Northern Farming Systems site—Billa Billa

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Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? | In Goondiwindi: (i) What are the trends that are expected in our farming systems? and (ii) How will these changes impact on the performance and status of our farming systems?*

Key findings

1. The district practice *Baseline* system is the most profitable to date. However apart from the 2016 winter crop there is very little difference between the seven grain systems.
2. Water use efficiency is higher for cereals than pulses and is highest in high-yielding crops.
3. Subsoil constraints are limiting PAW extraction by pulse crops.

Background

Grain production in the Goondiwindi area is largely based on a winter cropping system with summer crops grown as a disease break. Most farms operate on a zero or minimum tillage system, with strong reliance on stored fallow moisture. Summer crops are seen as an important part of the system, however are often grown on a greater water profile than winter crops as an insurance against hot growing seasons with variable rainfall.

The Farm Practices Research project (DAQ00192) was established in 2014 with the first crops planted winter 2015. This report investigates the activities and insights from the Billa Billa site in 2017-18 summer and 2018 winter seasons. Previous activities and insights can be found in *Queensland grains research* (2015, 2016 and 2017/18).

The Billa Billa site is located 50 km north of Goondiwindi on the Leichhardt Highway. The soil is a Duplex, with a sandy surface over a grey clay. The original belah and brigalow trees were cleared and the paddock used as long-term pasture before being developed for crops in the late 1990s.

What was done

Consultation meetings in late 2014 and early 2015 developed nine locally relevant systems to investigate at Billa Billa:

1. **Baseline** is typical of local zero tillage farming systems with ~1 crop per year grown using moderate planting moisture triggers of 90 mm plant available water (PAW) for winter and 120 mm PAW for summer. Crops grown are limited to wheat/barley, chickpea and sorghum, and are fertilised (nitrogen (N) and phosphorus (P)) to achieve average seasonal yield potential for the PAW prior to planting.
2. **Lower crop intensity** reflects a conservative rotation accumulating more PAW prior to planting the next crop. Long fallows provide a cropping frequency of 4 crops in 5 years (0.8/year), with the same nutrient management as the *Baseline* system.
3. **Higher crop diversity** allows a greater suite of crops to be grown to better manage disease, root lesion nematodes and herbicide resistance. Moderate PAW levels for planting each crop (90-120 mm) manage individual crop risk and target one crop per year. The unique rules for this system focus on managing root lesion nematodes, with 1 in 2 of the selected crops to be resistant to *Pratylenchus thornei*, and 1 in 4 crops resistant to *Pratylenchus neglectus*. To manage herbicide resistance, two crops utilising the same in-crop herbicide mode-of-action cannot follow each other. Crops grown in this system include wheat/barley, chickpea, sorghum, mungbean, maize, faba bean, field pea, canola/mustard and millet. These crops are fertilised (N and P) to achieve average seasonal yield potential for the PAW prior to planting.

4. **Higher legume** aims to minimise the use of nitrogen fertiliser by growing every second crop as a pulse (legume), with a preference for greater biomass and greater carry-over nitrogen benefits. Crops grown are similar to the *Baseline* (wheat/barley, chickpea, sorghum) with additional pulse options (faba bean, field pea, and mungbean). Moderate planting triggers of 90-120 mm PAW. Crops are fertilised (N and P) to achieve average yield potential for the PAW, with nitrogen only applied to the cereal crops.
5. **Higher crop intensity** aims to minimise the fallow periods within the system and potentially grow three crops every two years. Crops are planted on lower PAW (50 mm for winter and 70 mm for summer) and have a greater reliance on in-crop rainfall. Crop choice is the same as the *Baseline* system, but with mungbean added as a short double-crop option. These crops are fertilised (N and P) to achieve average seasonal yield potential for the PAW prior to planting.
6. **Higher nutrient supply** has N and P fertiliser applied to allow the crops to achieve 90% of the maximum seasonal yield potential for the PAW at planting; with the risk that crops will be over-fertilised in some years. Planted to the same crop as the *Baseline* each year; the only difference is the amount of nutrients applied.
7. **Higher soil fertility (Higher nutrient supply + organic matter)** is treated the same as the *Higher nutrient supply* system, but with an upfront addition of 10 t/ha organic carbon (70 t/ha compost) at the start of the experiment to raise the inherent fertility of the site and to see if this fertility level can be sustained with the higher nutrient inputs.
8. **Grass ley pasture** uses the perennial Bambatsi grass pasture to increase the soil carbon levels naturally. The pasture will removed after 3-5 years and returned to the *Baseline* cropping system to quantify the benefits gained by the pasture phase. The pasture will be managed with simulated grazing with a forage harvester to utilise a pre-determined amount of biomass.
9. **Grass ley pasture + nitrogen fertiliser** repeats the *Grass ley pasture* but with 100 kg N/ha (217 kg/ha urea) applied each year over the growing season to boost dry matter production, which is nearly always constrained by nitrogen deficiency in grass-based pastures, to improve the rate of soil carbon increase.

