nitrogen management

in stubble retained systems in Central West NSW

Project code CWF00018

KEY MESSAGES

- Managing Nitrogen (N) in a stubble retained farming system is not unlike a cultivated system, provided allowances are made for the impact of stubble.
- In years with a good market outlook, a full moisture profile and high stubble loads at sowing, an extra allowance of 5 kg of N per ha per tonne of stubble present at sowing may be necessary to allow for N 'tie-up'.
- Cereal stubble should be thought of as a source of carbon (C) for microbes, not as a source of nitrogen (N) for crops. In no-till systems, only approximately 6 per cent of a crops N requirements is derived from stubble.
- Deep banding N can improve N uptake, yield and protein of crops, especially in stubble retained faming systems.
- The yield potential of a crop will be limited by any nutrient the soil cannot adequately supply. Poor crop response to one nutrient can often be linked to a deficiency in another nutrient or management technique. Crop response can also be linked to soil constraints such as acidity, sodicity or salinity, problems with beneficial soil microorganisms or pathogens.
- Generally stubble treatments (standing, mulching, cultivating and burning) imposed late in fallow had no impact on N response in the 2014 and 2015 seasons due to a hot, dry spring.
- Stubble grazing during the fallow with sheep has been shown to increase soil N levels at sowing.
- Crop sequencing with legumes can increase soil N levels for subsequent crops.
- The risk/reward of chasing yield and protein with topdressing needs to be considered on an individual business level, taking into account the season and stored soil moisture from summer fallow.

Background

The N demand for maximum yield and protein of dryland crops in Central West NSW is unpredictable until late crop development, because of variable spring weather conditions (particularly rainfall), and N fertiliser can be one of the largest variable costs in wheat production. Organic N in the soil profile provides the basis for N mineralisation in addition to the crop residues that are cycled near the soil surface. Recent research (Angus, CSIRO, 2013 Forbes GRDC Update) suggests that organic N declines by 2 to 3 per cent in continuous cropping systems annually. Fertiliser applications or growing grain legumes reduces the rate of decline but does not maintain the level. To maintain yields with continuous cropping it is suggested that the application of N fertiliser will need to double over the next 40 years.

Current urea fertiliser manufacture is based on the use of natural gas or other hydrocarbon feedstock to produce 'syngas' which then reacts with N to produce ammonia. Urea is manufactured when the ammonia reacts with carbon dioxide and modern manufacturing facilities are highly efficient. The outlook is that whilst the availability of natural gas is unlikely to limit N fertiliser supplies, the cost of manufacturing is unlikely to fall.

All these issues are pushing growers to use N fertiliser more efficiently and has seen them adopt topdressing with urea as an important management strategy to balance the seasonal risks and rewards of N fertiliser input.

Various approaches to N budgeting have been developed to assist growers in allocating dollars to N inputs as they attempt to maximise returns and minimise risk.

A common rule of thumb used to determine crop N demand is 40 kg/ha of N per tonne of expected grain yield. In agronomic N accounting logic, this benchmark assumes that supply is around twice the amount likely to be removed, and accounts for N recovery rates from soil and fertiliser. It also accounts for some N that will not be removed such as that remaining in crop residues. The N budget should also account for any soil N at sowing or any N that may mineralise in-crop and these amounts discounted from the total N demand to derive a target fertiliser rate.

Despite these assumptions, this 40 kg/ha continues to be a widely used 'number' during the in-season decision making process to top-dress crops, where growers are not using computer-based decision support tools to decide on top dressing rates.

Growers using this rule of thumb consider observations of crop performance, a 'gut feel' about how the season will finish and a knowledge of their business position and market expectation to determine the spend (risk) on N fertiliser.

