilling window becomes limited and the likelihood of successful crop establishment decreases, there is invariably a better opportunity to get a spring crop established and amidst a balanced rotation it is a credible option.

One of the recurring themes about water I came across in virtually every country I visited was that water infiltration vastly improved though long term No-tillage. This leaves soils more resilient to surface pooling and facilitates better movement of water through the profile. This was something that was even brought up by farmers in the dry regions. Despite infrequent rainfall, it is vital for them to capture whatever they receive and avoid run off and pooling, something that wasn't achievable if using intensive cultivations.

Although I'd heard this several times, it was proving difficult to see physical evidence of it, unless you happen to be undertaking a visit during a high rainfall event. In South Dakota I met Kent Kinkler who had been No-tilling for a number of years and had seen the benefits on his farm with more reliable crop performance, establishment and water retention. I went to see his planting operation, but was confronted with torrential rain for the duration of the morning. Virtually every field I drove past had some form of pooling with water sitting on the surface, and then I found the field where his planter was. It was at this point that I was convinced that the stories I had heard with regard to better water infiltration were correct. Although the surface may have been sticky, there was no water sitting anywhere on the field. Seeing was certainly believing in this instance.

Figure 11. Improved infiltration after heavy rain in South Dakota

Brazil is a country that has huge amounts of rainfall at times. 150 mms is not uncommon in one hour and bearing in mind the topography in some of the different regions it is easy to understand why they can suffer soil erosion. This is countered with contour banks across the middle of the fields to prevent the loss of topsoil and nutrients from the action of large volumes of water. I also came across this situation in one region in Australia. After a number of years using No-tillage the upper layers of soil had stabilised and the requirement for contour banks was reduced. This type of situation can be related back to various people who had reported better infiltration.

Figure 12. An example of the challenging topography in southern Brazil

Cover crops have a huge part to play in the South American countries. They help to act as a barrier against the soil surface drying, but they also have a massive role to play in helping to prevent slumping during heavy rainfall events. It is important to understand the role that different root systems have in opening up pore space and alleviating compacted layers within the soil. Eddie Nolan, who manages a large estate in Argentina, suggested that not only were cover crops important, but the crop root system itself had a vital role to play.

He suggested that looking more closely at how different crop root systems behaved was as important as a cover crop's role. For example corn and wheat roots have little sideways movement which has a benefit for water infiltration and also assists with the capillary action of the soil for water passage and storage. In order to open up the pore space in the upper soil layers more fibrous rooting crops such as linseed can be beneficial. The important message is that there should be a diverse crop *root* system within the crop rotation itself and this enhances the argument for a balanced rotation rather than a system of monoculture.

The fact that all the people I had met were saying the same thing convinced me that you actually need a good reason to cultivate *anything* when the benefits for mitigating weather fluctuations are so vastly improved with No-tillage. These were the exact words used by Antonio Cinti Luciani who annually No-tills with perfect results an entire block of 30,000 acres in North Carolina without cultivations!

Inter-row sowing can also play a key part in wet conditions when trying to work with high residues with potentially less volume, coupled with the vital factor of patience that can influence the success or failure of crop establishment in No-tillage.

Figure 13. Eddie Nolan placed a high value on the role of rotation.

5.3. Patience and working with the extremes

When meeting a host of different farmers with different interpretations of how to deal with varying weather and ground conditions, having patience was an important element that was repeatedly mentioned. I have come to the conclusion that, with No-tillage, patience is the most valuable commodity and is invariably the most difficult to manage.

When assessing wet conditions Jack Desbiolles was clear that waiting for a dry crust to form on the surface was of the utmost importance, especially with a disc based seeder, to allow the slot to be closed back over. A soil's inherent stickiness reduces with an improvement in soil organic matter content (SOM) and a long term management approach towards No-tillage should have organic matter content as one of the key focal points. For cropping systems in the UK with a predominant bias towards autumn cropping this is a vital point. The soil profile at this time of year is continually "wetting up" and, with soil temperature dropping, germination rates are adversely affected.

… with No-tillage, patience is the most valuable commodity and is invariably the most difficult to manage.

The ability to plant crops in September rather than October can mitigate this effect, but sowing date may be influenced by weed pressure from blackgrass which has peak germination in September. The true value of better weed control and reduction by rotation is crucial in attempting to achieve reliable success with No-tillage. It allows better utilisation of the September planting window to maximise optimum establishment conditions.

It could be argued that a tine based system may be able to work for longer and better in wetter conditions, especially on clay soils. However the important factor when working to optimise a No-

tillage system is that regardless of whether the drill can handle and work in the conditions, the focus should be on the compaction and potential puddling effects from working in very wet situations. Desbiolles's (2010) research illustrated that seeding at a reduced sowing depth to avoid contact with the wetter soil lower down was beneficial, and any operation that minimises the mixing of residues with wet/sticky soils is desirable. High levels of surface residue may be beneficial in reducing the direct contact with a sticky soil surface. The compromise may be potential slot closure issues as the surface underneath is not exposed to the drying effects of sun and wind. However this could potentially work far better in the autumn than the spring, where the management of the level of over-winter surface residue should be treated cautiously on heavy clay soils.

It is easy to understand why waiting for the right conditions is a vital element to the best growers. This didn't always mean soaking wet soils are the primary problem, but damp conditions in the morning and late evening can also hamper performance. This is an issue associated with disc based systems when drilling into high residues leads to increased risks of hair pinning and sub-optimum establishment.

Figure 14. Ben Marshman (centre), a beacon of excellence in dry land farming

Ben Marshman is an impressive young grower from Owen in the Clare Valley who extols the virtues of patience with his disc based system, and is extremely mindful of the negative impact that sowing in damp conditions can have upon successful crop establishment. In order to eliminate the potential risk of hair pinning he is prepared to wait until mid-morning for the morning dew to disappear before he starts drilling, but was safe in the knowledge that he could achieve greater daily levels of output with his disc seeder as he isn't restricted by the forward speed. Forward speed can affect the level of soil throw from tine drills from one row to another, thus hampering even crop emergence and reducing outputs depending upon drill width. However, the difference between tine and disc

can be a balance between personal choice and what the aim is in the first place. There are pros and cons for both. During my visit in the Clare Valley I also met Allan Mayfield, an independent agronomist who has a long term trial at his Hart trial site with a tine vs. disc comparison and he has found that, in terms of yield, there is little to choose between the two.

Douglas Giles, a Cross Slot contractor I visited in the North Island of New Zealand, endorsed the patience factor. He assesses conditions before undertaking a job and is prepared to wait or even walk away from a job if they were not right - even if the customer is pushing to get things done. I have been left in little doubt that with No-tillage there is greater emphasis in not only selecting the right conditions to plant the chosen crop, but to be patient enough to wait for the ground conditions to be correct. Sometimes this potentially may stretch the drilling window later in the spring than would traditionally be considered ideal, but conversely if you move to a single pass system, selecting the right day rather than calendar date has never been more critical.

I have been left in little doubt that with No-tillage there is greater emphasis in not only selecting the right conditions to plant the chosen crop, but to be patient enough to wait for the ground conditions to be correct.

With the reduction in loose soil through tillage, and better water infiltration rates, you have a better opportunity of returning to the land after heavy rainfall events as the soil strength will have increased due to lack of tillage. The ability of the soil to carry machinery before losing structure is referred to as soil strength and this will always be at its weakest when the soil is at its wettest state.

5.4. Striking the balance

In the UK we are more likely to be on the receiving end of wetter conditions, but planning for just one condition when our weather is so unpredictable is a risky strategy. The plan for No-tillage should take into account both very dry and wet and treat those two impostors just the same.

As has been discussed, whether the bulk of the weather conditions are wet or dry, the principles for utilising No-tillage are very similar and can be summarised below:

- Infiltration rates of water are crucial for both retention and removal
- Residue and cover acts as a buffer to heat and heavy rainfall
- In wet periods residue can allow better travelling and planting opportunities
- Be mindful of a machine that will work in wet conditions as there can be potential catastrophic effects from soil compaction and smearing in very wet conditions.
- No-tillage machines with limiting factors in certain conditions may help the decision making process
- Organic matter is a crucial factor

The attitude associated with when to choose to plant a field and when not to, is very important. In the Entre Rios region of Argentina, there are some of the most difficult clay soils (pictured below) that I have encountered.

Figure 15. Soil in the Entre Rios region of Argentina

I met two growers in this region who were adamant that without No-tillage, crop establishment on these soils would be virtually impossible, and it has enabled them to crop areas that previously would have struggled for performance. Their window for optimal establishment is small before the change from too wet to too dry occurs, and they did not underestimate the value of cover in its capacity to protect the soil from various detrimental elements.

No-tillage needs time to become truly effective especially if you refer back to the table on page 10. It can be 4-5 years before starting to see the real benefits. This was confirmed by Allan Meijer of the Vernon James Institute, North Carolina, who considered it was at least 5 years. This was echoed by several others as well. As the process builds, worm numbers naturally increase, and this aids residue breakdown and creates natural drainage channels. Any form of cultivation returns you back to stage one of a recurring cycle that can never improve.

Within this chapter the elements that hold the key to allowing No-tillage to work on farm regardless of the conditions have been mentioned - and the starting point has to be soil organic matter as the key driver to this process.

6.0. Five critical factors

6.1. Soil organic matter

I realised soil organic matter (SOM) was an important element within soil, but I hadn't realised how pivotal it was in allowing No-tillage to prosper and the qualities that it brings to a farming system.

Talking about raising SOM levels is one thing, in practice it requires a dedicated mind-set and a focused approach. Fortunately there are some terrific examples of people who understand this and are making it work across the globe.

