High Residue Zero-till Farming Systems in Central West NSW: the Strip and Disc System

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Richard Quigley, 2020 Scholar
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Executive Summary

The strip and disc farming system is intended to maximise crop residue by reducing disturbance to crop material resulting in delayed decomposition.

From the research and findings observed while travelling as well as experiences on the authors own farm (due to travel restrictions from Covid19), it can be concluded that the strip and disc farming system will increase ground cover and crop residue on the soil surface when compared to traditional zero tillage farming systems. With this comes a range of benefits including increasing infiltration and storage of rainfall and increasing water use efficiency to grow more crop per drop. This will increase profitability of farmers, particularly in moisture limited environments. The system is not without its challenges, but these can be overcome with management techniques and agronomic advice. More research must be done to quantify the benefits as well as an economic analysis to provide clear economic benefits.

The strip and disc system is compatible with sprinkler and drip irrigated cotton, as well as dryland cotton production by increasing moisture storage and water use efficiency and profitability, but not with conventional furrow irrigation due to the tillage requirements of the system.

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Foreword

Alongside my family, I manage a mixed farming enterprise consisting of sprinkler and furrow irrigated cotton, dryland wheat, barley, chickpeas, canola, and opportunity dryland cotton. We also have a grazing operation focused on breeding and finishing sheep and cattle. We are based near Trangie, and central west, NSW, Australia.

In 2016 we demonstrated a Shelbourne XCV42 stripper header in 5 tonne/hectare (t/ha) wheat through our Shelbourne dealer Hutcheon and Pearce. We were pleased by the stripper concept, the long straw and the benefits, but could not reduce large loss (~ 250 kgs/ha or 5%) from the combine harvester, without having made any modifications to the combine rotor. This was in the middle of a well above average winter crop harvest with weather pressure looming time was scarce. Many changes to concave modules, and adjustments with rotor speed and concave clearance, fan and sieve settings without any significant change. With the pressure of harvest, the decision was made to revert to the draper header and continue harvest after a full day of trialing the Shelbourne stripper header.

From 2017-2020 the eastern side of Australia suffered from severe drought. The vast majority of crop residue ground cover was lost, considerably worse in paddocks grazed by livestock. Many areas suffered moderate to severe wind erosion. These conditions hindered infiltration of the limited rainfall received during this period, and indeed when the drought broke in March 2020. During the drought, stripper straw would have significantly reduced the effects of wind erosion protecting soil and would have increased the infiltration of the little rainfall received. It was the drought that encouraged me to apply for a Nuffield Scholarship to research and adopt the strip and disc farming system. I was accepted as a scholar in 2020 but our travel was postponed for two years due to Covid19. This hindered travel but did not stop us researching and implementing the strip and disc system whereby Quigley Farms purchased two stripper fronts for use in the harvest of 2020. Our strip and disc farming system was fully adopted across the farm and we have not looked back.

Some experiences in this report are based off our own learnings from adopting the strip and disc farming technique across both rain grown dryland, and irrigated farming systems, although personal study time was completed on a Global Focus Program and individual study in the USA in 2022/23, as details in Table 1.

Table 1. Travel itinerary

Travel date	Location	Visits/Contacts
Week 1 November 23, 2019	Marrar NSW	Daniel Fox Matt McKinley
Week 2: March 2020	Brisbane QLD Stradbroke Island	Contemporary Scholars Conference
Week 3: June 6, 2022	Singapore	*Global Focus Program* Singapre markets ANZ Singapore Louis Dreyfus Company Meat and Livestock Australia
Week 4: June 10, 2022	France Loire valley	*Global Focus Program* Fromagerie Maurice Fromages D'Angel Rouge Des Pres

Week 5: June 15, 2022	England	*Global Focus Program* Cranfield University Adam and Lauren Banks insect protein British Chlorophyll Allerton research farm Meon Springs Allerton Project NIAB – National institute of Agricultural Botany Goodwood farm Rathany estate
Week 6: June 23, 2022	Alberta, Canada	*Global Focus Program* Steve Laroque Mountain view Colony Hilton Ventures Lyall, Ed and Phillip Miller Price Family Rimrock Cattle Co Sunterra Farms grocery store Beck Farming Kevin and Lauren Nixon St. Mary River Irrigation District Perry Farms
Week 7: July 1, 2022	Washington DC, USA	*Global Focus Program* Foreign Agricultural service Natural Resource Conservation Service USA Department of Agriculture Bayer
Week 8: July 6, 2022	Iowa, USA	Tyrell Bennet Amana Farms Nick Mayer Henry Shepard Ruth Mcabe Heartland co-op USA Department of Agriculture Kurt Laymen O'Connell Organic Acres Couser Cattle Company
Week 9: July 24, 2022	Northern Territory and Western Australia, Australia	Bruce Connelly, Tipperary Station Douglas Daly Research Farm Sam McBean Brendan Griffiths Russel Keeley, Trevor Bass, Nick Bass Matt Stott, Steve Buster KAI, Jim Engelke & Luke McKay Petter Cottle CGS Jason Learch Matt Grey Fritz Bolten

Week 10: August 15, 2022	Broadbeach QLD	2022 Australian Cotton Conference
Week 11: February 21, 2023	Moree, Gunnedah, Dandaloo, NSW	Sundown Pastoral Keytah Andrew Watson Bill Ferguson/Matt Farley
Week 12: July 6, 2023	Memphis, Tennessee, USA	Louis Dreyfus Company Adams Cotton Gin USDA Classing House
Week 13: July 10, 2023	Mer Rouge, Monroe, Louisiana, USA	Allan Spires Jake Perry Maclendon Sharp Double M Farms
Week 14: July 16, 2023	Hugo, Colorado, Denver, USA Clarendon, Panhandle, Lubbock, Texas, USA	Kalcevic Farms Poss Farms High Plains Harvesting Walker McAnear Lance Williams Dan Taylor – Busters Gin
Week 15: July 26, 2023	Blythe, California, USA	Michael Mulligan
Week 16: August 1, 2023	Dubbo, NSW	Weedsmart Dubbo Conference

Acknowledgments

I would like to thank the following for their support through my Nuffield journey. Without them, it would not have been possible.

Firstly, I would like to thank my co-sponsors, the Cotton Research and Development Corporation (CRDC) and Cotton Australia, and most importantly the levy paying cotton growers of Australia that have contributed to funding for my research. Hopefully my report can add value to your farming business. While this project is not primarily focused on cotton growing, but rather looks at the whole farm business of which wheat and other rotation crops are a key component, as well as the efficient storage of moisture in fallows for cotton production and increased water use efficiency.

I would like to thank Nuffield Australia for facilitating my Nuffield journey and creating the opportunity to travel and research across the world. A lot of time and energy has gone into organising our travel and experience. This also includes itravel in Griffith for organising transport for our Global Focus Program.

I thank the team at Quigley Farms for continuing operations on the farm and covering for me in my absence. This also extends to Tony, Sally, Tom and George Quigley and their families. I hope to share my learnings and journey with you all.

To all the beautiful, hospitable people who have hosted me on this journey. It has been greatly appreciated and look forward to returning the favour when you come to visit in Australia.

Next, I would like to acknowledge the Louis Dreyfus Company for their support, and generosity and engaging with their contact network during my travels. As well as my great friend and travel buddy, Billy Browning. We have had the trip of a lifetime together.

Also, the strip and disc family in Australia, including Dan Fox, Greg Condon, Charlie French and Brett Cumberland to name a few, as we learn and grow together. As well as our agronomy team led by Chris McCormack with help from Hamish Job.

And finally, to my beautiful wife Alexandra. Thank you for encouraging me to apply, joining the travels and your unconditional love and support. It has been such a rewarding journey and I have valued every second of it.

Furthermore, thank you to all the wonderful people that we have visited, who have hosted us and gifted us with their time and knowledge. Without all of you it would not have been possible to complete my research and report, so from the bottom of my heart thank you! And if I can help in any way or if I can return the favour, please reach out.

Abbreviations

CRDC	Cotton Research and Development Corporation
CTF	Controlled Traffic Farming
GPS	Global Positioning Systems
GRDC	Grains Research and Development Corporation
Ha	Hectare
IPM	Integrated Pest Management
Kgs/ha	Kilograms per hectare
Kgs/mm	Kilograms per millimetre
NSW	New South Wales
PAW	Plant Available Water
PWM	Pulse Width Modulation
PSPE	Post Spraying Pre-Emergent
QLD	Queensland
RTK	Real Time Kinetic
T/ha	Tonnes per hectare
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
USA	United States of America
WUE	Water Use Efficiency

Key Terms

Zero Till	Farming practices where tillage is not used in crop production, and minimal soil disturbance is achieved while seeding the next crop.