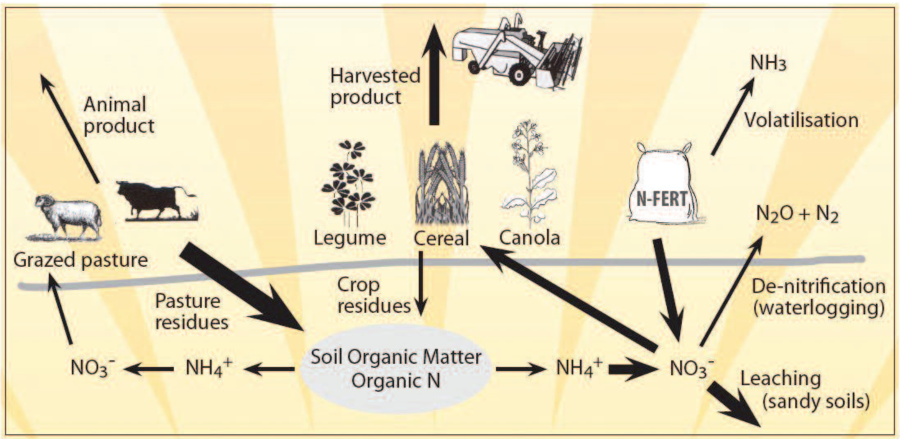

Figure 1: Principle N cycling pathways in a mixed cropping/pasture system (adapted from Peverill et al. 1995). Image sourced from soilquality.org.au

Nitrogen cycle

The N cycle (Figure 1) demonstrates how N from manure, fertilisers and plants moves through the soil to crops, water and the air. It is essential to understand these processes when it comes to making on-farm managerial decisions. The processes of N fixation, mineralisation and nitrification all increase plant available N whereas the processes of N denitrification, volatilisation, immobilisation and leaching decrease plant available N.

Nitrogen additions

Biological N fixation refers to the conversion of atmospheric N into a form that is available to plants. On farm, this process is undertaken by microbes that inhabit the roots of pulse crops and pasture legumes.

The process of N fixation requires energy, enzymes and minerals so if a plant available form of nitrogen is present then the plant will often use the available forms prior to fixing its own N.

Mineralisation is microbial decomposition of organic nitrogen from manure, organic matter and crop residues to ammonium. As this process is driven by microbes the rates at which this process occurs is reliant on temperature, moisture and the levels of oxygen within the soil. Ammonium is generally held on the soil particles and so is not liable to be leached.

Nitrification is the next stage on from mineralisation and happens when microbes extract energy by converting ammonium to nitrate. This process requires oxygen and produces nitrate which is immediately available to plants. N in the nitrate form is also susceptible to leaching.

The amount of mineralisation depends on the organic matter content of the soil, soil pH and soil water and temperature. Mineralisation can supply significant amounts of N in the autumn and spring, when soils are warm and moist.

Nitrogen removal

Crop removal in grain is the major loss of N in a cropping system – with around 20 kg N/t of wheat, 40 kg N/t of canola and between 30 to 50 kg N/t of pulse crop grain. Higher protein pulses (e.g. lupin) contain more N than lower protein pulses (e.g. chickpea). **Volatilisation** occurs when N is lost through the conversion of ammonium to ammonia gas. These losses may increase in very high pH (e.g. >9) soils when crop canopy is thin, sparse or absent and in conditions that favour evaporation such as a hot and windy day.

The losses related to volatilisation are higher for surface applied ammonium based fertilisers when compared to incorporated fertilisers, although research by Dr Graeme Schwenke and colleagues Bruce Haigh, Adam Perfrement, Bill Manning and Dr Guy McMullen of Tamworth DPI in 2011 and 2012 suggest these losses aren't as high as once thought. Typically less than 20 per cent (and as low as 10 per cent) of applied nitrogen is lost from urea added to arable systems based on these trials and other trials around Australia. However the greatest risk from volatilisation loss of applied N fertilisers occurs when light rainfall is received that is sufficient to breakdown the fertiliser granule but insufficient for incorporation.

Immobilisation is the opposite of mineralisation and is the incorporation of N into soil organic pools. Immobilisation occurs when the microbial population within the soil begins to compete with the crop for the N supply.

Incorporating materials (such as stubbles) with a high carbon to nitrogen ratio increases the microbial demand for N within the soil. Even though immobilisation is essentially temporary, added loads of carbon can lead to an additional N demand by the soil.

In retained stubble systems, the microbes that break down the stubble compete with the crop for N. As a result, it is important to budget for these nutrients when calculating the crop nutrient demand for the year.
A rough rule of thumb that is commonly used is that for every tonne of cereal or canola stubble 5 kg/ha of N will be immobilised ('tied-up') during the stubble breakdown process. This may or may not be important in CWFS districts when stubbles decompose during the crop growth, so the immobilized N may be re-mineralised within a crop cycle.

Leaching is the loss of soil N when water movement takes it out of the root zone of the crop. Soil particles have a poor ability of holding nitrate because both are negatively charged. This results in nitrates moving with water within the soil.