Dwayne Beck and Jay Fuhrer have been visited by a number of Scholars and there is a good reason for this as they both understand soils inside out. Dwayne was clear that organic carbon off-take should be treated in the same manner as phosphate removal; that it needs replacing and the value placed upon retaining residues was vital. In fact organic matter in the form of crop residue being removed from the field should be viewed as trailer loads leaving the driveway.

Allan Meijer has a long term trial on a heavy site in Piedmont where regular tillage SOM levels are only just 0.5%, but the No-tillage area was at 2.5% illustrating how detrimental intensive tillage can be to building the organic layer. Bernardo Romano (pictured below) told a great story of how a farm that started off with SOM levels of 5% had reduced it to 3.5% within 5 years through intensive cultivations and when you bear in mind Jay Fuhrer considers it can take up to 10 years to build 1%, preservation is vital.

Figure 16. Bernardo Romano

But it is not just the carbon of crop residues that should be taken into consideration, it is also the carbon within a cover crop that needs to be taken into account when assessing how to improve SOM.

The importance of balancing carbon within a rotation is crucial in No-tillage and Dwayne Beck's focus upon this, especially in terms of the carbon: nitrogen (C:N) ratio. There are simple, basic principles to adhere to.

The C: N ratio is based upon the amount of carbon units to the amount of nitrogen units of different crop residues and is a significant factor in the speed of decomposition (NRCS 2011). A rule of thumb for the ideal balance for soil maintenance from soil microorganisms is 24:1.

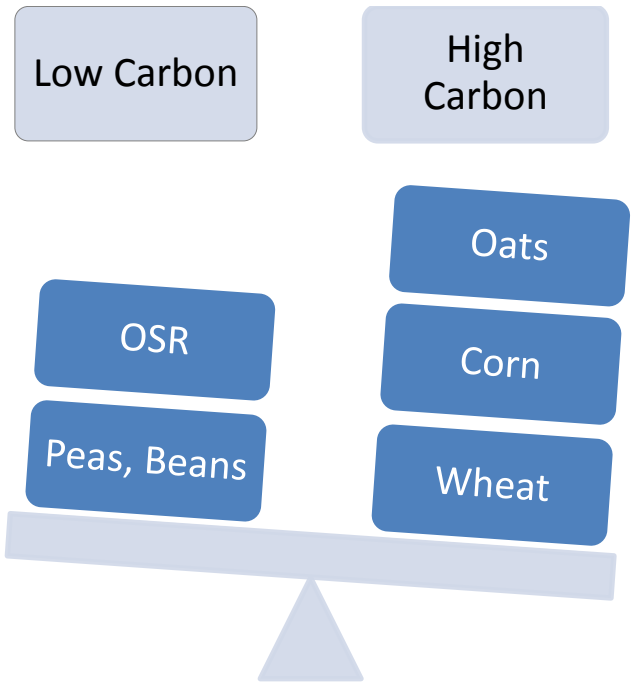


Figure 17. A simple diagram to illustrate balancing carbon balance between different crops.
Source : the author

Low C:N ratios like peas have (25:1) will be consumed by the microorganisms within the soil reasonably quickly with little excess of either element left over. But with a crop such as wheat (80:1) in the rotation that has a much higher level of carbon than the equilibrium, the microorganisms would require additional nitrogen to balance off the huge levels of carbon to consume the residue and break it down into organic matter and plant-available products.

Put in simple terms and in context for UK conditions, having 2 carbon-heavy crops such as oats followed by wheat in the rotation, would be too heavily carbon-biased for the microorganisms to break down in adequate time compared to wheat followed by beans or oilseed rape. This inevitably leads to nitrogen lock up and difficult conditions for successful crop growth and establishment. Therefore a rotation that balances low and high C:N ratio crops is crucial in alleviating potential pitfalls in crop establishment in demanding conditions, and is why the value of a balanced rotation has never been more pertinent.

6.2. Rotation, rotation, rotation!

Rotation was a subject that came up regularly in the countries I visited and was absolutely crucial for just about every farmer I encountered. Certainly a defining moment for me was during my time in New Zealand when I visited several farms that had direct drilled peas. Not only did this go against everything that I would have expected to be optimal conditions for pea growth, but it was the position within the rotation that made me take a step back and reassess how a rotation should change.

I met with Mark Scott who as a No-tillage contractor was undertaking a range of different jobs, but explained how No-tillage peas had really evolved. Instead of traditionally following a short term grass ley with wheat a lot of growers turned the rotation on its head and put peas into this slot. The benefits were better weed control and competition but if you think more deeply and consider the soil condition logically, the structure post grass from increased root and worm activity will potentially be as good as anything that could be cultivated.

Figure 18. No-till peas near Invercargill

With the size of some of the stones in New Zealand, one can clearly understand why No-tillage is so advantageous by not bringing them to the surface through cultivation. Crop performances are recorded as being better which is fairly impressive for a country that doesn't have a massive requirement to undertake No-tillage because of its favourable weather conditions.

When the importance of C: N ratio is taken into account it is easier to build a better picture of how a suitable rotation would fit and Dwayne Beck in the US was focussed on achieving the right balance. It might be stating the obvious but he said that a balanced rotation was the single most critical factor

affecting the health and productivity of a future wheat crop, which for the majority of the UK is traditionally the main cash crop.

A 5-course rotation was favoured by Dwayne, but the vital element is that it should be flexible and there are a whole host of different ways of achieving this with different crop permutations; but I have been left convinced that the focus must be on building organic matter in conjunction with a rotation that balances the carbon return in sequence.

… (Dwayne Beck) said a balanced rotation was the single most critical factor affecting the health and productivity of a future wheat crop

The same message came across in other parts of the USA and Brazil where the focus is shifting to long term goals - rather than short term gains – to be had from the position of different crops within a rotation. This can add different characteristics and diversity; the flip side - too much diversity - may be counter-productive!

Figure 19. Dwayne Beck illustrating the benefits of 27 years of No-tillage on soil condition (note the background level of crop residues)

Rotation appears to be closely linked with No-tillage and increasing organic matter levels, and it takes time to build the rich layer in the upper soil which helps alleviate traffic issues and acts as the barrier to soil protection and is the transfer system for better nutrient cycling.

During my time in North Carolina and other countries, 5 years seemed to be a standard response time to see the true benefits and when the 2-4" layer of SOM is built, the micro-climate within this zone can be completely different to the soil layer below it. Even in the Mato Grosso region where the cropping was intense, the top growers were looking at their long term viability and asking

questions of their rotation and what crops could fit better to alleviate soil and pest problems. Dwayne Beck placed high value on reducing the effect of volunteer plants on subsequent crops within the rotation.

The messages that I gathered from the various counties rang loud and clear. Balanced rotations are crucial for carbon balance and building soil organic matter; and also for alleviating pest and weed problems further down the line and to help reduce the impact of soil traffic and compaction.

6.3. Understanding and dealing with compaction

The one element that I have always been concerned with, but did not expect to encounter, was the issue of compaction which came up regularly on a lot of my visits across Brazil and Argentina. Interestingly the issue was being actively dealt with by the best and ignored by others.

Figure 20. An example of a corn plant root hitting a compacted layer at 10-12-cm

Compaction can be caused by a whole number of different factors - from harvesting in wet conditions to planting in wet conditions - but the simple fact is that it's a very significant problem that won't rectify itself and why there is a case for flexibility in a No-tillage system. One of the early Brazilian No-till pioneers, Sebastiao Conrado, stated that compaction is linked with poor management rather than anything else and that although animals can be beneficial within the rotation, their potential impact upon compaction should be considered carefully.

There were a number of growers who were in their terms "scarifying" the land, which would be equivalent to using a subsoiler to relieve the problem. Aguinaldo was the farm manager on a 28,000 hectare estate near Lucas Do Rio Verde (Brazil) and he had seen a rise in yield of 0.6 tonnes per

hectare in his soya bean crop by introducing this rotationally. Despite a long history of No-tillage the issue was not going away and he felt it had to be dealt with. In this region in the early years of conversion rice was a good initial choice for being able to cope with low pH soils, but it also has fantastic root structure and some were re-introducing it for that quality alone. Linked to what was mentioned with regard to the value of rotation and a long term approach, this bucked the trend away from the intensity of the soya-corn-bean rotation as it also helped the farmers introduce a further break to help reduce the intensity of the pest pressure that is evident in this region.

Figure 21. The power of rice roots to open up soil structure

The picture above illustrates the power of rice roots to open up soil structure. Some growers also found that utilising a narrow fertiliser boot on their seeders when planting corn was a popular method for addressing compaction as it could be dealt with in one operation, and only used as and when necessary. This seemed quite a simple and practical way of addressing matters and is certainly

something that needs careful consideration for our UK conditions. With previously deep cultivated soils and moist conditions at harvest and even with No-tillage, the damage from harvest traffic can still have an effect. Compaction shouldn't be ignored and some form of sub surface cultivation may be required to rectify an issue.

Some growers also found that utilising a narrow fertiliser boot on their seeders when planting corn was a popular method for addressing compaction.

The limiting factors of root development and their ability to access moisture in dry conditions was a big concern for Guilherme Buck of the Dekalb TDR team in Sorrisso, Brazil. He had a great understanding of soils and getting the best out of them. What I found refreshing about his approach - he worked for a seed company - is that although they had some market-leading corn varieties he felt it important that all his sales team were aware of the importance of soil structure and the limiting factors that can restrict crop performance. His major concern is the amount of compaction that he was continually encountering in longer term No-tillage. As the drier periods were getting hotter and longer and, despite most seasons having received sufficient rainfall to mitigate poor rooting, he is clear that unimpeded root access to water and nutrients is going to be vital in future.