Objectives

The objective was to investigate how to retain crop residue for longer in zero tillage farming systems, as well as the benefits and challenges associated with this. This included research systems and practices involved in achieving this, with topics of interest including:

- stripper headers (fronts)
- seeding practices that manage to plant through high residue loads
- combine set up to allow for stripper header use with acceptable grain loss
- fallow efficiency
- soil health
- crop competition and the mulch effect
- soil temperature and frost
- nutrient tie up
- disease inoculum from previous year’s crop residue
- herbicide and fungicide options and applications
- how high residue systems coexist with irrigated and dryland cotton production
- cover crops
- weeds

Chapter 1: Introduction

Dryland crop production systems in the arable zones of Australia are commonly production limited by climatic factors including moisture availability, incidence of frost events at flowering, and high temperatures or moisture stress during grain fill (Barlow et al. 2015). Low moisture availability and heat stress are particularly common in New South Wales (NSW). Over the years, new agronomic management practices and technology have been developed and widely utilised to reduce the effect of these climatic factors, allowing growers to achieve remarkable yield increases and efficient utilisation of inputs (Turner & Asseng 2005).

One major strategy to combat moisture availability has been to store rainfall in the fallow period (the period between the harvest of one crop and the planting of another) for utilisation in the following crop, increasing the Plant Available Water (PAW) to that crop from stored soil moisture.

Protecting fallow moisture has been a long-time focus of grain crop production, but over the last 20 years has moved from predominantly tillage practices to the chemical control of weeds, resulting in the zero till or minimum tillage adoption of modern Australian grain growers.

The ‘no till’ movement has been driven by technology gains increasing the ease and efficiency of chemical applications, including Global Positioning Systems (GPS) autosteer and automatic rate controllers. In recent years, this has been further enhanced by section control, Pulse Width Modulation (PWM), and optical sprayers. These spraying advances have been coupled with Controlled Traffic Farming (CTF) and inter-row or on-row seeding, to give modern grain production in Australia. Modern Australian grain farming practices have advanced through research, development and uptake of technology, agronomic management and varieties, on results-based performance.

As Australian grain farmers are efficient and world leading in their management and operations, all gains in productivity and cost savings going forward will be minimal, as these are the 1% gains that cumulatively make a significant difference. This will be the case until new disruptive technologies are developed and implemented.

The no-till movement has been a significant yield enhancer for grain producers and is now widely adopted across the industry increasing fallow moisture, reducing erosion, increasing water use efficiency (WUE), and most importantly, increasing yields.

However, agronomic opportunities still exist to capture and store more water, reduce evaporation, and use PAW more effectively. Kirkeggard and Hunt (2010) in their work listed residue management, crop sequencing, and weed control to name a few.

Residue management to increase fallow efficiency is a key focus of this report and this research, focusing on stripper headers harvesting cereals and the opportunities and challenges provided by the implementation of these practices.

Chapter 2: The strip and disc system

2.1 Stripper header (stripper fronts)

A stripper header is a type of combine harvester attachment (front) used to harvest cereal crops such as wheat and barley, oats and rice. A stripper header is designed to strip the grain from the plant stem, leaving most of the plant material remaining standing in the field. Stripper headers consist of a rotating drum or rotor with rows (8) of stripping fingers. The drums containing the rows of fingers rotate at high speed (400-700 RPM) and strip the grains from the stem as the stripper header passes though the crop. The stripped grain and some crop residues are then thrown up against the hood towards the rear of the header where they are transported towards the harvester feeder-house via a table auger, and into the harvester. A large proportion of the crop is threshed by the action of the stripper header passing through the crop, resulting in the harvester becoming largely a separating unit, separating threshed grain from the crop residue. The stripping process significantly reduces the amount of material that passes through the harvester as most of the plant material remains behind in the field. This offers significant advantages of reducing engine load, horsepower usage and fuel burn, increasing harvesting efficiency compared to traditional harvesting methods of a draper or table auger header (front).

Shelbourne Reynolds is currently the most common stripper platform on the market (2023). They have been manufacturing stripper headers since 1989. Since 2012, they haveproduced an xcv42 model that is 42 foot wide. This particularly suits the popular 12-meter CTF swath width widely adopted by Australian farmers. Two manufactures have also started to produce stripper headers, Applequist Manufacturing in Kansas (USA), and Khart Industries in Saskatoon, Canada.

2.2 Conventional harvesting and residue spreading

Traditional methods of cereal harvesting cut half the plant off and feed it through the harvester to then thresh and separate the grain from the plant material, predominately using crop on crop threshing techniques in rotary combines. The combine then attempts to spread the cut plant material back across the swath width, which is often not achieved satisfactorily. An even spread of residue across the full swath width is crucial but is rarely achieved with factory residue spreaders. This is exacerbated by the adoption of large 12 metre swaths, and not possible at this point with larger 18 metre swath widths without aftermarket belt extensions to more residue spreaders further out from the combine, or specialty aftermarket choppers.

If residue is not spread the full cut width, issues arise from the uneven distribution of crop residue including:

- plugging of seeders at seeding
- different moisture levels across the swath at seeding, making uniform broadacre seeding difficult, and
- uneven distribution of nutrients across the swath width

Residue spreading was one of the contributing factors in choosing to adopt the stripper disc system. The windrow of thick straw/chaff that landed one metre inside the extremities of the 12 metre cut width often gave us issues at seeding and poor establishment as illustrated in Figure 2.

Wheat straw by weight comprises 0.76% nitrogen, 0.05% phosphorus, 1.14% potassium (Pulske *et al*. 2018). If the harvester cut the straw at 50% of its height during the harvest process and didn't spread it to the edges of the cut width and the straw fraction was 5t/ha this would mean a removal of 2.5t/ha of crop residue including 19 units (kgs) of nitrogen, 1.5 units (kgs) of phosphorus, and 28.5 units (kgs) of potassium. The difference would be greater than this as the remainder of the cut will have more than its original biomass increasing its nutrient loading. If this happens consecutively over several years on GPS CTF tramlines, then it could lead to serious nutrition inequality across the swath and the field.

In the case of a legume like faba beans that can fix upwards of 200 units (kgs) of nitrogen per hectare (ha) in a growing season and are often selected as a crop choice due to their nitrogen fixing ability. If this crop residue is not spread evenly then so too are the nutrients across the swath.

Uneven distribution of plant residue by factory residue spreaders (from 50-200%) also provides differences in soil moisture levels across the swath width, and thick thatches of chaff that incur challenges at seeding and plant establishment. This creates challenges at seeding with some row units being too wet and some too dry compromising seeding performance, as well as providing trash flow issues and 'hair pinning' (when a disc cannot cut through heavy layers of chaff resulting in poor soil seed contact).

Figure 1 Poor spread pattern of factory residue spreaders, showing the uneven distribution of plant material across the swath width. (Source: Rhylie Botheras)

2.3 Disc seeders

Single disc seeders are minimum tillage seed drills that utilise a sharp disc running on an angle of approximately 5-7^{o} to cut a slot in the soil, place the seed and close the slot. They are often required for paddocks with high residue loads due to the sharp disc that cuts through the soil also cuts through the crop residue, allowing for good seed soil contact. Where straw is long and whole this process occurs easily. However, if a harvester has not distributed crop residue evenly across the full cut width, the thicker layers of straw of chaff cause hair pinning of the residue around the disc and prevents good seed soil contact and seed germination, as shown in Figure 2.

Figure 2 Poor spread pattern of factory residue spreaders with uneven distribution of plant material across the swath width, and subsequent poor crop establishment (Source: Author)

The rolling nature of disc seeders allows for long residue to pass through the machine without catching on static components. This is a huge advantage in seeding crops into high residue environments. In contrast, the static nature of a tyne seeder makes seeding into high residue fields very challenging and often results in burning stubbles. The tynes can act as rakes raking residue into piles and plugging the seeder, preventing it from doing its job. Residue handling on tyne machines can be aided by the addition of disc coulters, which run engaged in the soil just in front of the individual tyne unit and aim to cut the longer pieces of residue to make them shorter to allow the residue to pass through the machine and avoid residue raking. Tyne seeders often require high residue loads to be mulched, slashed or mown into smaller pieces in order to handle them at seeding (Figure 3).

Figure 3 Slashed (or mown) wheat straw for trash flow purposes (Source: Author)

This is often the case with cereal and canola stubble. The use of a disc seeder will not guarantee getting through extremely large stubble loads, however, will significantly help.