The rate of nitrate leaching will be dependent on the rate of crop uptake which removes nitrate from the water, and the amount of water and nitrate within the soil profile. Heavier soils are less prone to leaching and nitrate loss than lighter soils. In-crop topdressing of N on light soil types may minimise leaching.

Denitrification occurs when N is lost through the conversion of nitrate to a gaseous form including dinitrogen and nitrous oxides. This is quite common in waterlogged soils when the microbes begin to use oxygen contained in nitrate-N for their respiration.

Denitrification means any loss of these inert N gases impacts in two ways. The loss of N from the crop production system may limit productivity, while losses of gaseous N to the atmosphere can increase the greenhouse gas emissions.

CWFS collaborated with Birchip Cropping Group (BCG) on the GRDC-funded project that compared nitrous oxide emissions under efficient grain production. In the Central West area, it was found that nitrous oxide emissions were relatively low due to the area being a low rainfall environment. The emission spikes that were observed during the trial coincided with rainfall events in the area. These emission spikes quickly returned to a near zero value eight days after the event. This suggests that the potential loss of N via denitrification is relatively low in Central West NSW.

Stubble removal either by burning, baling or grazing are also N removal pathways. Depending on its origin, there is around 5-10 kg N/t of crop residue. If the crop residue is burned, then around 80 per cent of that N is lost from the paddock.

Managing the risks and rewards of nitrogen

Variable spring conditions in CWFS districts, the cost of N either from fertiliser or 'grown' by break crops, the market price of grain and a grower's individual perception of 'risk' all combine to a complex decision making matrix about managing N in any given cropping system.

Managing N in a stubble retained farming system is not unlike a cultivated system provided allowances are made for the impact of stubble in the cropping system. Decision support tools are available that predict the seasonal response and economic returns from fertiliser N applications. Whether these tools are used or not, some general background information about a grower's system will be required and the following generic process for what needs to be adapted for each situation or crop type.

Selecting the right rate: Target a yield potential at the start of the season, whether it is based on average wheat yield or above average, depending on optimism.

Calculate the amount of N required to reach your target based on 40 kg N/t of yield potential. The yield multiplied by the N required indicates the crop N demand.

From this N demand you determined, deduct the amount of pre-sowing mineral N and estimate the amount of N that will be mineralised during the season. Pre-sowing mineral N can be determined by undertaking soil testing. CWFS trials have shown that starting N will be in the range of 30 to 80 kg N/ha (0-60 cm), depending on rotation. Extra N may be needed where N losses by leaching or denitrification are likely, and under heavy stubble loads add an extra 5 kg N/ha for each tonne of stubble residue.

Importantly, remember the yield potential of a crop will be limited by any nutrient the soil cannot adequately supply. Poor crop response to one nutrient can often be linked to a deficiency in another nutrient or other management technique. Crop response can also be linked to soil constraints such as acidity, sodicity or salinity, problems with beneficial soil microorganisms or pathogens.

Selecting the right time: Some N will be present at seeding either from the base fertiliser or from N already present in the soil. Around 40 kg N/ha in the top 60 cm should allow wheat to get to Z30 without yield penalty. The period of high N demand commences at Z30. In response to seasonal conditions and yield potential, look to top up the N supply to the potential N demand. Usually in CWFS districts, in most seasons the best results are obtained from earlier applications.

Applying N at seeding will provide good early growth and generally has a higher efficiency than N applied later. In-crop applications rely on rainfall to wash the N into the root zone and in the Central West area, there may be limited events of sufficient rain to wet up the topsoil. Topdressing onto dry soil, without follow up rain, is likely to result in low crop uptake and poor N efficiency.

N can be applied up to flag leaf emergence, to maintain or boost grain protein depending on seasonal conditions, soil moisture availability and market outlook. The rates of N can be adjusted in response to seasonal conditions. Usually growers who top-dress for protein will be prepared to store grain on-farm and market directly if the season turns dry and results in high screenings. They will argue that high screenings, high protein wheat can be marketed direct off-farm to achieve similar returns to lower protein grain with acceptable screenings delivered into the bulk system.

CWFS Outcomes from Nitrogen vs Stubble Trials 2014-15

During 2014 and 2015, CWFS conducted trials at its regional sites investigating if different stubble treatments imposed towards the end of the fallow changed the yield response to N. These trials were set-up to also test if splitting N applications to enable fertilising on seasonal outlook, changed the risk to applying N in lower rainfall, marginal cropping areas.