Nestor Canali was possibly the most inspiring No-tiller I met. Along with some other growers in the Rio Grande do Sul region of Brazil he shied away from the use of cultivation to deal with compaction and felt they could achieve the same with the use of cover crops. He has some terrific points about how he has dealt with compaction and No-tillage since its introduction in 1994.

- Observe the problem compaction areas in dry conditions to be aware early on
- Avoid using cultivation to correct the issue
- "Red flag" compaction - always keep it in mind and deal with it when it occurs
- It may take 2 seasons to override the problem
- Employ robust cover crops instead of cultivation (his choice was black oats and vetch)
- Properly managed No-tillage reduces the likelihood of compaction over time
- If possible avoid harvesting in wet conditions

It may sound simple, but Nestor had some of the most outstanding No-till crops I have seen anywhere in the world and it was from this and visits in the United States that the role and use of cover crops became a greater focus.

See picture of Nestor on next page

Figure 22. With the brilliant Nestor Canali (left) in some perfectly established No-till soya beans

6.4. The role of cover crops and investing wisely

Cover crops might currently be the must-have accessory, but their significance within a No-tillage rotation cannot be underestimated. Their value was reinforced within several countries I visited and their rate of adoption is growing significantly.

In countries like Brazil and Argentina, cover is critical to provide a barrier to the elements from the heat, to prevent rapid moisture evaporation and to prevent the surface slumping from heavy rainfall. Not only do they have the benefits of weather protection, but it helps to keep the soil surface cool, and maintaining a field covered at all times is the priority.

I have been fortunate to meet some who really understand what they are trying to achieve with cover crops and, linked to the management of organic matter, their role in helping to build soil carbon in the important 2-3 inch layer is extremely vital.

This isn't a section that I consider I need to go into massive amounts of detail about as it has been covered by many Scholars before me, but the basic principles of having deep rooting species to punch through compacted layers to help with water flow, and shallow fibrous roots to open up the upper surface pores, give a good indication of what needs to be achieved.

Marlyn Richter in North Dakota had suffered badly with erosion on his soils and converted to No-till in 1998. He had experimented with different mixtures, but he considers a 6-7 species mix best. His focus was on increasing the SOM content whilst also providing protection for his soil to counter-balance swings in weather. With dedication and the right focus, you can make significant changes to soils and he has achieved this by using robust cover crops and rotational grazing. His initial base

SOM levels were as low as 0.8% in some areas and he had increased the levels in his fields up to 2.5% - and up to 3-4.5% on some others; a staggering achievement from his initial base levels.

The fact that it is possible to increase these levels offers huge potential. As the crop rotation has greater diversity within it, so the soil biology will increase allowing more rapid breakdown of carbon-heavy crops. Initially whilst the biology is starting to work then straw may be better removed until the breakdown process starts to increase.

Figure 23. Marlyn Richter in a cover crop of triticale and vetch

Nestor Canali put as much emphasis on investing in his cover crops as in his main cash crops to get the best from them, which would include fertilising to get sufficient growth. Although there are some advocates of planting into green cover, depending upon the components of the mix, there can be potential issues with the breakdown of residues and the locking up of nitrogen and root exudates affecting crop germination. Nestor considered that it was vital there should be a minimum of 40 days between the desiccation of the cover crop (in this case black oats and vetch) to ensure that it was properly dead prior to planting the next crop. Along with rolling the residue flat and then either planting across it or on the same direction of travel would result in less risk of hair-pinning, especially as the cover is by now more brittle rather than a soggy mat. Simon Cowell in Essex was wary of using cover crops. In his own field scale trial he had noticed negative effects upon establishment of a spring pea crop if the cover was either terminated just before or just after drilling, but mimicking grazing and destroying up to 6 weeks before planting resulted in a better level of establishment.

In Australia sunflowers were used. They have naturally deep and vigorous tap roots to punch through deep troublesome layers, an effect some growers felt they couldn't achieve by mechanical methods. Dealing with compaction in wet clay soils like we have in the UK when they are in a very plastic state increases subsurface damage, and smearing at depth that won't correct the initial

problem. But a living root can do so much more in achieving better pore space and transporting water away from wet surface layers, as well as capturing sunlight and nutrients, and offers far better potential. I didn't encounter anyone in any of the countries I visited who considered bare soil was a good idea and it certainly raises the question of the validity of fallow land within a rotation.

Ron Heineger and Alan Meijer from North Carolina, pictured below, were looking at the potential of cover crops to reduce thrip damage in soya bean crops so the "added value" of cover crops shouldn't be underestimated.

Figure 24. Ron Heineger and Alan Meijer were looking at the potential of cover crops to reduce thrip damage in soya bean crops

I saw the other extreme of how far you can take cover cropping with a visit to Steve Groff in Pennsylvania. He is experimenting with inter-row seeding of a cover crop in standing grain maize, the theory being that the cover crop is in place and ready to take over once the crop has been harvested; innovative, simple and brilliant.

6.5. Dealing with weeds

For No-tillage to be reliably successful in the UK and more specifically for any farmer who has an issue with blackgrass, delayed drilling in late October and No-tillage are uncomfortable bed fellows. There would be less exposure to risk of adverse conditions if drilling could be carried out predominantly in September, but this is where the sea-change of rotation as a key element can help with weed control and all is certainly not lost, as I discovered.

The successful growers using cover crops were seeing far less weed pressure and 40% less weed pressure was widely reported under a range of circumstances, which is significant. Sebastiao

Conrado in Brazil emphasised the same point as Nestor Canali: that investing properly in the cover crop was of great importance. Apart from its soil protection properties and contribution to SOM, making the most of a decent cover crop can help reduce the herbicide requirement in the following crop. He stressed that herbicides should be used wisely within the rotation.

But it is not just cover crops on their own that are bringing benefits; with No-tillage and reduced soil invasion and movement there are some key points that came up from different experiences:

- USA - 97% of weed seeds left on soil surface disappear within 3 years
- Impossible to achieve the above figure with cultivation
- Australia -similar to the US, but potential rise in numbers in year 2 before tailing off in year 3
- Know your weed and limit its favourable conditions to thrive
- Cover cropping can significantly help to reduce these populations
- Low disturbance drills can reduce weed germination by 92%

Ben Wundersitz is a grower in the Port Adelaide area who echoed the sentiments of better weed control from No-tillage, and was experiencing fewer issues than when using tillage. But he still required pre-emergence sprays to be really effective. The choice of drill would also appear to have a significant effect upon subsequent weed germination and Dwayne Beck (USA) had two theories with regard to drill choice. One is that you could choose a system that has high disturbance, but low diversity, and can also encourage greater weed risk and high levels of weed germination. But Dwayne's ultimate panacea for drill choice would be low disturbance and high diversity that would reduce the incidence of weed populations.

Depending upon what depth land is cultivated to can have a huge bearing upon which soil layer the weeds are closest to. Shallow working disc-based systems will therefore promote weed seeds in the upper surface layer, where they are more susceptible to predation and hostile germination conditions. A system that avoids mixing throughout the soil profile and avoids delayed and prolonged germination requires a higher level of management and attention to detail.

Growers in Australia are taking a proactive approach to reduce harvest weed seed distribution. Chaff carts which catch the chaff directly off the back of the combine and collect in the bin trailed behind the combine are one option, but dealing with the heaps afterwards can be an issue. There are those using chaff decks which collect all the chaff and weed seeds from the sieves and place them directly into the wheel marks of the combine, a hostile environment for growth; but it does permit inter row spraying with a total herbicide when under a CTF (Controlled Traffic Farming) system.

Although it is well known that a lot of blackgrass seed is shed before harvest, there are still a surprising number of seed heads that can be found within the crop at this stage, and there is the potential that a proportion of this seed could fall into the wheel marks of a CTF system. I was surprised to learn from Stephen Powles of AHRI (Australian Herbicide Resistance Initiative) that even when wild oats appear as if they have shed all their seed, 40% of seeds can still be in the ear at harvest. Although not a complete answer, in the UK we are now trying everything possible to combat one of the biggest threats to sustainable crop production.

Figure 25. Chaff decks being used in Western Australia

It was during my visit to AHRI (Australia Horticulture Research Institute) that I was able to understand more about their issue with ryegrass. They are experiencing issues as we are with blackgrass. Intriguingly the modelling illustrated how a resistant patch of ryegrass can affect plants within a perimeter four times the size of the original zone, certainly food for thought and more credence to one of Sebastiao Conrado's key tips for No-tillage that herbicides should be used wisely and weeds put under pressure from a robust cover crop.

7.0. Nutrients and seeding rates

7.1. Nutrient availability and cycling

As the upper surface layer of soil improves from No-tillage creating its own micro climate, there are real benefits to the ability of the soil to better hold on to and retain nutrients. I wanted to know what the impact was upon the amount of nutrients required and, specifically, key elements such as phosphorus.

Gypsum was used in most of the countries I visited to add sulphur to the following crop, but it also helps with the deeper rooting of crops and helps to increase organic matter levels.

During a visit to one of the Embrapa research stations in Brazil evidence was presented on the importance of applying phosphate, and crucially also the improvement of nutrient retention and availability under a No-tillage regime. Djalma Sousa showed me data illustrating that Brazil had naturally low phosphate soils in some areas and 30% of those are degraded; which is on par with the global figures and echoes Jay Fuhrer's observations.

Djalma was also noticing poor fertiliser efficiency, generally due to over fertilising in the first place but, with improved organic matter under No-tillage, Djalma had seen fertiliser efficiency rates increasing from 75-90%. He also reinforced the importance of organic matter in reference to the improved availability of phosphate in the organic form as opposed to under a conventional system, and he reports 1t/ha more carbon sequestration from No-tillage as an additional benefit.