Double disc planters are also an effective planting tool in large residue loadings, as shown in Figure 4. Double disc planters work in a similar context to single disc planters but have two opposing discs each running at a 5-7^{o} angle, each with a gauge wheel to set seed depth. Traditional row crop precision planters are double disc machines. Double disc planters are usually more prone to hair pinning because of the larger surface area provided by two sets of blades touching. However, this can be minimised if discs are offset, slightly different sizes or one is scalloped or fluted allowing the discs to travel at different speeds or angles creating a more distinct cutting edge to cut trash.

The most common disc seeders utilised in strip and disc systems in Australia seem to be the single disc units, in particular the John Deere 1890 Single Disc, NDF disc planters, Excel, Serafin and Boss row units to name a few.

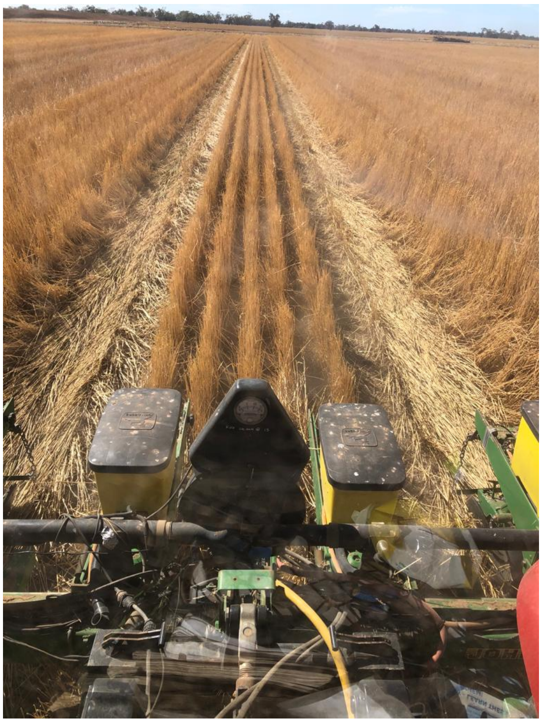

Figure 4: A double disc planter successfully inter-row planting through a large, stripped stubble load (Source: Author)

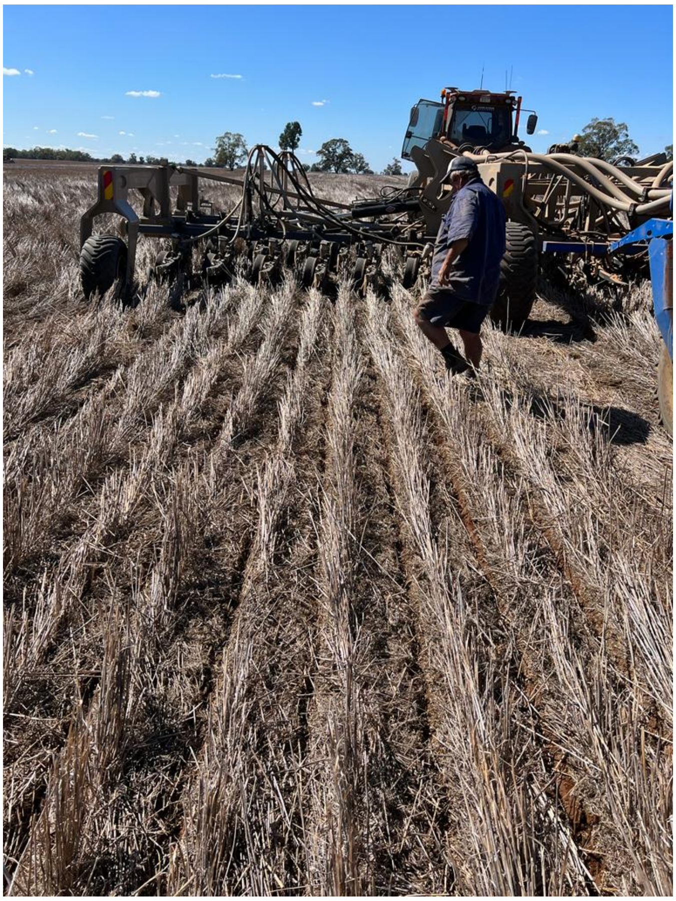

Figure 5: Canola sown into two consecutive years of wheat stripper straw at 2kgs/ha with a NDF single disc planter that established 20-30 plants/m^2 to grow 3.3t/ha of canola, highlighting the high trash flow capabilities of single disc planters when using inter-row planting with a high degree of accuracy (Source: Author)

Chapter 3: Benefits of the striper header

3.0 Harvester efficiency

Due to the nature of stripper headers only the grain, husk and leaf material are stripped for processing by the harvester. Thus, stripper headers have been shown to increase throughput efficiency by between 30% and 50%, and even 100% in some cases. Every grower visited in Australia and across the world has attested to an increase in harvester capacity and efficiency, and there is more to be done in this space to increase capacity whilst maintaining and reducing losses.

The capital purchase of a stripper provides a very cost-effective increase in harvester capacity, especially when compared to another harvester. Many growers also stated that the increase in harvest efficiency and reduced engine loading has allowed them to reduce one combine class size, often resulting in an AUD $50,000-$100,000 capital saving by adopting a stripper header. Growers also noted the reduced wear, repair, and maintenance on machines due to only processing the grain and chaff fractions of the plant, and not having to feed the remainder of plant material through the machine.

Harvester efficiency was also observed by the ability of the strippers to start harvest earlier when straw was still partly green and allowed the stripper headers to harvest much later into the night or '24 hours' because they did not have to process damp straw that would stop conventional draper headers from harvesting. This creates a huge amount of value in situations of weather pressure, by providing more operating hours in the day (in some cases, up to 40% more).

Large gains in fuel efficiency have also been gained from not having to process the straw fraction in the harvester. Engine loads often did not exceed 65-70% and result in burning considerably less fuel (50% in most growers' experience), combined with increased harvesting speeds further reducing cost per hectare and per tonne harvested. The fuel saving over 200 separator hours of harvest would be considerable towards repaying some of the initial capital cost of the stripper header (particularly with current diesel prices over AUD $2 per litre, 2023).

A correct harvester setup with a stripper header typically sees 0.5-2% loss, half of that from the stripper header itself and half from the harvester, which is viewed by the industry as an acceptable loss. There is room to improve this and will be a key focus of growers in the future. Factors affecting stripper header loss include row spacing, crop density, yield, hood height, finger orientation, and combine forward speed.

Correct combine harvester setup for the use of a stripper front often requires significant modification but depends on the combine harvester type. The Shelbourne Reynolds app and website provide modification and setting recommendations. In the author's experience, these have been a good starting place but still require more fine tuning and further research to get full efficiency and minimal losses.

Experience with stripper headers has predominately focused on Case IH Flagship Combines, as shown in Figure 6, which require the implementation of 12 straight separator bars, spiked rasp bars in the rear of the combine, hard thresh in concave Module 1, followed by round bar concaves in Positions 2, 3 and 4. Additionally, the rotor veins are in the slowest position and included 10° threshing elements over the front half of the rotor. This setup is largely courtesy of Daniel Fox of Marrar, NSW.

Figure 6 Modifications to a Case IH Flagship rotor threshing elements, including straight separator bars and 10° rasp bars (Source: Author)

Figure 7 Case IH Flagship Combine LHS rotor with hard thresh helical concave in Position 1, and round bar concaves in Position 2, 3 and 4, with paint removed from grain separation in Position 2 round bar concave after only one season (Source: Author)

The stripper header relies on a wall of crop material and the hood to create a shield against the stripping rotor to prevent the stripped grains from exiting out the front of the stripping rotor and onto the ground. Thin plant stands, wide rows (over 350mm) and poor yielding crops are subject to higher losses. Increasing ground speed and decreased hood clearance have been shown to reduce stripper header loss (Wilkins et al. 1996) which is great for increasing productivity.

Reduced ability to thresh grain is an issue with stripper headers in hard to thresh wheat varieties. Typically, rotary harvesters with conventional headers rely on crop on crop rubbing action to thresh the grain from the ear. In the case of a stripper header, there is not a crop-on-crop action due to the lack of straw in the rotor. The system relies on most of the grain being threshed by the stripper header and the combine acting largely as a separator. This has resulted in phasing out hard to thresh varieties like *Spitfire* and replacing them with easier varieties to thresh. This is not without risk though as often easier threshing varieties are more prone to pre harvest losses.

Shelbourne Stripper headers in Australia mostly come with ‘cups down’, meaning that the stripping rows themselves are facing downwards, leaving a more aggressive leading edge facing away from the crop. This is the least aggressive setting. In most places visited in the world (in particular, Colorado and Kansas, USA), many growers run their ‘cups up’ in the most aggressive position, which may aid in harvesting hard to thresh varieties, or cups up/cups down on alternate rows of stripping fingers.