Table 1. Crops grown at the Billa Billa site

Wheat	Faba bean	Sorghum
Barley	Field pea	Canola
Fallow	Chickpea	
Grass pasture	Mungbean	

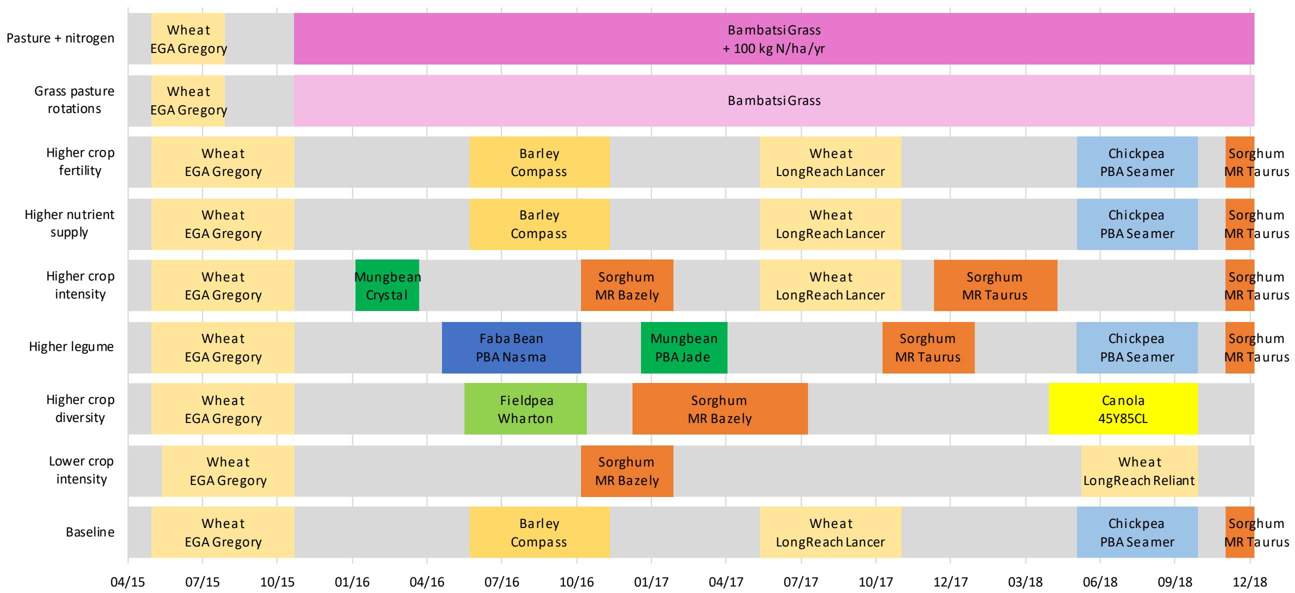

Figure 1. Crop sequences grown at Billa Billa following the defined system rules, plotted on a time scale. Colours represent the crop type as indicated in Table 1.

Results

The low-yielding mungbeans grown in the *Higher legume* system in 2016-17 left a wet profile below 30 cm, but the dry winter in 2017 did not allow it to be double cropped to wheat. This system was then planted to spring sorghum on 10 October 2017 (Figure 1). 245 mm of in-crop rainfall (most prior to flowering) grew a big crop, but a dry grain-fill period resulted in yields of 2.9 t/ha with 11.4 % protein and 40% screenings.