Figure 26. Phosphate trial at Embrapa illustrating its importance.
Note difference when compared to no applications in the last 17 years

Djalma's long term trial with phosphate application to corn shows how dramatically important phosphate is to plant growth. As with most aspects of No-tillage patience is required to reap the longer term benefits of increased nutrient cycling and retention.

7.2. Fertiliser placement

It became apparent amongst the seasoned No-tillers I encountered that the placement of fertiliser in the early stages of conversion was vital, especially in soils with low phosphate indices.

In difficult growing conditions and with soils that do not naturally release nitrogen - compared to cultivated soils which mineralise nitrogen (an effect that impresses cosmetically, but does not necessarily lead to yield increase) - there is a value to placing nitrogen near the seed. With phosphate, a product that does not move easily within the soil, the closer it is to the growing seed, the easier it is for the root system to take it up and placement just to the side of the seeding zone, rather than directly in the zone, is preferable.

When there are large volumes of carbon-heavy crop residue, their value becomes even higher with the growing crop competing with the decaying residue. It was something Dwayne Beck valued highly and a grower from Wendonside, New Zealand, was placing fertiliser with all his crops for precisely these reasons. DAP (Di-Ammonium phosphate) is a popular choice amongst growers in New Zealand.

Figure 27. Overlap illustrating the benefit of fertiliser placement in No-till oats

The fundamental issue with this system in the UK is the autumn fertiliser restrictions to not only crops, but also the total amount of product that can be applied. This is something that really needs revision if using a No-tillage system and specifically placing fertiliser.

In New Zealand they were placing phenomenally high rates of DAP, up to 300 kgs/ha, which would provide the crop with 54 kgs of nitrogen and 138 kgs of phosphate and this could be in a crop of peas! An average rate of fertiliser for all crops in general appeared to be around the 215 kgs/ha mark, and this rate was commonplace amongst No-tillage exponents in all the countries I visited, specifically to help overcome the short term nutrient lock up of P and N in the early stages.

The advantages of placing fertiliser have been clearly illustrated by Baker, Cross Slot, New Zealand, (2007) in trials in barley, fodder radish and maize as illustrated below:

Method	Fertiliser placed	Fertiliser broadcast	No fertiliser applied
	Yield t/ha	Yield t/ha	Yield t/ha
No-tillage	10.914	4.523	1.199
Tillage	10.163	5.877	2.999

	No Fertiliser	Horizontal placed in 20 mm side band	Fertiliser & seed mixed	Broadcast fertiliser
Barley	1.889 t/ha	2.58 t/ha	2.538 t/ha	2.432 t/ha
Fodder Radish	3.24 t/ha	3.763 t/ha	2.809 t/ha	3.543 t/ha

The yield benefits in this situation of placing fertiliser as opposed to broadcasting are clear, and the practice optimises usage. Some growers were placing seed within the row, but there is a greater risk of seed burn in this situation, especially at the higher rates that are being used in New Zealand, but in respect of climate and yield there is similarity with the UK.

Figure 28. Corn planting on an angle after soya beans in Brazil; triple hoppers for seed and fertiliser

Fertiliser placement at drilling was also favoured by Arno Weiss and his farm manager Fernando in the Cerrado region of Brazil, with phosphate being the key element for them. The farm manager is clear that P availability to the plant increases their roots and their ability to source nutrients and moisture down through the soil profile. Another very interesting point that Fernando brought up was that he favoured planting crosswise at different angles to the previous season as he considered it made the roots chase more phosphate than just utilising the same area each time.

7.3. Seeding Rates

Another point that regularly came up was the importance of seeding rates under No-tillage. There is a temptation to assume that due to the lack of soil movement and consistent seed placement, germination will naturally be better. However many growers I met increased seed rates, especially in the early stages, to buffer against difficult situations.

Consequently one of the key messages was that if you start off with a low seeding rate and obtain sub-optimal establishment, everything from the start is going against the wellbeing of that crop. Slugs are a key issue for the UK farmer and I was surprised to find them in Australia in some regions, as well as snails, and there was no hiding from them in New Zealand! So along with predation and poorer conditions, at the risk of stating the obvious, there is a stronger case for maintaining seed rates, rather than cutting them back. It also appeared that wheat plants with a longer coleoptile (the stem between ground level and formation of first leaves) prospered under No-tillage.

One of the key messages was that if you start off with a low seeding rate and obtain sub-optimal establishment, everything from the start is going against the wellbeing of that crop.

Ultimately, patience is the most valuable factor, if the most difficult to manage, for the most successful No-tillers.

No-tillage provides the advantage of being able to delay drilling until the conditions are appropriate, be that soil temperature or soil condition, safe in the knowledge that, as there is little soil movement, the risk of moisture loss is low. Ultimately, patience is the most valuable factor, if the most difficult to manage, for the most successful No-tillers.

Investing in cover crops properly is vital to manage nutrient use and a thin cover crop isn't going to smother weeds and protect soil in the same manner; and this backs up the theory of both Nestor Canali and Sebastiao Conrado to invest as wisely in your cover crop as you would with your main cash crop. It's there to do a job for the soil and is why it the investment in the system is so important.

Although you may be fertilising the cover crop, it is the storage centre for nutrients for the following cash crop, so good establishment is vital.

8.0. Drill choice and considerations

8.1. Parameters for drill choice

There are a plethora of drill types on the market, and some will clearly work in high levels of surface trash better than others. As with many situations everyone has to start somewhere and the ultimate goal has to be a system that works successfully in the majority of situations.

The drill is a key feature of the whole system, but it should be viewed as one of several "gears" within the system to make it work in relation to residue, rotation and organic matter.

I visited Trevor Syme in Western Australia, a long term No-till farmer who had recently taken over a new block of ground which had been under pasture for a number of years. He has made the progression from tine to disc on the bulk of his land, but opted for the disc straight away in the new block. The lesson Trevor instilled and was echoed by others was that using a disc drill may be the panacea in terms of reduced disturbance and optimum seed placement, but some soils may not be ready straight away. He considered that he would return in the short term (3-4 years) to his narrow tine based DBS tool bar until the soil had balanced itself enough and the biology had got going to allow him to use the NDF disc unit he had across his whole acreage.

The drill is a key feature of the whole system, but it should be viewed as one of several "gears" within the system to make it work in relation to residue, rotation and organic matter.

The glaring issue with tine drills is their inability to work successfully in high levels of trash and residue. They are more likely to guarantee optimum establishment whilst early adopters get to grips with No-tillage techniques, allowing breathing space to understand the greater level of management required when using a disc based machine.

Key criteria to be considered in relation to drill choice are:

- Soil type
- Residue level & ability to work in trash
- Crop rotation
- Ability to retain moisture
- Below seed loosening
- Inter-row sowing
- Seed row firming

8.2. The choice between tine or disc?

The NDF (Australian manufacturer) disc unit users I encountered were all seeing vastly improved crop establishment in very testing dry conditions. Ty Kirby was another Western Australia convert

and he even felt that their success in dry crop establishment in dry conditions was almost getting "too good" as sometimes he considered they were pushing the limits on ground that was struggling with moisture. This relates back to Bill Ritchie's point on the ability to obtain establishment under No-tillage even in soils that appear too dry due to the relative humidity within it.

Figure 29. One of the many NDF disc units I encountered

It is certainly easy to understand why Ty's establishment had been so good; the NDF is a beast of a machine and has clearly great weight transfer for establishment in hard conditions. But ultimate success is down to the attention to detail that is required to get the best out of these machines. Marlon Richter likened the importance of monitoring the condition of seeding discs and not allowing them to get too blunt to "*attempting to cut raw meat with a blunt knife*" - as cutting through high levels of trash is often the main requirement in No-tillage.

Tines are a safe entry point into No-tillage, but ultimately may restrict the final leap into soil improvement and users may remain at the transition phase (5-10 years) as highlighted on page 10. But they should not be dismissed for all growers; for varying reasons the disc based approach does not suit some of them or their soils. Darren Longmire, a grower who is based in Spalding in the Clare Valley, fitted this description. He had tried a disc system, but it didn't work for him as he found that his crops didn't have as much vigour compared to under a tine system, and also he experienced reduced emergence, highlighting the importance of maintaining and even increasing seed rates.

Darren also considered that, in his location, having decent crop vigour was crucial for competing against ryegrass. I found in Tasmania where they can experience in excess of 800 mms of rain, some growers had reverted back to a narrow tine for its consistency, and would call on a disc drill contractor when required. I would strongly endorse flexibility in having the choice of system to suit

the prevailing conditions. Simon Cowell in the UK was the best example of this, he had the choice of a tine drill and two types of disc drills (none overly expensive) and depending upon whether the ground was too hard or too wet for either of the disc systems, he had the freedom to default to a tine drill.

Figure 30. The popular DBS tool bar tine system favoured by Darren Longmire and others

Discs ultimately help with reducing surface disturbance and weed germination, but are reliant on a dry surface crust to allow soil to fill back over the seed furrow, and do require operators to be more patient in waiting for the surface layer to dry sufficiently ahead of drilling. When a good layer of soil organic matter has been built up, this acts as a natural buffer for compaction, and trafficking allows the utilisation of a disc based system more easily and magnifies the importance of soil strength.

8.3. Soil Strength

Soil strength can be classified as the resistance of the soil to deformation and erosion from either loosening or compaction, and it is the weakest link between particles and aggregates that determines the overall soil strength *(Watts & Dexter*). Tine based systems can gradually reduce the soil strength through continued loosening of poorly structured soils and are less susceptible to

establishment failure in soils with high strength, where sub-optimal results from a disc machine may occur due to poor penetration. In the early stages of conversion a tine can be a useful introduction to reducing the strength of the soil ahead of disc seeder adoption, a strategy employed by Trevor Syme in Western Australia.