3.1 Fallow efficiency

Fallow efficiency is used to describe the amount of moisture as a percentage or proportion that has fallen in the fallow period and stored in the soil that becomes PAW, contributing to plant growth or yield (Verburg and Which, 2016). In Australia, the term fallow refers to the period between subsequent crops (6-12 months), whereas the term long fallow refers to the skipping of a crop in the crop sequence to store more moisture for the proceeding crop or for other agronomic reasons such as weed or disease control.

There are a lot of complex factors involved in the simple equation of fallow efficiency including soil type, compaction, topography, crop residue, rain intensity, rain days, temperature, timing of rainfall, and weed control. The fallow efficiency of modern Australian grain farmers is typically somewhere in the order of 25% of rainfall that falls over the fallow period that can be utilised by the following crop.

Australia’s climate is extremely variable. This is even more so in the dryland farming region of central west NSW. The region receives between 400mm and 600mm of rainfall on average per year depending on location, but this can vary from >150mm to < 1,100mm. The average evaporation of this region is over 2,000mm, as shown in Figure 9 and 10. Therefore, moisture is most often the limiting factor to rain-grown cash crop production, and whatever can be done to store more moisture and turn it into PAW and production must be done where feasible to maximise yield, profitability and sustainability.

The cropping regions of NSW and southern QLD typically receive significant rainfall (in the order of 60%) in the summer fallow period. These rainfall events need to be stored as efficiently as possible to be put towards the next crop. Winter crops are predominant in these regions due to the much slower evaporation rate during the winter months.

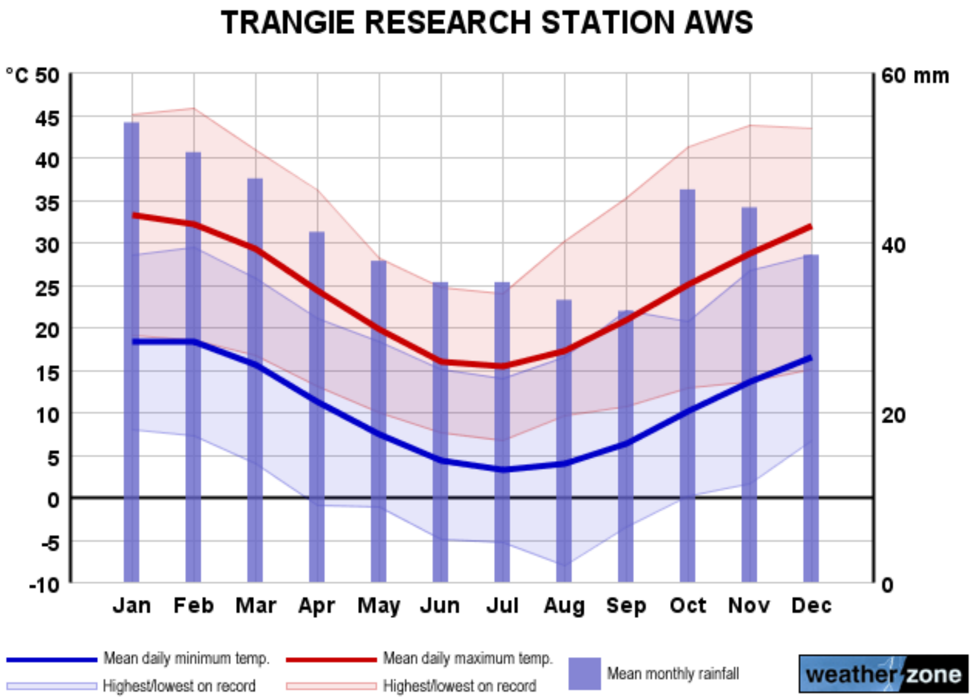

Figure 8 Graph illustrating seasonal averages of Trangie, NSW (source: Weather Zone, ??)

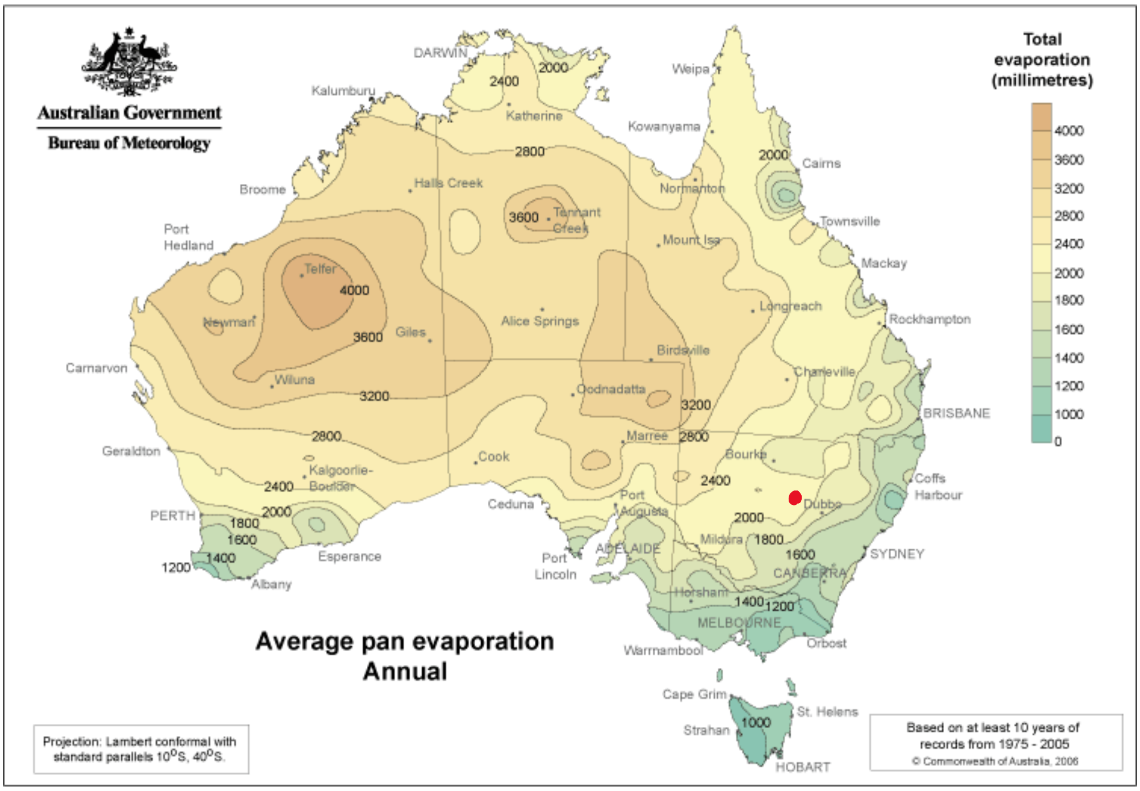

Figure 9 Bureau of Meteorology average pan evaporation annual rates for Australia. We farm approximately where the red dot is located (source: Bureau of Meteorology,??)

Unkovich (2006) investigated the contribution of fallow moisture towards wheat yield over several years in several regions. In central west NSW, they found that summer fallow rainfall contributed up to 2t/ha (or 72% of mean) simulated wheat yield. Highlighting the importance and effectiveness of stored fallow moisture, and not surprising when looking at the average climate in Trangie, in central west NSW, where the author farms. Figures 8 and 9 highlight winter months being the lowest rainfall received on average.

According to Zeleke et al, (2014), the effects of stubble on fallow efficiency showed that as stubble loads increased in fallow fields so too did moisture content and PAW. Their work indicated that a 6t/ha stubble rate can increase the end of fallow period soil moisture by up to 60%. Similar themes have been observed in Texas, USA, where a 4t/ha wheat stubble was compared to a bare fallow. Unsurprisingly there the wheat residue caught nearly 50mm more moisture than the bare fallow (Unger, 1978).

As mentioned above, residue management and ground cover play a large role in fallow efficiency. At the harvest of a cereal crop, there is the same amount of residue if it is harvested conventionally with a draper front or a stripper header. The difference lies in the additional time it takes for the stripper header residue to break down as it has not been broken up into small pieces and distributed onto the ground. The cumulative effect over several years is where the stripper front will accumulate more crop residue. And more crop residue will store more moisture and more moisture will grow more crop, and the cycle will continue.

According to Henry et al. (2008), “the use of a stripper header harvesting cereal grains leaves significantly more standing crop residues that will be retained longer than residues following harvested conventionally with a draper header”. The result is more protection of the soil from wind erosion and greater precipitation storage efficiency during fallow periods. The other thing to note is that draper harvested cereal residue can be subject to relocation via high wind speeds, reducing the amount of residue and moisture storing ability.