Stubbles were left standing, cultivated or burnt and N treatments (applied as urea) were developed based on grower yield expectations for the site, with a budget of 20 kg N/ha per tonne of estimated grain yield. The N timing treatments were: all N applied at sowing, split 50/50; half upfront and remainder at Z21 and split 3 ways; upfront, Z21 and Z30.

Key findings from these trials were:

- Generally stubble treatments imposed late in fallow had no impact on applied N response.
- Split N applications did not improve yields and had only a very minor impact on grain quality.
- Split N application in 2014 or 2015 was not a way to reduce financial risk as opposed to all N fertiliser up-front since crop outlook at Z30 was always positive.

Both 2014 and 2015 had hot dry finishes to the season, which would have impacted on yield.

NB: Historic grain protein levels less than 11.5 per cent indicate N limited yields. Historic grain protein levels 11.5 to 12.5 per cent indicate adequate N to achieve yield but may have limited protein. Historic protein levels greater than 12.5 per cent indicate N was not limiting and soil water most likely limited yield.

View the 2015 CWFS nitrogen response paper or follow link below (Adobe Acrobat required):

http://cwfs.org.au/wp-content/uploads/2016/04/stubble-vs-nitrogen.pdf

View the 2014 CWFS nitrogen response paper or follow link below (Adobe Acrobat required):

http://cwfs.org.au/wp-content/uploads/2016/02/CWFS-2014-Stubble-treatment-vs-nitrogen-report.pdf

The roles of break crops and pastures on pre-seeding N supply

Sowing a break crop can provide many benefits to a farming operation, including allowing herbicide rotation, a disease break, providing livestock feed and increasing soil nitrogen if a pulse is used. From 2011 to 2015 CWFS conducted trials as a part of the GRDC funded Crop Sequencing Project to determine the role that break crops play in low rain fall environments. Figure 2 shows the soil N pre-seeding in 2013 for the Condobolin trial site, with crop rotations during 2011 and 2012 listed on the x-axis of the graph.

The two-year fallow accumulated the most soil N but as a management tool may not be economically viable and therefore less practiced.

Serradella pasture fixed more soil N compared to all the other break crop options, while field peas and vetch as one year break crops in 2011 fixed the most soil N in relation to the other legume break crops grown in the same year.

Canola has a high N demand, therefore growing a pulse break crop such as Serradella, maybe a useful strategy to either build soil N before or after growing canola. This double

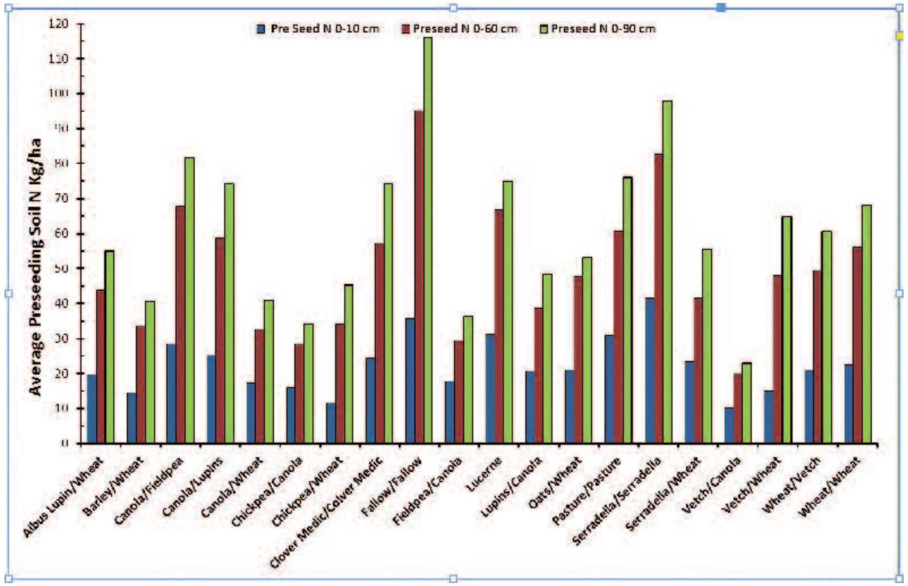

Figure 2: This graph shows the effect 2011 and 2012 break crops and pastures had on average 2013 pre-seeding soil N (kg/ha) at depths of 0-10, 0-60 and 0-90cm respectively (LSD @5% is 10.3 for 0-10cm, 20.7 for 0-60cm and 16.7 for 0-90cm)

Note: In this trial fertiliser was not used on the legume crops and a base rate of 50 kg/ha DAP was used at sowing for the rest of the crop species. Urea was top-dressed mid-season at approx. 4-5 leaf stage. No fertiliser was used on the fallow or voluntary pasture phases.

break could also help drive down soil pathogens that cereals are susceptible to.