The *Higher crop intensity* system was also planted to MR-Taurus sorghum on 11 December 2017, double cropped after wheat. This crop was planted at the end of the wet spring period of 2017, but with 190 mm of in-crop rain, achieved 2.35 t/ha grain yield with 3% screenings and 12.6% protein.

The *Higher crop diversity* system was planted to sorghum at the same time as the *Higher legume* system mungbeans in 2016, however the later harvest date (July 2017) and greater water extraction by the sorghum crop meant this system did not accumulate enough PAW to be planted to a summer crop in 2017/18. On 28 April 2018, canola was planted after a 10 mm rainfall event with 180 mm PAW. Crop establishment was approximately 30% of the target, so trickle tape was used to establish more plants. Hand cuts were taken at the recommended timing for windrowing (50–70% of seeds changed colour to red, brown or black), with harvest planned as direct heading when 90% of seeds changed colour. The crop received 45 mm in-crop rain prior to the hand cuts for a grain yield of 1.46 t/ha. An additional 90 mm rain fell between hand cuts (windrowing) and harvest and maximum wind speed was measured at 68 km/h five days prior to harvest, resulting in a reduced header yield of 0.8 t/ha.

After a dry May in 2018, it was decided to deep plant five systems. *Baseline*, *Higher nutrient supply* and *Higher fertility* had chickpea planted with 180 mm PAW. *Higher legume* was also double cropped to chickpea with 150 mm PAW and *Lower intensity* was planted to wheat after a long fallow, with 200 mm PAW. Like the canola, these crops only received 45 mm of rain prior to crop maturity. The fallowed chickpea (*Baseline*, *Higher nutrient supply* and *Higher soil fertility*) yielded 1.8 t/ha, double cropped chickpea (*Higher legume*) yielded 1 t/ha and the wheat (*Lower crop intensity*) yielded 3.0 t/ha.

The chickpea appeared to have extracted very little water below 60 cm this season, which combined with 135 mm rainfall from crop maturity to the end of November, provided an opportunity to double crop these systems to sorghum. The *Higher crop intensity* system was fallowed from May 2018 so also achieved its planting trigger for sorghum. On 26 November 2018, *Baseline*, *Higher nutrient supply*, *Higher soil fertility* and *Higher legume* were planted to MR-Taurus sorghum, with 140 mm PAW. *Higher crop intensity* was also planted to MR-Taurus sorghum on this date, but with 100 mm PAW.

The Bambatsi pastures were only harvested once in 2018 (on 27 March). Total dry matter cuts revealed an extra 450 kg DM/ha grown by the grass + nitrogen pasture (11,420 kg/ha versus 10,970 kg/ha), but an extra 700 kg DM/ha was removed from this system (4250 kg/ha versus 3535 kg/ha), with the same cutting height maintained for all plots. There was also an extra 2% protein (10.3% versus 8.3%) in the removed portion of the fertilised pasture.

Similar to previous seasons, 75% of the macro-nutrients removed in the previous summer were replaced on 16 November 2018 to compensate for nutrient removal that would normally be recycled by grazing animals.

Sufficient rain was received in the spring of 2018 to incorporate broadcast fertiliser and start pasture growth. However, with no rain after November the grass did not grow enough to warrant a spring cut as has been the practice in previous years.

Crops grown at the Billa Billa site are represented by specific colours for all figures and graphs through this report (Table 1).