3.1.1 Capture and storage of rainfall

Maximising crop residue in dryland farming systems has a large positive effect on the capture and storage of rainfall moisture. Heavy rainfall and large droplets can cause damage to the soil surface blocking pores and infiltration routes and causing surface sealing. The crop residue softens the rain drop impact to the ground leaving soil pores open and undisturbed to allow for high infiltration rates to be maintained and reduced runoff (Hunt, 2011). Crop residue also increases the friction coefficient of water that is in the process of running off. Consequently, slowing water movement down allows maximum time for infiltration into the soil to occur and increases stored soil moisture and PAW. This is even more critical in undulating topography.

Heavy stubble loads (5.4t/ha) have been shown to increase infiltration by 1.8 times when compared to light stubble loads (0.8t/ha) in Temora, NSW (Hunt, 2011), and more than doubled the amount of rainfall required to produce surface ponding or run off. Zero tillage and stubble retention have also been shown to increase infiltration rates of sandy clay loams and grey cracking clays in southeastern Australia from two to 8 times respectively (Bissett and Oleary, 1996). Freebairn and Wockner in their work in 1986, showed they could reduce run off by 35% with zero tillage management in Queensland.

Decreased runoff as a result of surface residue has been attributed to reduced soil crust formation and slowed flow rate across the surface due to greater water flow path disturbance, and greater resistance to flow (Steiner, 1994). Increased residues are responsible for decreased runoff, decreased evaporation, and increased infiltration, resulting in greater precipitation storage efficiency (Unger, 1978).

Not surprisingly, moisture storage was also a key factor in the utilisation of stripper headers around the world. This was the case in the USA, in particular in Kansas, Colorado, Texas and Wyoming, as well as Alberta and Saskatchewan in Canada, to name a few. Not only was this for the same reasons strippers are utilised in Australia to store moisture (as mentioned above), but also to catch snow and prevent it blowing away in their winters. This is an extremely effective way of retaining snow, for it to melt in the spring and increase PAW, as shown in Figure 10.

Figure 10 Conventional draper cut straw on the left-hand side, and stripper straw on the right-hand side in Canada, highlighting the importance of snow catch to crop yields (source: K Hart).

The Kalcevic family, and the Poss family, both in Colorado, USA had adopted the stripper harvesting system in an extremely dry climate of 12 inches, or 305mm. They both found that the stripper harvesting system allowed them to catch more snow and increase their fallow efficiency enough to grow profitable crops in a very arid environment by keeping more residue on the soil surface.

Figure 11 Visting the Kalcevic family farm on the first day of the 2023 wheat harvest with stripper headers, Bennett, Colorado, USA, 17 June 2023, with Billy Browning, the author, and Kent Kalcevic (Source: Author)

The Kalcevics' believed that land in their region was marginal for growing crops due to their arid but high elevation environment. However the stripper headers and zero tillage are allowing them to conserve more moisture and grow profitable crops across a large scale farm near Bennett Colorado. They had downsized a combine class and increased wheat yields with the adoption of stripper headers.

3.1.2 Stripper residue microclimate

Air will dry the soil considerably more than plant roots. This varies between soil types, in sandy clay loams this is 12mm+ and heavy clays up to 42mm due to their cracking nature and increased exposure to air (Verburg and Which, 2016). Standing residue is more effective at decreasing wind speed near the soil surface. The standing residue absorbs more of the wind's energy, raises the zero-velocity point above the soil and can produce a microclimate at the surface. Standing stripper stubble also vastly reduces wind speed and air movement at the soil surface.

Air is a key component in evaporation as it is the vehicle that removes moist air from close to the soil surface. When the air becomes saturated with moisture it will stop drawing moisture away from the soil. If the moist air is moved away from the soil surface (wind or air movement) it is replaced by drier air that has greater osmotic potential to remove more moisture from the soil or plants. Wind is a major driver in evapotranspiration rates, and so will protect seedlings until they grow out of the canopy layer (Verburg and Which, 2016). This concept cumulatively reduces evaporation over the fallow, increases fallow efficiency, and provides moisture more efficiently for use in subsequent crops. This concept is seen in conventionally harvested cereal crops, but to a lesser extent as stubble height is considerably shorter (30cm vs 90cm).

Figure 12 Conventional draper cut straw on the left-hand side, with stripper straw on the right-hand side, Canada (Source: K Hart)

Cereal harvesting methods can greatly influence residue amount and orientation, and subsequently soil water evaporation during the fallow period. McMaster et al. (2000), showed that soil water evaporation could be reduced by 20 to 50% as wheat harvest cutting height increased from 10cm to 50cm. A conclusion could be derived from these results that stripper straw should perform better again at reducing evaporation.

However, it should be noted, that stubble will not prevent all evaporation, it will just slow the rate of evaporation down. The more stubble, the greater the reduced rate of evaporation. Increased fallow efficiency comes from the soil surface taking much longer to dry out, allowing subsequent rain events to build on previous rain events to pulse deeper into the soil profile away from the evaporative zone in the soil (0-20cm). As evaporation rates change throughout the seasons, so too does the effectiveness of cover in storing moisture, significantly increasing in autumn, winter and spring, and reducing in summer months as a rule of thumb.

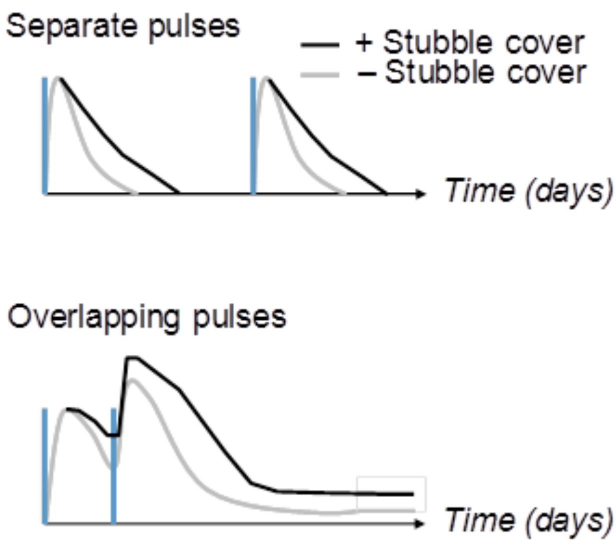

Figure 13 Rainfall events (vertical blue bars) cause pulses of soil water that last for different amounts of time in the presence (black lines) or absence (grey lines) of stubble (Source: Verburg & Which, 2016)

Figure 13 has been adapted by Verburg and Which and does not account for stripper stubble. When rainfall events overlap, more water infiltrates beyond the evaporation zone in the presence of stubble cover, and this will increase fallow efficiency. The level of stubble cover will directly impact this equation (Verburg and Which, 2016).

Another benefit of standing residue and slowing wind speed at the surface is that it will significantly reduce wind erosion, preventing much of the normal avalanching of soil material downwind (Woodruff et al., 1972 and Van de Ven et al., 1989). Wind erosion is a significant issue in Australia, particularly in droughts or dry times. Smika (1983), measured a 74% reduction in wind speed at the soil surface when standing wheat residue height was increased from 30 to 60 cm. Consequently, there may be significant differences in soil erosion depending on residue amount, type, quality, and orientation. This will be particularly important in droughts where planting rains are not received and ‘forced fallows’ occur.

3.1.3 Mulch effect

The stripper disc system can lead to large quantities of residue accumulating over several seasons. This provides a physical layer that prohibits weeds from germinating successfully, reducing weed seed populations and reducing weed numbers. This theory of crop competition and the mulch layer was mentioned at the Weedsmart Conference in Dubbo, NSW as ‘one of the big six’ modes of weed control (Condon, pers. comm., 2023). The straw in the inter-row also increases crop competition via shading and mulching mechanisms. This is a very effective way of combating weeds with a non-chemical option that is also extremely cost effective at basically no cost. An important consideration moving forward with growers’ environmental stewardship. The increased availability of moisture to weeds that do germinate provide better conditions for weed growth and subsequently easier to kill weeds that are actively growing and subject to less stress.

Figure 14 The mulch effect on crop residue at Poss Farms, Hugo, Colorado, USA, July 2023 (Source: Author)

3.1.4 Soil temperature

Increased levels of crop residue provide a layer of insulation for the soil. The remaining residue acts as a protective layer against direct sunlight. Residue is generally light in colour consequently reflecting sunlight radiation back into the atmosphere, rather than it being absorbed by the soil surface. This offers a significant advantage to collection, storage and longevity of stored soil moisture, particularly in summer as soil temperatures have been noted to be 10^{o}C + cooler in stripper stubble vs draper stubble, and 20^{o}C more so over tilled or bare soil (French, Fox, and McKinlay, pers. comm., 2019).