Crop rotations with break crops were more sustainable in terms of providing livestock feed and lowering the cost of N inputs than continuous wheat, and provided cheaper, more effective strategies for controlling root diseases, weeds and managing soil water, as shown by previous data from this project. Sowing a legume break crop or pasture can be a useful strategy to increase soil N for the following season's crop.

The impacts of stubble grazing on soil N status

Mixed farming systems are common place in Central West NSW due to the diversity that the mix of enterprises provides to the system. The farming systems are often chosen in a way that promotes the symbiotic relationships between the various enterprises on farm. A common example of such a relationship can be observed within the wheat /sheep farming system.

Sheep are capable of utilising crop stubbles in their diet, as well as converting that stubble into manure. Figure 3 shows what happens to the nitrogen within stubble when consumed by sheep. While 25 per cent of the N can be lost as ammonia from urine, the

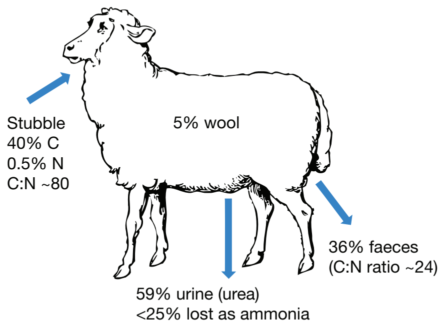

Figure 3: N pathways of digested stubble.

C:N ratio of the manure means that N in the manure is less likely to be immobilised.

A six-year trial was conducted at Temora by FarmLink Research and CSIRO that looked at the complementary relationships between sheep and cropping in stubble retained systems. Since the start of the project in 2009, the combination of grazing and retaining stubble has consistently proved to be the most profitable treatment.

This has largely been a direct result of the under acknowledged grazing value of stubbles ($133 /ha) as well as higher yields in the various treatments. The higher yields are believed to be a direct result of higher N availability following grazing.

Table 1 indicates the higher levels of mineral nitrogen under the grazed stubble system. It also indicates that the higher level

Table 1: Soil N level, grain yield and protein of stubble grazing management trial at Temora, 2009-2015.

Graze management	Stubble treatment	Soil mineral N to 1.75m (kg/ha)	Grain yield (t/ha)	Grain protein (%)
Nil graze	Retain	77	4.0	8.7
	Burn	92	4.5	7.9
Stubble graze	Retain	151	5.2	9.2
	Burn	146	5.1	9.1
P-value		<0.011	0.005	0.006
LSD (p=0.05)		4	0.2	0.3

of mineral N did carry over to grain protein even in spite of the high yields.

Based on these results it can be concluded that there is a profitable relationship between livestock and cropping enterprises. This symbiotic relationship can be best managed by grazing to a minimum of 70 per cent ground cover and adjusting fertiliser rates in order to account for the increase in mineral N levels under grazed systems.

Scan for further reading and trial results with N in retained stubble or follow link below:

https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/The-effect-of-grazing-and-burning-stubbles-on-grain-yield

More information:

- Hunt JR et al. (2016) Sheep grazing on crop residues increases soil mineral N and grain N uptake in subsequent crops. www.ini2016.com
- Hunt JR et al. (2016) Sheep grazing on crop residues do not reduce crop yields in no-till, controlled traffic farming systems in an equi-seasonal rainfall environment. Field Crops Research 196, 22-23.

Case study

Consultant: Chris Baker – Baker Ag Advantage
Location: Forbes, NSW
Topic: Managing his clients' nitrogen requirements in their stubble retained farming systems.

Overview: Chris manages a consultancy business for dryland and irrigation, mixed and continuous cropping farming enterprises in Central West NSW, focusing on management of crop rotations, herbicide choices and crop nutrition.

His clients' enterprises are approximately a 50/50 mix of continuous cropping and more traditional mixed farming operations including livestock.

The 2015 season got off to a 'perfect start' with a wet winter and good moisture profile, so N budgets were aimed at an above average crop. In some cases though, possibly too much urea was applied considering the dry finish, leading to an overabundance of canopy for the available moisture.

Chris's strategy for advising his clients on N management begins with soil testing to determine available N for the coming crop.