***Lower crop intensity* wheat at anthesis.**

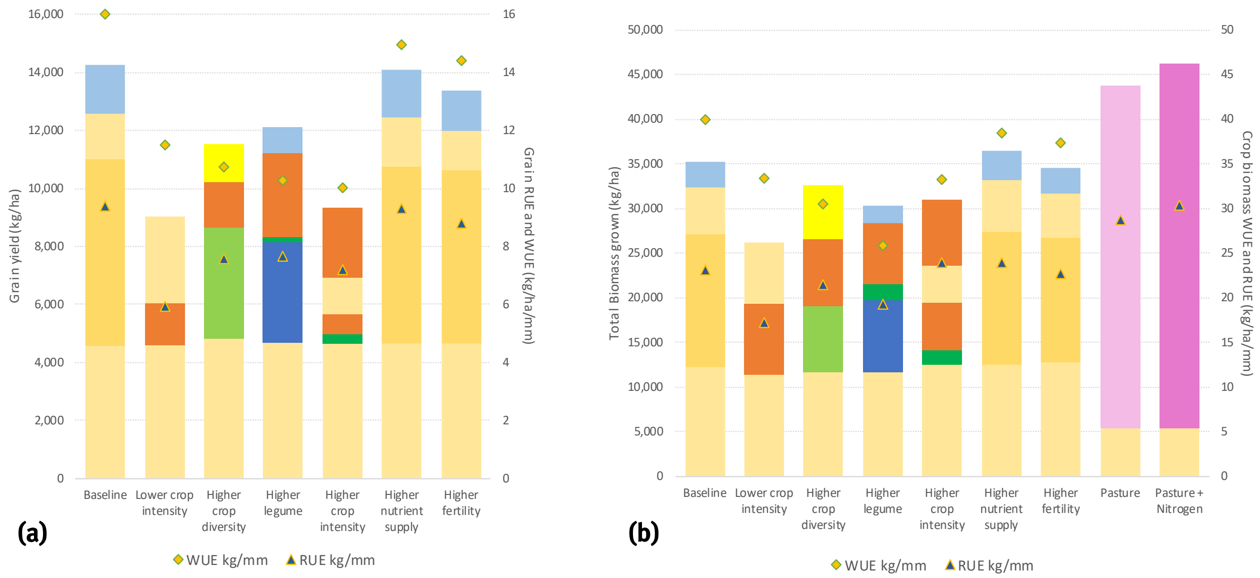

Figure 2. Cumulative (a) grain yield and (b) total dry matter grown for the systems at Billa Billa, with water use efficiency (kg of grain or kg/ha or dry matter per mm of PAW and in-crop rain used) and rainfall-use-efficiency (kg of grain or kg/ha of dry matter per mm of rain), including fallow rain.

Overall system performance 2015-2018

Accumulated grain yield (Figure 2a) across all years indicates the *Baseline*, *Higher nutrient supply* and *Higher soil fertility* systems are the highest yielding (14.2, 14.1 and 13.3 t/ha), with a similar trend for biomass production (32, 36 and 35 t/ha) (Figure 2b).

It is interesting to note that the *Lower crop intensity* and *Higher crop intensity* systems have produced a similar, lower accumulative grain yield (9 t/ha and 9.3 t/ha). However, the *Lower crop intensity* system has produced the least biomass (26.2 t/ha), approximately 4 t/ha behind the second lowest, *Higher legume*, and 9 t/ha behind the *Baseline* (35.2 t/ha). This lower biomass production (hence low stubble cover) is one of the main potential problems with the *Lower crop intensity* systems (leading to increased risk of erosion and organic carbon run-down).

As expected both the *Ley pasture* systems produced the largest amount of biomass (44 t/ha without N, 46 t/ha with N) (Figure 2b). Total biomass of the grass pastures is less than what was originally expected (grass only system ~10 t/ha more than the *Baseline* system), which is potentially a factor of higher winter rainfall in the first two years and three of four summers receiving below average rainfall (overall rainfall ~400 mm below average to December 2018), and pasture set-backs by forage harvesting rather than grazing. It will be interesting to assess if these differences in biomass production impact on soil carbon levels when the final comprehensive soil samples have been analysed.

Crop water use efficiency (WUE, efficiency of converting stored PAW and in-crop rainfall to yield) and rainfall use efficiency (RUE, efficiency of converting rainfall to yield) followed the same trends for both dry matter production and grain yield for all of the systems (Figure 2). WUE and RUE were highest for the highest-yielding crops. In six of the systems RUE was relative to the yield achieved, the exception being *Higher crop intensity* which was able to increase the proportion of rain used to grow biomass and grain with increased fallow efficiency. Conversely WUE favoured the *Lower crop intensity* system (relative to yield) with this system able to more efficiently convert the extra stored PAW to yield. *Higher legume* and *Higher crop diversity* had the lowest WUE relative to yield, due to these systems growing more canola and pulse crops.