3.2 Planting timing

Timing is crucial in any cash crop production business. Long-term research in wheat has shown that for every day after the optimum sowing window, a loss of 35kgs/ha/day can be expected, and in the author's opinion this is a conservative figure. Sowing timeliness is important to ensure crop growth and development occurs within the correct climatic conditions to optimise yield (Ward et al, 2021). Heavy stubble loads, conserved via stripper harvesting will help retain moisture closer to the soil surface, potentially allowing for seeding to take place on time many days or months after rain, or on more marginal planting rains (Hunt, 2011). This can be the difference between getting a crop established or not, which can have colossal impacts on potential crop yield and farm returns. This has been experienced by many farmers utilising the strip and disc farming system, and is one of the major benefits of the system.

Figure 15 Canola in stripper straw flowering earlier around the unplanted CTF wheel tracks where soil has access to sunlight warming the soil profile and accelerating plant metabolism and growth, compared to the remainder of the swath (Source: Author)

3.3 Economics of increased fallow efficiency

Stored soil moisture is extremely valuable in dryland farming operations. French and Schultz in 1984 modelled the potential yield of wheat based on PAW and rainfall, in the absence of other constraints. For every extra millimetre stored and utilised in the growing season, it could be expected to grow an additional 15 kilograms of wheat per hectare. In more recent experiences with modern varieties and agronomy (nearly 40 years later) this figure is more like 20 kilograms of additional grain per millimetre per hectare.

The average rainfall of Trangie, NSW in the fallow months of December to April, could be expected to receive somewhere in the order of ~250mm. If growers can increase fallow efficiency by 10% during this period from retaining more crop residue, that equates to 25mm extra moisture available to the crop. Multiplied by 20kgs per extra millimetre stored, results in growing an extra ~500kgs grain or AUD $180/ha of margin at today's prices (AUD $360 APW) or AUD $125/ha on an AUD $250 long term wheat prices (2023). This offers a significant increase in profitability and over scale should have a healthy return on investment in implementing the stripper headers. This estimate is conservative and fallow benefits could be greater than this.

3.4 Organic matter

Soil Organic Matter (SOM) is a key indicator of soil health. SOM in Australian soils is typically low, particularly in the low rainfall and high evaporation regions. A fundamental component of SOM is plant growth, of which is limited in the low rainfall and high evaporation areas of Australia's grain areas. Perennial grassland is known to have the greatest levels of SOM and Soil Organic Carbon (SOC), because of their ever-growing nature and ability to utilise rainfall moisture as it falls (Rosenzweig*, C* & Hillel, 2018*).* While perennial grassland systems are the best alternative for soil health, they ignore the social and economic importance of cropland for rural communities, the economy, and feeding the world. Cropping systems that maximize diversity, cover, and time a plant is growing, while minimising disturbance, and increasing aggregate stability at the highest rate for annual planted cropland. Soil health management is most successful when all the principles are implemented (Milodragovich, 2016).

SOM in the low rainfall and high evaporation regions is typically between 0 and 1%. SOM is important for soil health as it directly influences aggregate stability and biological activity, serves as a nutrient reservoir, and significantly increases soil water holding capacity. Zero-till has been a positive management strategy for increasing SOM over conventional tillage, and so too has increasing crop intensity. Zero tillage is positive as it slows the breakdown of SOM, retains soil structure and increases crop intensity (or reduces long fallow) and crop diversity as it maximises plant biomass produced per annum.

Another important factor in increasing SOM is to maintain correct soil pH and apply fertiliser to the crop or pasture. There has been research stating that correct soil pH and the use of fertiliser can have the most influential effect on improving SOM due to increases in plant growth and biomass above and below the soil surface, which consequently provides all the benefits listed above (Enwall *et al*., 2005).

The use of a stripper header has been referred to as a conservation harvest management technique to leave stubble length tall during the fallow period (Milodragovich, 2016). Conservation of residue will increase soil health, aggregate stability, infiltration, and water holding capacity, leading to increased crop production, increased residue accumulation, increased biological activity, and arguably most importantly improved drought resilience (Amézketa, 1999).

Stripper residue, storing more moisture and growing higher yielding crops will help to continue to improve soil organic matter and increase carbon levels. In the author's opinion, increasing stored moisture will have a similar effect to that seen by correct soil pH and fertiliser, at growing more plant material and increasing SOM and soil organic carbon, even if these gains are marginal.

"There will be a positive feedback loop as more moisture is available and aggregation increases. Soil organic matter will build, which will in turn increase water holding capacity and increase biological activity" (Milodragovich 2016) and in turn this will increase crop yields.

Soil temperature is also a key driver in metabolic rate of microflora decomposing SOM. Reduction in soil temperature from the strip and disc system reduces breakdown of SOM and increases levels of SOC.

3.5 Additional planting opportunities

Increased crop residue driving additional moisture storage is creating more favourable planting conditions and creating opportunities to plant additional crops outside of traditional cropping regions. Scott Poss in Hugo Colorado, USA, is farming in a marginal cereal growing region that receives 300mm of rain annually. The stripper header system and zero till farming has opened up their land to grow moderately low yielding corn at low populations, which is generating good returns and giving them a large upside due to a favourable season should it occur. Corn in their region has a great freight advantage, but is not a traditional corn growing region due to their dry climate. The Poss family this year have also been able to plant winter canola in 2024, a first for them on their farm.

In Queensland and NSW cropping regions I believe that the stripper straw will provide additional planting opportunities for dryland cotton and sorghum into new regions that are traditionally more marginal – particularly in forced fallow situations when planting rain for winter crops is not received. Increased stored moisture and better planting conditions will help establishment and increased residue will reduce inter-row evaporation in increase water use efficiency and crop yield.

Figure 16 Scott Poss, Alexandra Quigley and Billy Browning in Poss Farms, Hugo, Colorado, USA, dryland corn crop, July 2023 (Source: Author)

Figure 17 Moisture close to the surface under the mulch layer at Poss Farms in Hugo, Colorado, USA, indicating a viable planting opportunity was present (Source: Author)

Chapter 4: Challenges of the strip and disc system

4.1 Soil temperature and frost

The same factors that provide advantages during the summer months provide challenges during the winter months. Reduced soil temperatures reduce plant metabolic rates causing delayed early growth and development until the plant gets to a critical mass of ground coverage itself at canopy closure. At this point the plants are intercepting light before they reach the soil surface, for example, mid-late tillering in cereal crops or stem elongation in canola.

Frost events are temperatures that conduce the freezing of material on or near the soil surface. Frost is a stressor of actively growing plants and reduces plant growth, vigour and development. Soil, depending on texture and colour, can provide a significant buffer to frost, especially before canopy closure is reached. Soil exposed to sunlight radiation is warmed during the day and slowly gives off its heat during the night.

Soil is at its coolest temperature early in the morning before it begins to warm again the following day. The nature and volume of soil having such a large volume means it is slow to change temperature. This is extremely valuable in the mitigation of frost for developing crop seedlings reducing the severity of the frost. Where soil is covered by plant material that reflects the sun’s radiation back into the atmosphere, the soil does not warm in the same nature as exposed soil. This lack of temperature buffering can provide large setbacks to early crop growth and development and even seedling death in moderate to severe frost events.

Figure 18 Canola in stripper straw recovering after a severe frost event. Also note, the yellow leaf spot inoculum on residual wheat straw (Source: Author, 2021)

This concept is not only limited to winter cropping production and the effects can been seen in soil temperature sensitive summer crop options including cotton. Management techniques can reduce the effect by removing most crop residue from the row with row cleaners several weeks before planting of the summer crop occurs, allowing time for the exposed soil to warm up. This is possible due to the wider rows in summer row crop operations to allow the residue into the inter-row.

GRDC (2023), published in their *Stubble Initiative* document, that retaining more than 2.5t/ha of stubble can increase the risk of frost damage, making the frosts colder and longer, with lower temperatures at head height. The retained stubble reduces the heat radiating from the soil at night, resulting in less warming of the crop canopy.

4.2 Herbicide and fungicide application

4.2.1 Fallow spraying and optical sprayers

Zero tillage farming requires chemical control of weeds in the period between when crops are grown referred to as the fallow period. High residue loads and standing stubble physically provide a more challenging environment for herbicide applications to reach target weed species. This must be accounted for when setting up sprayers in these conditions. Nozzle set-up, spray quality and water volumes must be suitable for the types of herbicides being used and to account for somewhat reduced target efficacy. In the author's experience, efficacy has been good to excellent and not as big of an issue as previously thought. Particularly in summer fallows where targets weed size is larger.