Ultimately the strength of the soil will reduce over time, but is limited with continued use of a tine system. In adverse wet conditions when slot closure can be an issue, the tine will be more forgiving; however its limitations are clearly exposed in drier periods when moisture retention is critical.

Desbiolles (2010) highlighted that soil friability is a key component of soil quality and that when a soil is at its optimum condition for planting, it is also at its weakest for compaction. A management system that reduces soil strength and increases soil moisture at maximum friability is optimal.

8.3. Working with residues, cold and moist conditions

No-tillage soils take longer to warm up and even when others may be planting in a conventional system, the mental strength of being prepared to wait longer will be of greater benefit than drilling too early in to a cold seedbed - as often encountered in UK spring conditions.

Dealing with residues when they are dry is straightforward and row cleaners in front of a disc unit can be useful for sweeping debris out of the drilling row to help reduce the possibility of hair pinning; not an issue for tine drills, but a serious one for discs. Potentially drilling between the rows with a tine drill can help to avoid dislodging the stubble and could also help reduce the volume of trash passing through a tine drill.

Cover crops and heavy clay soils present opportunity and challenge in equal measure. Whilst on the one hand cover crops are a way of increasing SOM, friability, moisture and nutrient management, on the other they offer a big challenge for planting into. With a disc, the dry surface crumb is critical, and destruction well in advance as endorsed by Nestor Canali (minimum 40 days) makes perfect sense.

However, this does make the challenge for tine drill use greater under these conditions and, although grazing cover crops can be beneficial in terms of nutrient recycling and destruction, full stubble and residue retention is preferable. When I met Michael Horsch (Czech Republic) I liked his theory with regard to planting corn in parts of Europe with cover crops with RTK (Real Time Kinematic). Covers could be planted on wider rows (or similar rows) and in spring the area between the rows is planted, allowing better trash flow and also potentially a clean area of soil to work into, that additionally wold dry more quickly.

In parts of the United States, vertical tillage machines are commonplace with some growers using both zero and strip tillage. Although this goes against the long term goals and philosophy of true No-tillage, I consider it could be a useful option in the very early stages.

The theory behind these machines, even though they resemble a set of disc harrows, is that conversely they do not invert any soil and the residues are left on the surface. The difference is the discs are straight as opposed to scalloped, similar to the turbo discs on a Great Plains direct drill.

Particularly favoured after carbon-heavy corn by growers I encountered using them, they considered it helped the soil to warm up faster ahead of spring planting, helped accelerate the breakdown process of high carbon trash and also created some tilth. Crucially it maintained residue on the surface to act as a protective layer. Whether this would be a benefit in the UK is a subject for debate, but it could potentially help for early adopters in difficult conditions.

Figure 31. A typical vertical tillage machine as used in Kansas

8.4. Slot closure

The biggest challenge for most disc drills on clay soils is slot closure in very moist conditions. This causes smearing which can be very detrimental. Waiting for the right conditions and allowing a dry surface crust is vital. Triple disc drills can make this even more difficult as the first furrow is created before the following twin discs and, in this situation, decent furrow wall closing wheels have a lot of work to do. Some interesting work by Jasal (2007) highlighted that in wet conditions sometimes planting deeper can result in better furrow wall closure and reduced pressure on the closing press wheels, reducing the compaction over the seed zone.

But this is something the Cross Slot drill does brilliantly in a different way. The clue is in its name, but with the disc cutting the slot, and the seed placed to the side of the slot zone and into clean soil, it reduces the issues associated with hair pinning and seed exposed in an open slot.

Even with tine seeders, having the seed zone firmed after the sowing tine was very important. One grower I met noticed an 11% yield increase compared to not having seed row firming wheels on. In damp conditions this can be a hindrance for tine seeders. Jack Desbiolles was developing a coil type consolidation ring that would work in sticky conditions for tine seeders. Spoked press wheels are also an option for disc machines.

See picture on next page

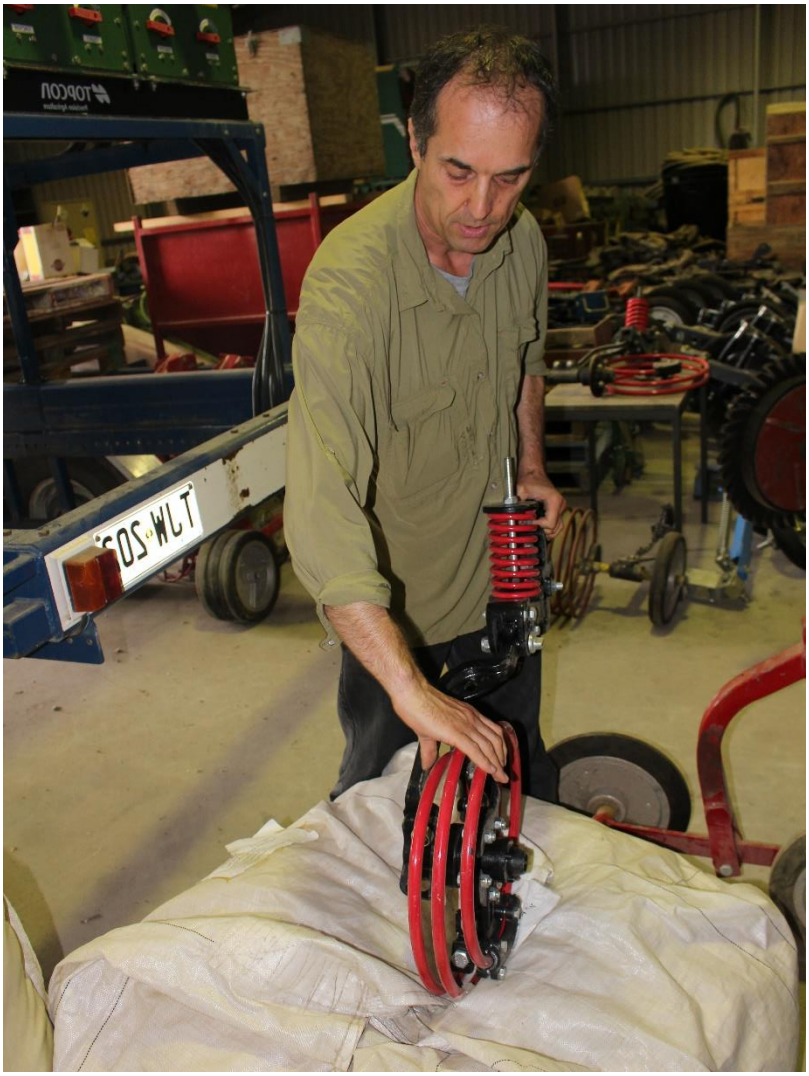


Figure 32. Jack Desbiolles (University of Adelaide) with the coil consolidation ring

8.5. Optimising seed placement

Marlyn Richter (North Dakota) considers that with higher residue levels, drilling slightly deeper can be beneficial; but evenness of seed placement and establishment is a desirable trait for any system. Yet to be able to put a figure on it is difficult. Fortunately this is something that Jack Desbiolles has researched!

Sowing Depth	Yield %	T/ha of 2.5		UK of 10 T/ha	
30-35 mms	95	2.38		9.5	
35-55 mms	87.5	2.18		8.75	
55-80 mms	80	2.0		8.0	
80-85 mms	75	1.88		7.5	
105 mms	70	1.75		7.0	

Source: University of Adelaide

The chart above illustrates Jack's work at the University of Adelaide where the importance of correct sowing depth (30-35 mms) was clearly illustrated. Even in what doesn't appear to be high yielding wheat, the relevance is still clear to see. The drop in yield can be quite significant and when I estimated (based on Jack's figures) a similar scenario for a crop of wheat in the UK it could amount to a potential 2.5 t/ha drop in yield. Although this may be an unlikely occurrence across the a whole field it perhaps illustrates why uneven fields can exaggerate a variance in yield and why accurate contour following, coupled with good seed to soil contact, is a crucial component of any drill; something not all can achieve.

Although seed singulation is used regularly with precision planters for grain maize and soya beans, there must be some clear advantages to having a wheat crop evenly spaced. Ron Heineger has looked at the effect of a delay in emergence of corn plants and has marked the slower emerging plants in his trials. He was seeing a 25% yield reduction even with a 3 day delay. Clearly there must be a correlation for even plant stands and well-spaced plants in a No-till situation, regardless of the type of crop.

Figure 33. Below: Direct drilled singulated winter wheat in Essex

The value of singulation encourages optimum, even establishment along the row, thus limiting gaps, maximising seed rates and potentially allowing for the scope of reducing seed rates.

8.6. Narrowing the drill options

One factor that came up regularly was: below seed level loosening. Rather than a form of deep loosening tine working ahead of a sowing tine or disc (like some of the strip-till type systems that are

currently seen in the UK market) but localised subtle loosening marginally below the seed, as opposed to seed placed directly in the base of a slot.

Although a lot of drills on the market are quite capable of No-tilling, not all of them work slightly deeper than the seeding zone; and then it comes down to the individual farm situation and the stage your soils are at in terms of speed of adoption.

Two disc drills that stood out for me were the NDF with its larger disc that worked below the coulter seed placement depth, and the Cross Slot drill where the disc works in a similar way, but enhanced further due to its seed placement in a clean zone just to the side of the slot. This can negate the potential effects of hair-pinning. There are other disc systems that will do an equally decent job and be able to work in high levels of residue, but in my opinion these two stood out. Disc drills may be the ultimate No-till drill choice, but they can all hair pin to some degree even when avoiding the conditions that make it worse (damp mornings etc.). The Cross Slot is the one drill that literally moves this issue to one side.