All of the pulse crops to date have had significant amounts of PAW left deep in the profile at harvest, which has led to double crop opportunities after every pulse crop grown at this site (Figure 1). This has also meant the *Higher legume* system has grown the same number of crops as the *Higher crop intensity* system (six), despite having the same moderate planting water triggers as the *Baseline* system, which has grown two less crops.

The days in fallow versus in-crop varies dramatically between systems, with the *Lower crop intensity* system having the largest number (903 days) versus the *Higher crop intensity* system with the smallest (613 days) number of fallow days. The moderate crop intensity *Baseline* system was similar to the *Higher crop intensity* system at 630 days in fallow.

This site started with 350 kg N/ha (Figure 3). The cereal crops have reduced the available nitrogen levels more than the pulse crops grown in the same seasons, particularly in the high yielding 2016 winter crops. In 2018 the canola crop in *Higher crop diversity*, appears to have decreased available nitrogen more than the wheat in *Lower crop intensity*, which was more than chickpeas in *Baseline*. The long fallows in *Lower crop intensity* have allowed more nitrogen mineralisation; when combined with the lower yields this system has maintained the highest plant available nitrogen levels. The 70 t/ha of compost added to the *Higher soil fertility* system in November 2015 has allowed this system to increase mineralisation slightly, so plant available nitrogen levels are gradually increasing relative to the *Baseline* and *Higher nutrient supply* systems, for the same crop rotation.

Profitability of the systems to date has largely been driven by the high yields in two seasons; 2015 and 2016 winter crops (Figure 2a, Figure 4). The high starting available nitrogen levels at this site has allowed the *Baseline*, *Higher nutrient supply* and *Higher soil fertility* systems to grow 11 t/ha of cereal grain over the first two years, without the expense of nitrogen fertiliser. As such, these three systems have been the most profitable, with their only point of difference being a higher starter P fertiliser rate in the *Higher nutrient supply* and *Higher soil fertility* systems.

The *Higher legume* and *Higher crop diversity* systems were both planted to pulses in winter 2016 that yielded less than the barley, but the higher value of faba bean and field pea meant their income was similar to the much higher yielding barley (Figure 2a, Figure 4).

To date the *Lower crop intensity* system grew three crops, compared to six crops in the *Higher crop intensity* system, and achieved similar cumulative gross margins. These two systems were in fallow for the highly profitable crop achieved by the other systems in winter 2016. As a result the *Higher crop intensity* and *Lower crop intensity* systems are providing the lowest economic returns to date, but have provided similar returns to the *Baseline* since 2016.

Implications for growers

Preliminary gross margin analysis (Figure 4) shows the *Baseline* to be the most profitable system to date. This is largely driven by the exceptionally high yielding cereal crops in the first two years of the trial reaching close to water unlimited yield potential. The summer crops for the same period experienced below average rainfall and temperatures in the hottest 10% of years, and so achieved lower grain yield, crop WUE and the gross margins in the *Lower crop intensity* and *Higher crop intensity* systems