Optical sprayers are sprayers equipped with cameras that detect chlorophyll or have cameras that scan images for weed species to detect, then send a signal to a solenoid to open and spray the target weeds. With cameras being one metre plus apart depending on the system, it is expected that results are going to be minorly compromised when compared to conventional draper cut stubble or bare fallows, but still effective, particularly with the increased 'crop competition' from the stubble.

4.2.2 Pre-emergent herbicides and disc seeders

As previously mentioned, disc seeders are often required in high residue farming environments to manage trash flow. Disc seeders combined with high residue loading covering the soil surface provide a challenging environment for pre-emergent herbicides to work and in some cases may not be compatible.

Pre-emergent herbicides will inhibit weed seeds from growing as they germinate. They require good soil contact to properly target weed seeds on and within the soil surface. Most pre-emergent herbicides are generally designed for use with tyne seeders as they physically move treated soil out of the seed zone. Using a disc seeder immediately reduces the number of pre-emergent herbicides available for use. This is however a quickly moving space with several new herbicides available that are compatible with the strip and disc system, consult an agronomist for research in this space as it is a dynamic and complex space, and a number of other factors come into play including soil type, climatic conditions and moisture levels.

Pre-emergent herbicides should be applied with large droplets that shatter and reach the soil surface, combined with high water volumes to penetrate the soil layer. A focus on solubility is important for pre-emergent herbicides to wash off the stubble and onto the soil surface with rain events to alleviate the high residue loads.

Figure 19 Two leaf sow thistle controlled in 5t/Ha + wheat stripper straw with a water rate of 48lts/ha coarse spray quality. Effective weed control is possible in heavy stripper straw. (source: author).

4.3 Disease inoculum

Crop residue, when intact will last considerably longer than if it has been dismembered through the harvesting process. Standing residue has minimal contact with soil resulting in it taking much longer to decompose. Consequently, old crop residue will be present for several years providing a disease bridge from one crop, through the rotation crop and into the subsequent crop (Figure 19). This is a minor but considerable production risk that must be accounted for in agronomic management with fungicide application and crop and variety choice. Consequently, some growers may opt for the double break management strategy to offset this risk, while still retaining adequate levels of crop residue.

4.4 Nutrient tie up

It has been reported that a third of crop nutrient is removed in the grain at harvest, one-third remains in the stubble fraction above the soil, and one-third remains in the root fraction. With crop residue persisting for longer periods, so too are the nutrients that are stored in the remaining crop residue. This delay in the nutrient cycle will cause nutritional shortfalls if not addressed adequately in nutritional programming. For example, a 5t/ha wheat stubble would have 38 units of nitrogen tied up (82kgs urea equivalent), which in stripper straw may take twice as long as draper cut residue to mineralise and return to the available pool of nutrients.

4.5 Mice, rodents and slugs

Unfortunately, long straw provides habitat for rodents, in particular mice. It removes the ability for predators to hunt easily providing them with an environment to thrive with a food source and cover. This can be a considerable risk at seeding time if not dealt with. Fortunately, zinc phosphide baiting with the seeding application (through small seeds box or bait spreaders mounted to the machine) has been very effective at controlling mice at an estimated cost of AUD $5 per hectare.

Slugs are a substantial pest in higher rainfall areas. With limited experience in this area, my prediction is that slugs will thrive in a cooler moisture environment provided by increasing crop residue and moisture levels. More research needs to be done in this area in the future.

4.6 Capital cost

The stripper header in 2023 comes in at approximately AUD $170,000 + GST + trailer. This is an additional capital cost to a business and means that up to three fronts for a combine harvester, a draper platform, a stripper header and a pickup header may be needed. However, with increased harvest efficiency and reduction in fuel burn over the lifetime of the machine this will go well on its way to paying for itself, as well as the ability to downsize one combine class while retaining similar or greater output.

Chapter 5: Effect of residue on summer crop (cotton) production

Summer crops require minimum temperatures for seeds to germinate and establish, for cotton ideally this is 14°C at 8am, with a predicted rising plane of soil temperature. The same factors that help reduce evaporation and reduce soil temperature in fallow periods also apply to fields planned for summer crops with heavy residue loads. This residue reflects light and solar radiation off the soil surface and back into the atmosphere, lowering soil temperature as a result. This provides the same benefits mentioned earlier, increasing water storage and fallow efficiency prior to planting and increasing WUE throughout the growing season. In locations with long growing seasons or dryland scenarios, this is not an issue because there is time to wait for the soil to warm up to adequate planting temperatures. In irrigated crops in regions with short growing seasons, however, this is not the case and strategies must be implemented to negate this effect or yield penalties could occur.

Most summer crops are grown in row crop configurations of 100cm or 75cm spacing or multiples of these widths respectively. Due to the relatively wide spacings of row crop rows, it allows for residue to be moved out of the plant line and into the inter-row. Management techniques have been developed for irrigated crops to partially circumvent this issue prior to planting by running residue row cleaners or strip tillage techniques to move residue out of the plant row. Ideally, this should be done well before planting to give adequate time for the soil to warm up. If this is not achieved soil temperatures can remain lower for longer compromising germination and in cool temperatures, and in wet years will compromise planting conditions by exacerbating moist conditions.

It has been widely reported the benefits of crop residue in summer crop production predominantly in sprinkler or drip irrigated systems and dryland scenarios. These benefits include:

- eliminating sand blasting of seedlings,
- increasing water infiltration and reducing run off or ponding,
- reducing evaporation, especially prior to row closure,
- reducing soil pore damage from water droplet impact, increasing infiltration,
- increased Integrated Pest Management (IPM) by severe reduction in thrip presence, and
- weed suppression in the inter-row, and increased weed control from fresher weeds for longer.

However, long residue remaining from stripper fronts has not been compatible with fully irrigated conventional furrow farming systems, providing significantly reduced trash flow during ground preparations, and blocking irrigation pipes, drains and recirculation systems. Stripper straw must be mulched into smaller pieces and incorporated to allow for ground preparation to be accomplished. Where it could be adopted is in red soils on zero or flat grade bank-less irrigation with infiltration issues, slowing water movement on and off the fields, increasing water penetration and water use efficiency from increased soil cover. However, fresh cover crops seem to be a better fit in this space as they are not as bulky and persist longer under furrow irrigation environments. This is expanded upon in the next chapter, *Cover crops*.

Where real opportunities with stripper straw present themselves are with zero tillage dryland cotton production, or limited water semi-irrigated cotton production due to its ability to catch and store more rainfall moisture and prevent evaporation in the inter-row. This would result in increased moisture storage, an increase in water use efficiency, and increased bales per megalitre. It would be necessary to do any ground preparation required, grow and harvest the cereal crop, and then long fallow through to cotton planting in a zero-till style to achieve the full benefit of the system. Harvest needs to be considered especially in conditions with low fruit set where picking cabinets or stripper harvesters are close to the ground, tall standing stubble can cause issues with the harvesting process. This stubble is best to be rolled in the direction of the planting and picking direction where possible.

Figure 20 Semi irrigated cotton being planted behind stripped wheat, highlighting the importance RTK GPS for effective inter-row sowing, and ability of disc planters to plant through high residue situations. (Source: Author)

Lance and Danielle Williams in Panhandle, Texas, USA, farm predominately corn and cotton across a large-scale farm. Lance said residue retention was an important part of their farming system for the reasons mentioned above in this chapter, particularly to fight the damage from sandstorms. They had residue choppers to cut cotton and corn stalks after harvest to retain residue on the soil surface.

Figure 21 a stalk chopper at lance and Danielle Williams Panhandle TX USA used to destroy old crop rows while retaining crop residue on the soil surface. (Source: Author)

Chapter 6: Cover crops

Cover crops are traditionally grown in between cash crops or in fallow periods, with their purpose not to harvest for income, but to enhance soil health, suppress weed growth and prevent erosion and nutrient loss from leeching and rainfall runoff. Cover crops are planted with a primary purpose in mind, for example, to prevent seedling damage from sand blasting/sandstorms, or to hold and store nutrients in plant material to prevent nutrient loss, or to sequester nitrogen from the atmosphere with legumes and rhizobia.

Cover crops have proven to be successful in several scenarios around the world, most of those in higher rainfall farming environments and predominately with the aim of adsorbing and storing excess nutrients to prevent them from leeching or running off into water ways, while encompassing the added benefit of increased soil health from more live roots. This was very common practice throughout the high rainfall regions of the USA (including Iowa, North and South Dakota, Nebraska and Illinois to name a few as shown in Figure 22), and very common throughout Europe and the UK.