He prefers a deep soil test to gain an understanding of N throughout the entire profile and uses the results as a benchmark to begin the crop's requirements for the season ahead. A soil test does not need to be done in a paddock every year as a N budget can be also be determined by the previous year's yield.

Once the available N is known and compared with available stored moisture and predicted season, Chris has the conversation with his client to assess N requirements for the coming season. This will also include what result the client is looking for.

- Are they are aiming to grow a 2.5 t/ha crop of APH wheat?
- Would earlier application of N be more beneficial than later applications?
- Is the risk worth the possible reward?

With regards to time of application, Chris goes by the old rule of thumb of applying 70 per cent of N demand at sowing time and 30 per cent in-crop. Better results are obtained from earlier applications in most seasons, and more N is available to plants when applied in soil than top dressed N.

2015 proved a difficult season for some crops as too much N was applied early leading to a large amount of leaf matter and a drier profile during the crops' finish. A 'trickle feed' approach would have been the better option, but in a drier growing zone such as Central Western NSW the opportunities don't always arise later in the season.

However, in 2015 the growers who applied N still came out ahead in yield and protein at harvest.

Chris also maintains that yield increase should be the overriding goal rather than aiming to increase protein. Many barley crops this year also had extra N applied throughout the growing season. Yield is king.

Within his client base in Central West NSW, break crops and good N fixing pastures play a large role in maintaining N in the soil. Although in 2015 the final yields of some break crops were low, they still fixed a large amount of N as they grew well throughout the season and had good biomass.

Listen to a podcast of Chris's case study or follow link below·

http·//cwfs.org.au/podcast/ nitrogen-application-and- budgeting/

Technology and predicting nitrogen response

A range of computer simulation models are available to assist growers in making N application decisions. One to consider investigating is the free app Yield Prophet Lite®, which has been developed from the Yield Prophet® online platform. Yield Prophet® has the ability to generate reports for individual paddocks detailing real-time crop progress and yield potential (according to the moisture and nutrient status of the soil).

Launched by Birchip Cropping Group (BCG) on June 12, 2016, the Yield Prophet Lite® app is a tool that lets growers estimate their potential crop yields based on forecast rainfall probabilities for the rest of the season. The app, which had been developed in partnership with CSIRO, uses data from the Bureau of Meteorology's highly regarded POAMA/ACCESS seasonal forecasting system to predict how the season might finish and the likely resulting crop yields.

The app can be run at any time during the growing season. All growers need to do is specify their crop type (wheat, barley, canola or oats), select the closest Bureau of Meteorology weather station and input some quick details about rainfall, starting soil N, water and carbon, and any N applications.

The app will then calculate a range of water and N limited yield potentials for your crop and tell you the likelihood of different future rainfall amounts for the rest of the growing season.

The Yield Prophet Lite® app for iPads can be downloaded from the iTunes store. Android, iPhone and PC users can use the app via the web at· www.yieldprophet.com.au/yplite/

References

- Angus CSIRO, 2013 GRDC Grains Research Update Forbes, 2017 GRDC Grains Research Update Wagga Wagga. soilquality.org.au, Peverill et al 1995.

Acknowledgements

- CSIRO, GRDC, Birchip Cropping Group (BCG), FarmLink Research, Chris Baker (Ag Advantage, Forbes), Matthew Burkitt (Northparkes Mine), John Kirkegaard, Tony Swan, James Hunt, Gupta Vadakattu, Kelly Jones.

Disclaimer

This guideline has been developed by Central West Farming Systems Inc. (CWFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble initiative, funded by the Grains Research and Development Corporation (GRDC). The initiative involves farming systems groups in Victoria, South Australia, southern and central New South Wales and Tasmania collaborating to validate current research at a local level and address issues for growers that impact the profitability of cropping systems with stubble; including pests, diseases, weeds, nutrition and the physical aspects of sowing and establishing crops in heavy residues.

During 2012 discussions with local producers resulted in CWFS identifying 13 subjects that impact on the management decisions for producers in Central West NSW.

Since then CWFS has undertaken a range of research, development and extension (RD&E) activities focusing on these subjects. These publications are an attempt to capture those activities and provide regionally specific guidelines for producers aiming to retain stubble in Central West NSW.

A primary part of this work has been to correlate existing resources and research from several organisations and CWFS thanks these respective organisations for their work. CWFS and the GRDC also thank the experts who technically reviewed these guidelines.