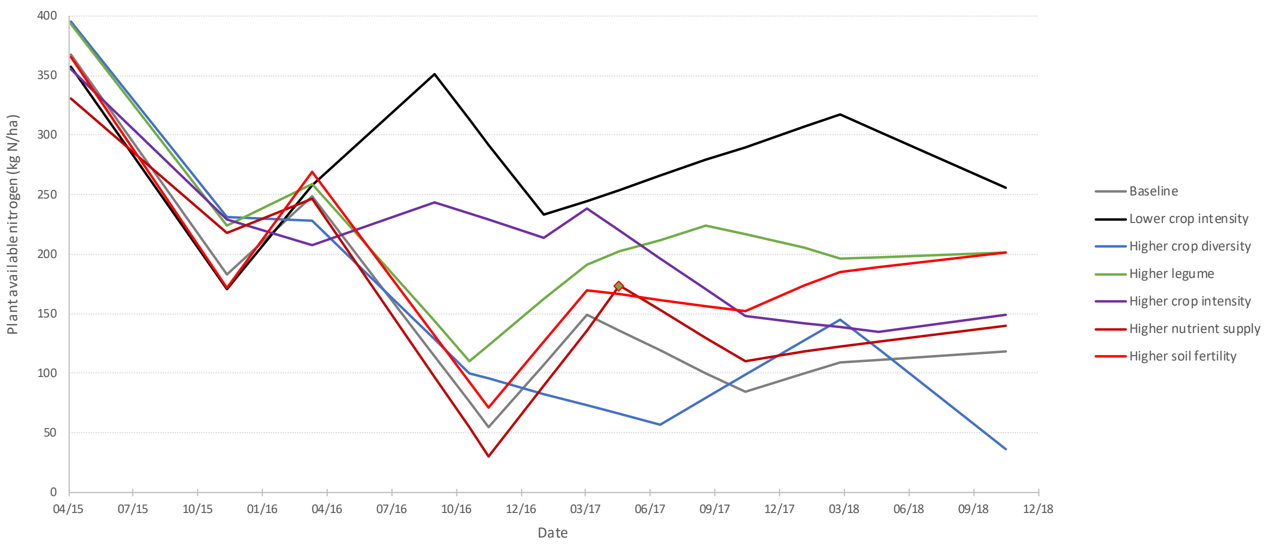

Figure 3. Dynamics of plant available soil nitrogen (nitrate and ammonia), measured prior to planting and at harvest of each crop. ◊ includes nitrogen added as urea in *Higher nutrient supply* system.

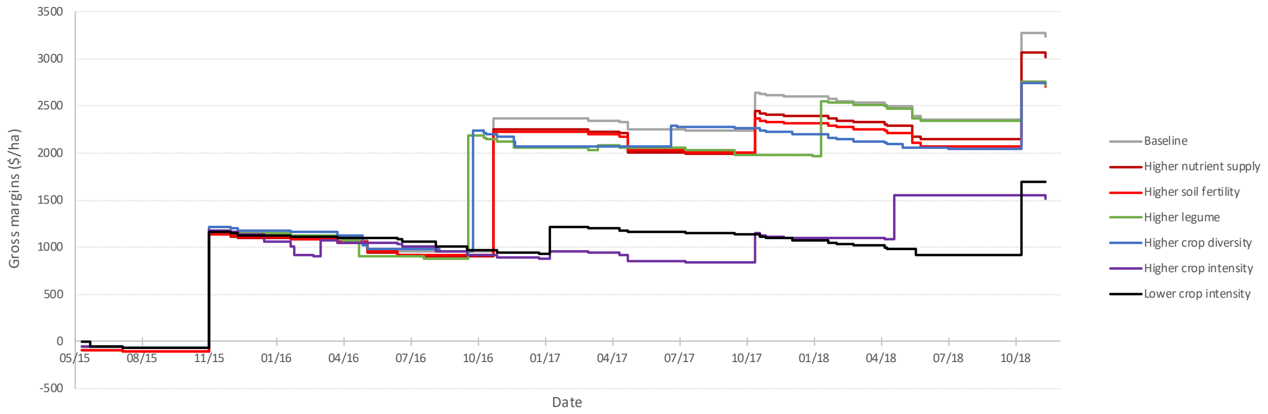

Figure 4. Cumulative cash flow for each of the systems at the Billa Billa site.

in this period. These systems are performing quite similarly to each other for both total grain yield and gross margin, despite the *Higher crop intensity* system growing an extra three crops. If this trend continues through the life of the trial it would suggest there is no financial difference between long-fallowing or taking double-crop opportunities to change between winter and summer crops.

Pulse crops are not using water as efficiently as the cereal crops to produce biomass and grain at this site, however the higher value of these commodities means the gross margin return (and $/mm) are equal to the cereal dominated systems. Additionally, the high sodium content of the soil below 30 cm has meant pulse crops have left extra water behind at harvest, providing more opportunities to double-crop.

Deep planting chickpea with a precision planter at the Billa Billa farming systems site.

Acknowledgements

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Trial details

Location:	Billa Billa
Crops:	Bambatsi grass, sorghum, canola, chickpea and wheat
Soil type:	Belah, Duplex
2018 rainfall:	420 mm

Canola starting to flower in *Higher crop diversity*, with wheat in *Lower crop intensity* behind.