There are situations where a tine drill may still be preferable. The narrow points as used on the DBS and Seedhawk type drills ticked a lot of boxes for fertiliser placement, below seed loosening and accuracy of seed placement. Their limitations arise when working in high density covers. Perhaps where livestock are available, grazing can help alleviate these issues. Overall the key requirements of a drill are as follows.

- Accuracy of seed placement
- Contour following
- Furrow closing and consolidation
- Trash handling
- Ability to cut through residue
- Reduced surface disturbance.

9.0. Flexibility and fitting into UK conditions

9.1. Approaching No-tillage on farm and the call for diversity

Expecting instant results and miracles from No-tillage is unrealistic; but there can be little doubt as to the value of No-till and cover crops as a system for improving soil condition and its ability to withstand whatever nature can throw at it.

Dwayne Beck (USA) often referred to weeds as the symptom that a farming system does not contain enough diversity and a change in philosophy would be to treat the cause and not the symptom. Too many arable systems have lacked diversity in recent years.

Although some form of limited cultivations have been mentioned, they must be justified for good reason, as the effect of tillage can have a catastrophic effect on soil macro and micro fauna. It could in fact be compared to the effect of an earthquake in the soil. The great misconception is that tillage is necessary for crop production; the fact that tillage can lead to soil degradation and erosion and is a symptom of an unsustainable farming system (Rolf Derpsch – Germany and Latin America) should not be ignored.

9.2. Staying Flexible

If there is one thing I have learnt that should have come across in this report it is that the "P word": patience: is a vital component if anyone is to learn how to work with challenging and changing weather elements. For drilling contractors like Mark Scott and Douglas Giles in New Zealand, performing a good job in the right conditions is critical, and by equal measure a sub-standard job in poor conditions limits the crop potential.

There are times when a soil's plastic limit may be too high to obtain slot closure and a tine, although it may cope with the situation better, is perhaps allowing you to drill into an environment which isn't appropriate. The ability to take a step back and wait will pay bigger dividends in the long run as opposed to forcing crops into conditions which can only lead to sub-standard results and an uncompetitive crop that cannot compete with weeds.

Each farm is individual and there is no descriptive list on how to overcome problems with wet and dry elements; everyone should be prepared to experiment in a number of ways:

- Try different cover crop mixtures
- Experiment with different cover crop destruction times
- Develop a rotation that encourages diversity
- Vary drilling depth to suit the conditions
- Find what level of residue you can work with
- Discover the limiting factors of individual field restricting furrow/slot closure
- Mastering the dry is easier, beating the wet is better!

Figure 34. Douglas Giles, successful long term No-tillage through patience management

9.3. Work/life balance

One of the unexpected bonuses a lot of people mentioned to me was how much improved their home life was. This is the added bonus, similar to the cost reduction that in my opinion comes through using No-tillage when higher investment in equipment is not needed.

This first came to light during one of my first visits in Australia when the first two farmers I met said the same thing.

Figure 35. Troy Missen from Ballarat, better yields and better life balance from No-tillage

Both extolled the virtues of not having to spend hours on a tractor cultivating fields in preparation ahead of planting, and neither of them wanted to go back to that system. Certainly as a teenager, big smoke, large cultivators and long hours are king; but being a bit older and wiser that desire is not the same, especially with an understanding of soil preservation and the realisation that equally good yields can be achieved in a better way. There is a case for less is more and, in the case of No-tillage, the window of opportunity for planting is wider than most think, and the flexibility that reduced disturbance brings with it should not be underestimated.

The days of chasing clods around dry seedbeds are a thing of the past for the top exponents I met. They are not relying on the weather to do them a favour to get crops established and they are able to "pick their moment" far better and not to the detriment of the quality of their home life

9.4. Learning by the mistakes

It would be great to think that it is possible to get everything right all the time on the road to No-tillage, but in reality life has a habit of not being like that. One of the questions I put to Sebastiao Conrado (Brazil), who knows a few things about No-till, was what were his top tips for success?

Amongst the many hints and tips he gave, the first one was not to mess your soil up in the first place! Sometimes remedial action is required to correct the mistakes of the past, but the one that struck a chord for me from him was: "Mistakes will occur, but success comes from planning how to manage those risks as they will definitely happen".

Figure 36. A lesson from the very wise Sebastiao Conrado

No-tillage is a big step change in management and understanding and although there are a number of different drill and cover crop options available, each farm and even each field has its own individual quirks and problems. To make the system work for any individual there is no set script, but finding a path that suits a particular farm can only come from trial and error. As Sebastiao put it so eloquently, inevitably things will go wrong along the way, but it is accepting that this will happen and planning for potential pitfalls that will ultimately lead to long term success.

9.5. Mentoring and learning from others

Amongst the many things I came across on my travels, one of the associations that impressed me the most was The Victoria No-till Association, which has a fantastic membership base and great camaraderie.

I was taken aback by the number of members they had and the willingness to openly share with each other experiences both good and bad. There was a common goal that they all wanted to farm as successfully as they possibly could in one of the most challenging climates.

But it wasn't just the information sharing that was beneficial. There was a mentoring process for the younger generation coming into farming and learning about No-till. This was undertaken by the senior members of the Association. Chris Drum mentioned earlier in the report was one of them. I thought this was a great way of transferring knowledge, not through someone standing on a podium lecturing on how to do things, but from experienced hands-on professionals who saw it as their duty to guide newcomers. Brilliantly simple, but perhaps illustrating how knowledge transfer and sharing can be done.

10.0. What has to change?

10.1. Attitude and the resistance to change

I have heard many terrific quotes from a whole host of different characters across the world, but no-one summed up the thought process better than John Baker when he said "*People want things to get better, but are they prepared to change ?".* It's difficult to argue against that comment. But the stark reality is that soils are not improving under intensive cultivations. Admittedly under certain cropping regimes this cannot be helped, but there is certainly a lot that can be addressed.

The basic fact that crop debris is unfairly labelled "trash" when actually it is part of the building block of improving soil health, feeding microbes and helping the biology to get going, is one attitude that needs to change. There may be instances in the early stages of No-till where large volumes of straw may be a hindrance and require removal; and this is not admitting defeat, but understanding the flexibility the situation demands.

The best piece of steel you can own is a spade!

A decision to undertake No-tillage is a big commitment and although it may mean less time in the seat, it requires a dedicated mind and the willingness to look more closely at what is happening within the soil. The best piece of steel you can own is a spade! Get the soil biology right and the roots of crops and cover crops will provide the drainage when you need it and, because the soil is not full of unwanted air, it can hold onto moisture when it is most required.

10.2. Bare means bad

I didn't meet anyone on my travels who thought bare ground was a good idea at any stage. I can still recall the state soil would be in post set-aside and, with talk of fallow for controlling blackgrass, I can't help but feel negative thoughts towards such measures.

The list of names is too long to mention, but be conditions wet or dry, all the people I encountered felt soil should be covered or have something growing on it at all times, and it is easy to understand why.

… be conditions wet or dry, all the people I encountered felt soil should be covered or have something growing on it at all times and it is easy to understand why.

The key resource of soil will thrive and organic matter will build more quickly if soil is covered, maintaining the building blocks for glomalin to thrive, which is crucial in the process of a working soil. As such, soil organic matter should be viewed as the Velcro that brings everything together, binds the important nutrients and is the buffering agent against compaction, erosion and changing climatic conditions.

The mental barrier to go through is that surface residue is a friend - and not an enemy that can impede crop development. Mixing decaying material to depth has far more dire consequences. The conversion of surface residue into organic matter will speed up in time. Turning fields brown is the antithesis of what is the main aim.

10.3. UK rotations need to adapt

Rotations and carbon balance have been mentioned earlier, but it is fairly clear that a classic rotation of wheat and oilseed rape is both imbalanced and doesn't offer the environmental diversity that No-tillage demands.

The challenge of trying to establish crops that previously would have been considered impossible on certain soils types, and the better carbon balanced a rotation, the greater the diversity that follows.

Creating an environment that takes away the conditions that allow certain weeds to thrive on an annual basis will pay huge dividends in the long run; but it has to be understood that No-tillage will not be an instant fix for some, but that the long term gains far outweigh any short term pain.

11.0. Summary of the findings

This report has highlighted the issues associated with crop establishment and varying weather patterns; longer periods of dry weather can prove to be as difficult to work with as periods of wet weather. But the one commonality that should be acknowledged with regard to both types of climatic conditions is that there *is* a system that allows you to live with both and cope in equal measure, without defaulting to using unnecessary cultivations.

What has become clear throughout is that soil degradation is happening on a global scale and the wise are waking up to the realisation that farm practices need to adapt to reduce this burden and begin to stop the loss of organic matter and soil in the process. In the various countries visited the implications of wind and water erosion have been highlighted and their impact understood resulting in a better understanding of what the long term benefits are.

But, from a change to a No-till system, in practice other benefits have come along with it, both for regions that have traditionally struggled to retain water or those that have suffered from pooling in high rainfall events. Their soils have transformed over time to witness better infiltration rates and water holding capacity. There is plenty of evidence showing both reduced pooling effects in high rainfall events, and also how the retention of residues and increased cover have provided the soil with a protective coating against the effects of hot weather, acting as a buffering agent. The benefits that have come in hand with this have been more consistency with farm yields, reducing the peaks and troughs of past systems, and giving growers more confidence to use No-tillage since there is less likelihood of a yield penalty yet, at the same time, a more consistent establishment.