Figure 22 A custom built cover crop seeding machine, adapted to a high clearance sprayer to seed cover crops in growing corn crops in Iowa USA, featuring impressed fellow scholar Billy Browning at a Heatland Co-Op field day in July 2022, near West Des Moines Iowa. (Source: Author)

Another example of cover crops being used, this time in dryer conditions is in high wind arid environments to protect seedling from sandstorms and prevent "sand blasting" of seedlings upon emergence. This was common practice in west Texas to prevent ring barking and subsequent damage of cotton seedlings. We saw this in detail on our travels at Walker McNair, and Dan Taylor's farms near Panhandle and Lubbock . Texas, USA, respectively. Walker was planting cereal Rye in September and terminating in April. This was also to help combat water restrictions on irrigation ground water pumping capacity. Walker's comments were that the cover is helping no doubt, for weed suppression particularly for hard to kill weeds such as parma amaranth and eliminating sand blasting, both common issues in west Texas. Walker believed that the rye cover crop was a particularly important part of growing wide row cotton when utilizing acres subject to water restrictions. Lance and Danielle Williams also attributed to how they needed to have some sort of crop residue on the soil surface to prevent damage from sandstorms to newly emerging crops, predominately cotton and corn. This is also now common practice of Australian cotton growers on drip or sprinkler irrigation systems, and some furrow scenarios, and has been for over 10 years.

Figure 23 Bill Browning, Walker McNair and Richard Quigley in Walkers's water limited wide row (60") Cotton with a sacrificial Rye cover crop near Clarendon, TX, July 2023. (Source: Author)

There is also an argument that a growing crop during the winter months will collect more moisture from the air through overnight dew than traditional fallows with stubble retention practices. The theory is that cumulatively over a period can harvest moisture and store it in the soil profile for utilisation later (Scott McCalman, pers. comm.).

In lower rainfall environments, (like the majority of Australia), there is not often the surplus moisture available to grow both cover crops and cash crops (or double crop cash crops) in the same year in dryland farming systems, unless above average rainfall is received. Dry environments are regularly limited by water availability for plant growth and crop production. If both are attempted, chances are that one will fail. Prioritizing water usage for cash crops in dry climates is essential to maintain productivity and remain economically viable. This is the crux of conservation tillage practices adopted by the majority of Australian grain and cotton growers mentioned earlier in this report.

Most of the grain and cotton growing regions in Australia are not typically high rainfall like other countries, so nutrient loss is also not a common reason for adopting the growing of cover crops.

Increased crop residue on the soil surface provides most of the benefits of a cover crop while still being able to produce cash crops that are both economically and environmentally sustainable.

Figure 24 Richard Quigley and Dan Taylor in Dan's Cotton with a sacrificial wheat cover crop near Ropesville, Texas, July 2023. (Source: Author)

Cover crops are being trialed in large scale field trials and are becoming more common in Australian furrow irrigated farming systems that have troublesome soil types to irrigate. These troublesome soil types seal up after subsequent irrigations and subsequently have poor infiltration and reduced crop yields as a result, and are traditionally seen on lighter red soil types (sandy clay loams) compounded by steeper field grades (0.1% or greater). Crover crops grown purposefully to increase infiltration in quick succession of planting irrigated summer crops have been very successful to combating these issues.

Cover crops seem to be more effective than old crop residue as fresh cover crops are well anchored to the soil and have current root canals that help significantly with water infiltration and increasing friction in the furrow reducing the speed of water flow. These cover crops have traditionally been cereal crops, however with the recent incorporation of Bayer's Extend Flex Cotton traits (dicamba, glufosinate and glyphosate tolerant) legumes and brassicas can now be incorporated into these cover crop systems to create mixed species cover crops that can fix nitrogen and help with cotton disease management. I think this will be prevalent in cover crops of the future of Australian Cotton farming systems. Cover crop root systems also feed the soil microbiology with their exudates stimulating and promoting soil health.

Figure 25 Photo of Billy Browning's mixed species cover crop nearing termination on a historically poor irrigation infiltration soil type, to increase soil health and infiltration throughout the irrigation season, near Narromine, NSW. (Source: Author)

Conclusion

From this Nuffield research, travel and farm visits, as well as experiences on the authors' own farm, stripper headers are compatible with modern zero tillage grain production and dryland summer crop farming systems in Australia. Increased PAW, increased yields, increased harvester efficiency and reduced costs are all compatible with stripper header implementation, ultimately increasing profitability and sustainability. Consideration must be taken for soil temperature, frost, planting timings, seeder trash flow capabilities, increased pest and disease pressure, and herbicide challenges. I see the most benefit from stripper headers and increased levels of crop residue in Australia's semi-arid grain growing regions, and the benefits will be reduced in higher rainfall and cooler environments.

Small cumulative increases in stored soil moisture and increased water use efficiency of crops grown will make considerable increases in profitability as growing costs are not significantly increased but production is, especially in below average rainfall years.

Reduction in weed germination and growth will be observed with stripper header uptake, as well as weeds being actively growing for longer making weeds easier to control in adverse conditions reducing pressure on herbicide control options.

Significant Increases in harvester efficiency and throughput are observed with stripper headers, along with reduced engine load and fuel burn and reduced wear and tear on combines, resulting in a reduced cost per tonne or per hectare harvested. Stripper headers also provided longer operating hours as they are much less affected by damp straw throughout the night, increasing daily harvester hours. This is combined with a reduction in fuel burn by up to 50% due to processing less crop volume in the combine harvester.

Stripper headers are not compatible with conventional furrow irrigated cotton production in Australia without residue management techniques to move or mulch long cereal residue. This is mainly due to hindrance of ground preparation from trash flow issues blocking implements and creating poor or uneven seed bed conditions and hindering irrigation activities by long straw impeding irrigation practices, particularly in blocking furrows, drains, pumps and pipes in the recycling of irrigation water. Residue reduces flow of water through Mannings formula and can result in water logging.

Manageable crop residue is however a very important part of cotton production, particularly in sprinkler and drip irrigated cotton and dryland areas to reduce the effects of sand blasting and early insect predation from thrips, and increase infiltration and water use efficiency.

Cover crops are an increasingly valuable tool in Australian cotton production with the implementation of Extend Flex herbicide traits allowing for the incorporation of harder to kill mixed species cover crops, allowing nitrogen fixing and disease benefits. This will be more prevalent in sprinkler and drip irrigation, as well as furrow irrigated areas with known infiltration issues.

Stripper headers are considered a tool of conservation agriculture that is applicable to large scale grain farms across Australia in semi-arid grain growing regions, which will increase the sustainability and profitability of farm businesses.

A very high level of attention to detail is required to implement the management techniques outlined in the strip and disc farming system. Without this attention to detail and the high levels of accuracy required undesirable results will occur.

Recommendations

From my research into this topic, I make the following recommendations:

- Implementation of the strip and disc farming system into semi-arid grain growing regions of Australia will increase crop production and profitability without considerably increasing cost of production. Conservative estimates expect an increase in fallow efficiency of 10%, of which if moisture is limiting could be converted into an additional 500kgs wheat/ha or an additional $125/ha AUD in grain income at long term wheat prices.
- Implementation of the strip and disc system should provide planting opportunities in marginal or dry years that may not be there in conventional zero tillage systems or full tillage systems.
- Implementation of the strip and disc system should reduce severity of the effects drought in your business.
- The strip and disc system is less compatible in higher rainfall environments and environments prone to slugs.
- Significant research and strict attention to details needs to go into the system to gain the full plethora of benefits.
- Significant research needs to go into correct combine setup to ensure unsatisfactory grain loss is not observed.
- The strip and disc system is not compatible with conventional furrow irrigation systems that dominate the Australian cotton industry.
- Cover crops will continue to be pivotal in sprinkler and drip irrigated cotton crops, as well as difficult to irrigate furrow irrigated soils and should be implemented where possible.
- Cover crops for cotton production should incorporate mixed species to fix nitrogen and combat disease, to get a free kick while reaping the benefits of traditional cover crop usage.

Further research needs to be undertaken in the following areas:

- Harvester efficiency, losses and throughput. Combines are capable of greater than 100t per hour in crops like corn. More research is required as to why similar results from combines with a stripper header that is just separating the grain from the chaff fraction cannot be achieved without excessive grain loss. Currently, machines investigated are limited by grain loss and threshing capability.
- Explore other combine types, and their setup to maximise throughput and reduce loss. This should focus on exploration into twin rotor combines (New Holland CR series and JD X series), and drum threshing combines (Class) with large separating areas.
- Investigate the amount of carbon stored for longer periods in the stripper disc system. Crop residue is taking up to an additional 12 months to break down, resulting in a carbon sink for this additional period.
- Research into if the strip and disc system can increase soil organic matter through reducing soil temperature and increasing levels of crop residue.

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