It has highlighted how the role of RTK can be beneficial for inter-row planting; this can be crucial for stubble retention to act as a windbreak and also to allow potentially better trash flow for drills that may otherwise struggle. There is the added advantage that under limited moisture conditions, planting close to the root ball of the previous crop can offer more moisture than solely planting in the middle of the gap between rows.

Patience has been a common theme throughout; being prepared to wait for the right conditions to drill into is vitally important compared to forcing the seed into sub-optimal conditions. Also it must be recognised that even damp, dewy mornings can compromise disc seeder performance through increased hair-pinning.

Cover crops stand out not only as a vitally important in helping retain all year round cover, but also as a way of managing moisture and helping to alleviate soil structural problems through the use of root systems with different modes of action. Investment in a cover crop is as important as the cash crop as it is part of the whole system and they can also help to speed up the increase in soil organic matter, the fulcrum of a successful No-tillage system. As the SOM increases, the soil's ability to withstand traffic and reduce the potential impact of compaction goes hand in hand with it; but with poor management SOM can be depleted at a quicker rate than it can be built. The role of a balanced rotation that allows a better ratio of carbon heavy and carbon light crops in the right sequence is vital, and it is the understanding of the rate of breakdown of their residues that can dictate the success or failure of a crop within the sequence.

One factor that has unexpectedly come to the fore has been the issue of compaction and the recognition of its potential limiting capacity for roots to water and nutrients shouldn't be underestimated. Although it can be an issue, it has been shown that these limitations can be dealt with in a number of ways and using a cultivation to alleviate the problem shouldn't be seen as an admission of defeat, but the recognition and willingness to sort the problem.

The choice of drill has been shown to depend upon the factors surrounding the field conditions it has to work in; whether cover crops are utilised or not; and whether there are large volumes of trash to deal with; how difficult it is to obtain sufficient slot closure: all have an effect upon the choice of a drill. A reduced-disturbance disc drill has been shown as the panacea for choice, ticking all the correct boxes for seed placement, trash handling and reduced surface disturbance; however there can be a place for tine drills in certain situations and especially in the early stages of conversion. Fertiliser placement is also an important part and the report has also shown how, over time and as the soil improves, nutrient cycling, retention and availability all increase.

Amongst the points that have come up is the fact that general standards and quality of life have improved for many; but success depends on a wider understanding and an attitude of fully embracing everything that No-till has to offer.

12.0. Discussion

From what I have seen and experienced on my travels across the world, the common themes were loud and clear: that intensively cultivating ground has not been improving soils, in fact entirely the opposite; and that unless current farming systems adapt and evolve, the ramifications are numerous.

Based upon the facts given by a number of people, soil is being degraded without some actually realising it is happening. This speaks volumes and the time for change has come. Some of the astute advanced growers have made or are making these changes and it is about securing a future for the generations ahead of us. Although weather is mentioned within the title of the report, the main thrust is more concerned with a change of attitude and adopting a system that allows soils to thrive and not be abused.

No-tillage is without doubt the key to unlocking the cycle of soil enhancement and improvement in a changing and challenging environment. It has become clear to me that there need not be a one-size-fits-all approach in allowing No-till to work in extremes of weather.

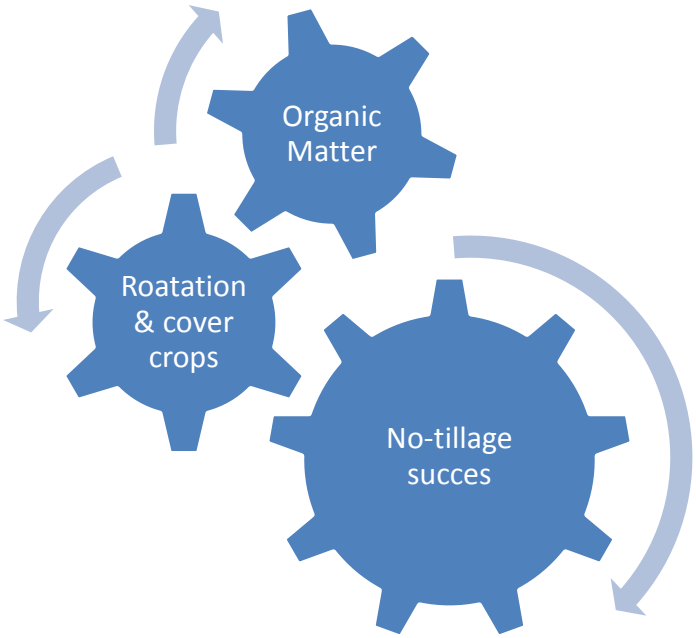
The starting point for some has to be what condition your own soils are in. Roots are a great indicator of the potential problems that are happening below the ground. The picture below clearly illustrates what happens when a soya bean root hits a compacted layer.

Figure 37. Roots have a story to tell

I have learnt that if there is an issue with a compacted soil layer, utilising a subsoiler to relieve the problem is not an admission of defeat, but an acknowledgement that a quick cure to the problem, to allow better results from No-tillage - can be employed. It is not to say that cover crops can't do this

on their own, but it is more important to understand that in dry conditions, roots must have unimpeded access to water and nutrients. Also it should be understood that in wet soils the root system is going to do a better job than anything mechanical can, in punching through difficult soil layers rather than smearing soil layers at depth; giving more credence to the whole No-tillage system in the long term.

It has also clear that there are simply times when conditions for drilling are simply not right and when the greatest test of management – patience - has to come to the fore.



Without doubt building organic matter is the central key, but if this is to be successful it has to be in harmony with the use of cover crops and the right rotation. Some of the key pitfalls to be wary of are as follows.

- Continual autumn cropping
- Insufficient residue retention and focus on development
- Expecting overnight miracles
- Soils with poor drainage
- Rotations with no diversity
- Understanding cover crop content and requirements
- Unwillingness to accept mistakes

But from a practical aspect what can be done on farm to enhance the chances of success and what things need to be considered?

- Cover at all times, residue in-crop and living cover out of crop
- Understanding the limitations of cover crop destruction time
- Angle of sowing in dry periods to maximise moisture
- Care with closing wheel pressure in damp conditions
- Drilling depth, its importance for crop consistency

- Residue placement, residue management so wheels can clear the seed zone as required
- Different root structure types in cover crops and commercial crops
- Focus on increasing the soil organic matter content
- A tine drill's performance is significantly improved by the addition of a firming wheel
- As the soil biology and SOM improves, so does the ability of the soil to withstand traffic

There is no prescriptive method that can suit every farm and every situation, but there has to be a focus target: what do you want to achieve in 5 or 10 years?

What crops will provide you with the right carbon: nitrogen balance that will make No-till easier but also allow the increase in crop diversity that is vital - whilst also creating an environment where the most problematic weed in an individual farm's situation finds conditions difficult to thrive?

No-tillage gives better opportunity of long term crop success through reliable performance and the soil's increased ability to withstand the two polar extremes of wet and dry yet still deliver consistent performance. No cultivation system can guarantee success.

Ultimately when it rains, which field would you prefer to drive on: the field cultivated to depth, or the one that is like a flat paddock to drive over? That is the benchmark to No-tillage success.

13.0. Conclusions

1. Regardless of country and climate the message was clear: greater consistency in crop performance was achieved under No-till and, more specifically, growers didn't experience the same degree of lower yields in poorer years.

2. No-tillage allows you to manage both extremes of the weather cycles; there is greater chance of establishment in drier conditions; better water infiltration compared to tillage; but selecting the right conditions in which to drill is critical.

3. Maintaining and focusing on improving Soil Organic Matter is the building block and barometer to success, the protective shield to the soil, and the engine room to soil biology.

4. Rotation is vital for introducing greater diversity and balancing carbon levels. This plus the use of cover cropping for nutrient retention and water management allows No-tillage to be employed more successfully.

5. Drill choice is critical and a lower disturbance disc drill with the ability to place seed in a clean zone with localised below-seed loosening is the pinnacle. The drill is a component of the whole system and soil type and level of cover, plus point of adoption should drive the decision making process.

14.0. Recommendations

The knowledge bank across the world and the growing number of people adopting No-tillage in the UK has given me the confidence that, regardless of the season and climatic conditions and with a "can do" attitude, No-tillage is indeed a no brainer.

1. Take a step back and look at what are the most challenging drilling conditions that you can face, and customise your cropping.
2. Look at the overall rotation that will allow you to direct drill sequential crops that balance carbon and avoid potential pitfalls of consecutive high carbon crops.
3. Use cover crops as a structural and water management tool, focus on what the cover crop is giving back in terms of structure, organic matter and nutrient capture, and avoid the trap of looking for direct returns.
4. Great care and attention are crucial for understanding the impact of decaying cover crop material and the timing of cover crop destruction, especially ahead of spring crops when the soil surface may take longer to dry.
5. In wet conditions waiting for a dry surface crust is crucial to the success of a direct drill. This may prove more difficult in the autumn as days become shorter compared to the spring and emphasises why a balanced system can allow for September drillings in optimum conditions.
6. Understand the weed dynamics of the farm and the impact of different drills and limited rotations; be weed smart!
7. Establishment is everything; the windows are greater, but choosing the day is the devil in the detail.
8. Do not rely solely on cover crops to sort out higher levels of compaction; sub-soiling can be a more instant fix for a longer term gain and is not against the rules.
9. Choose the drill that is right for your farm and situation; understand its limitations and how it can cope in both ends of the weather scale.
10. Don't expect instant results in year 1, if there are, great! But remember the four stage process and that cost savings are the added bonus from adoption of the system from everything else that goes with it.
11. Remember there is no right and wrong way, no wrong or right drill; there are some machines which tick all the boxes, but it is what suits an individual farm and an individual budget.
12. Attitude and willingness to make the system work are the sure signs for success!

15.0. After my study tour

Although we have played around with a form of direct seeding - albeit not the purest - on the home farm for a few years, I have certainly returned from my study tour buoyed with enthusiasm and left in little doubt that the changes we need to make are for the better.

Initially on farm we have started looking at over-winter cover crops for the first time, ahead of both winter and spring barley, and have instantly had greater success compared with fields which have only been cultivated. The water management through the soil profile was far superior, with a better friable layer underneath and, in complete contrast to the cultivated field, it dried out more quickly, although we had to be patient with the start date for drilling.

However, we found drilling conditions were far better, more friable and benefited from the better moisture retention at drilling compared to moisture loss at cultivation.

Figure 38. Mulika spring wheat on the home farm, direct seeded after an overwinter cover crop

Apart from the structural and moisture management benefits we have also seen an additional 40 kgs/ha of Nitrogen captured by the cover crop - confirmed by the N-Min soil analysis results - backing up the claims of various people I encountered. It has certainly opened up a whole new and exciting chapter in the way we farm and, as a result, our cover crop area will be increasing ahead of all spring crops for this coming year and we will be looking at different types of mixes as, in the first year, the benefits have been so clear to see.

The next step will be to look closer at our choice of drill and looking very closely at low disturbance disc drills, due to the history of some of the other land that may not be quite ready for full No-tillage. A tine-based direct drill will still have a place in the short term.

I always considered the acid test on our heavy soil would be the soil condition in the spring and it has been better than anticipated. This has made the decision making process re adopting new techniques far easier since the first results have been so clear and defining.

We have always focussed on good soil management and improving the structure, but now we are in a position to move to the next stage. Coupled with a better understanding of what a balanced rotation is, ours is naturally evolving, whilst helping in our annual battle with blackgrass!

The momentum that is growing In the UK to succeed with No-tillage is amazing to watch and, seeing how the understanding has changed, there is greater confidence that the system can be successful; certainly from the early stages I am seeing no reason to want to turn back.

My mantra has always been to have an establishment system that takes reliance on weather for creating or manipulating a seedbed out of the equation. That system is clearly No-tillage and mitigates the risks associated with changing weather, plus it brings so many added benefits that cultivations cannot provide.

16.0. Executive summary

The weather always seems to be the subject most discussed between farmers: too wet, too dry, not enough rain, too much rain - and this invariably links in to the factors affecting the ability to get a crop sown in the ground into an optimum seedbed.

Two separate seasons of contrasting weather convinced me that, in some seasons, cultivations in wet soils were actually doing more harm than good and in dry autumns they weren't actually needed in the first place: moisture retention was far more important. From my experience, in both of those situations direct drilling could work and I wanted to find out how the most successful practitioners of No-tillage succeeded in challenging climates and how they managed their technique in both wet and dry seasons.

I chose to visit Australia as the ultimate dry challenge, with Tasmania and New Zealand offering a different perspective with higher rainfall and, in the case of New Zealand, conditions more akin to what we experience in the UK. The USA gave a balanced perspective of both conditions. Brazil and Argentina, being early adopters of No-tillage but having to manage severe weather that causes untold damage from erosion, were a barometer of how to manage No-tillage in a tropical climate.

What I soon discovered was that No-tillage was providing the opposite to what is sometimes commonly associated with direct drilling in the UK; that water infiltration was greatly improved and there was less pooling on fields as a result of this. The fact that farms in drier regions were able to retain water better, but also weren't suffering from flooded fields either, spoke volumes. The icing on the cake was that they all spoke of more stable crop performance and, importantly, in a difficult season they were not experiencing the low points associated with cultivation.

I also discovered the value of cover cropping within the rotation, what it can do, and also the importance of balancing carbon correctly within the rotation, crucially understanding why rotation is so critical. Organic matter and improving organic matter was shown to be the central cog that drives everything and improving organic matter levels was crucial as they can be depleted so easily. But it was also clear that compaction was a growing issue in some areas and required addressing to allow unimpeded root access. The best farmers were acknowledging the issue, others chose to ignore it completely, and those using No-tillage considered that their crops could sustain growth for longer in very dry periods.

I am left with little doubt that No-tillage has evolved and morphed into a better system than that of the era of the 1970s and the basic facts are clear to see: direct drilling is a far more stable system for crop establishment and management. The introduction of cover crops adds a whole new dynamic to the situation and, with the right rotation, a focus on increasing soil organic matter, the attitude and understanding that patience is crucial, No-tillage has re-entered the building.

17.0. Acknowledgements and Thanks

Firstly I would like to thank my wife Ellie who encouraged me to apply in the first place. She has been so supportive whilst I have spent the best part of 3 months travelling across the world: it has been tricky at times especially being away from my two children Lily and Sam. Coupled with having to endure the times when I have found writing difficult, she has been a rock throughout the process and I wouldn't have been able to experience what I have without her fantastic support back home. But the internet and Face-time certainly made life easier on the road!

Big thanks to my father-in-law and the team at John Sheard Farms for holding the fort whilst I have been away.

I would also like to thank Rebecca Geraghty and AHDB for their sponsorship which allowed me to experience this wonderful opportunity, and especially Eleanor Perkins for your help with editing my blog posts!

Thanks and much appreciation to my fellow Scholar, Mark Bowyer, my travelling companion in South America.

Last but by no means least, the Nuffield Farming Scholarship Trust as, without them, none of this would have been possible.

UK & Europe

Brian Reynolds, a long time mentor and inspiration and some great contacts in North Carolina!
Jim Orson, for your help with establishing contacts in Australia
Simon Cowell, a heavy land farmer proving No-till has no boundaries
Michael Horsch, Richard Godwin
Will Vaughan-France and the team at Monsanto, beyond the call of duty with contacts in South America
Bayer Crop Science, Syngenta & Nidera for their support
Juno McKee for her time spent on a very thorough proof reading!

Australia

Victoria: Victoria No Till Association, especially Kerry Grigg who organised some brilliant meetings. Tim Pilkington, Troy Missen, Chris Drum, Ash & Peter Teesdale, Paul Oxbrow, Alistair Murdoch, Simon Craig, John Ferrier.
Adelaide/Clare Valley: Allan Mayfield, a terrific host, boundless energy and organising some brilliant visits and a fine athlete! Jack Desbiolles, fantastic research in No-tillage systems, Ben Marshman, Steve Wicks, Darren Longmire, Greg Butler (SANTFA), Steve Wicks, Steve Matchosz, Ben Wundersitz, Caroline Roenfeldt, Brett Roberts, Bob Nixon (NScH), Nick Gillett (NScH), Ty Kirby, Trevor Syme, Audrey Bird,
Stephen Powles, Mike Ashworth and Qin Yu from AHRI, outstanding research and dedication
Tasmania: Greg Gibson (NScH), Michael Chilvers (NScH), Angus, Askin Morrisson, Jay

New Zealand

Dean & Sara Syme, Mark Scott, Andrew Smith, Roger Lasham, Jason Thompson for all your help organising meetings, Morgan Horrell, John Baker & Bill Ritchie at Cross Slot, Douglas Giles

United States

Antonio Cinti Luciani at Open Grounds, a stunning large scale enterprise in a stunning location
Gabriele Onorato, Mark Elliot, Mike Thompson and the team at IFC, Kriss Young, Michael (Texas), Ron Heineger and Allan Meijer at the Vernon James Institute. Kent Kinkler
Dwayne Beck at South Dakota Lakes research farm, Jay Fuhrer at NRCS, Marlon Richter, Steve Groff

Brazil

Jennifer Ralston, Jose Barioni, Guilherme Buck, Lucas Oliveira, Fabricio Bazanella - without your help none of the outstanding visits would have been possible especially with your hospitality and translation!
Gabriel Junquiera, Carla Dutra, Vivian Uemura, Luis Schuster, Ivan Schuster, Renato Trentin and the team at Razera Agricola, Nestor Canali, a beautiful location, outstanding crops and No-till farmer, Marielle Pickler & Sally Thompson for organising a great week of visits, hospitality & superb translation, Maicon Thomas, Luis Amorin, Volmir Favero, Walmor Tiggermann, Astor Stronchon, Djalma Sousa, Arno Weiss, Jose Carlos Maichaki, Sebastiao Conrado, a trio of some fantastic No-till exponents

Argentina

Alejandro Giradi, Gustavo Meyer, Juan Reichart, Maria Del Pilar Samaria Tiscorina, Fernando Delfino, Martina Kirszman & especially Cruz Goti - thankyou for helping to organise some terrific visits and once again your help with translation! Eddie Nolan, Luis Sabbatini, Juan Pablo Mocorrea, Bernardo Romano, Mauricio Davidovich, NIco, Paulo and Ignacio.

Apologies to anyone I have forgotten, but finally to my Mum and especially my Dad who have always believed and encouraged me to pursue my career in agriculture, this is for you!

18.0. Reading lists

Direct Drilling & Reduced Cultivations (1981): Harry Allen

Disc seeding in zero-till farming systems (2010): Mike Ashworth, Jack Desbiolles & ElKamil Tola

No-tillage Seeding in Conservation Agriculture (2007): C J Baker, K E Saxton, W R Ritchie, W C T Chamen, D C Reicosky, M F S Ribeiro, S E Justice & P R Hobbs

Situational analysis of No-tillage systems in WA & recommendations for the way forward (2005): Rolf Derpsch & www.rolf-derpsch.com:

www.nrcs.usda.gov

Soil friability: theory, measurement and the effects of management and organic matter content (1998): C W Watts & A R Dexter

Avoiding sidewall compaction at planting-Don't plant too shallow (2007): Jasal