Net water benefit of cover crops in Northern grains production. Farming water with ground cover

Andrew Erbacher[1], David Lawrence[2], David Freebairn[3], Neil Huth[4], Brook Anderson[4] & Graham Harris[2]

[1] Department of Agriculture and Fisheries, 22-26 Lagoon St, Goondiwindi, Qld, 4390, andrew.erbacher@daf.qld.gov.au
[2] Department of Agriculture and Fisheries, 203 Tor St, Toowoomba, Qld, 4350.
[3] DM Freebairn, Wilston, Qld, 4051
[4] CSIRO, 203 Tor St, Toowoomba, Qld, 4350.

Abstract
Low groundcover increases risk of soil erosion and reduces fallow efficiency. To remedy this cover crops can be grown to increase groundcover, but does the increased ground cover improve fallow water accumulation enough to recover the water used to grow the cover crop? To answer this, cover crops were planted into a long fallow following skip row sorghum, and sprayed out prior to growing wheat. The main cover crop was White French millet, which had different termination timings imposed. Other crops included sorghum, lablab and a mixed species (millet, lablab and tillage radish), which were all sprayed out at the same time as the mid-terminated millet. By planting of the subsequent wheat crop, all cover crop treatments, except the lablab, had recovered the water they used prior to termination, with some accumulating more plant available water (PAW) than the control. Increased ground-cover improved establishment of the wheat and all cover crop treatments had higher grain yield than the bare control in a drier than average season. These results confirm a crop can be grown and sprayed out to improve ground cover in a long fallow, without having a net negative effect on PAW, with yield benefits in the following crop in excess of what can be explained by increased soil water.

Key Words
Cover crop, Plant Available Water, millet, ground cover, stubble.

Introduction
Effective capture and storage of rainfall across the whole farming system remain major challenges for northern grain and cotton growers. Typically, only 15-30% of fallow rainfall is captured for use by dryland crops, with up to 75% being lost to evaporation, and a further 5-20% lost in runoff and deep drainage (Freebairn et al. 2009).

In these farming systems, low groundcover in fallow fields can increase the risk of runoff and erosion. By implementing cover crops into crop rotations, growers may increase ground cover to protect the soil from erosion, with added benefits of biomass recycling, which helps maintain soil organic matter and biological activity as well as providing additional nitrogen (when legumes are used). In addition, cover crops also offer an opportunity to increase infiltration and fallow moisture storage for better and more profitable grain and cotton crops across the northern region of New South Wales (NSW) and Queensland.

Improved ground cover offered by cover crops may be of benefit following wide or skip row sorghum that is used in marginal areas to reduce the risk of crop failure (Whish et al. 2009); following crops like chickpea that have low residual stubble; and following tillage for weed control or Helicoverpa resistance-management. Grains Research and Development Corporation (GRDC) funded Farming systems projects are assessing ways to improve system water use to achieve 80% of the water and nitrogen limited yield potential in our cropping systems and have identified crops with low fallow efficiency that may benefit from increased ground cover. GRDC's Eastern Farming Systems project (Whish et al. 2009) and Northern Growers Alliance trials both suggest that cover crops and increased stubble loads can reduce evaporation, increase infiltration and provide net gains in Plant Available Water (PAW) over traditional fallow periods. Consequently, a GRDC and Cotton Research and Development Corporation (CRDC) co-funded project is intensively monitoring cover crops to quantify the amount of water required to grow cover crops and the impact of increased stubble loads on the accumulation of rainfall as plant available water (PAW) over the fallow period and the subsequent impact on crop performance and yield. Thus cementing cover crops as a key part of improved farming systems; providing increased productivity, enhanced profitability and better sustainability.

Methods

Crops

The Bungunya experiment was established in a long-fallow paddock following skip-row sorghum that was harvested in early February 2017. The paddock had deep phosphorus applied in August 2017 and was 'Kelly-chained' in September 2017 to level the paddock, leaving it with little cover until the planned wheat crop in May 2018. Cover crops were planted in small plots (6 m x 18 m) on 11 October. Treatments varied according to planned termination timing and cover crop type. Three termination dates were implemented according to key growth stages of millet; Early-termination at first node (Z31) when the crop begins stem development, Mid-termination at flag leaf emergence (Z41) when the reproductive phase begins, and Late-termination at anthesis (Z65) for peak biomass production. Cover crop species grown included White French millet (*Panicum miliaceum*), grain sorghum (*Sorghum bicolor cv. MR Taurus*), lablab (*Lablab purpureus cv. Highworth*) and a mixed species which included millet, lablab and tillage radish (*Raphanus sativus, cv. Busta*) (Table 1).

Hand cuts were taken at termination of each cover crop treatment to estimate biomass produced, and repeated prior to planting of the wheat crop on 1 May 2018.Wheat biomass and grain yield were estimated with hand cuts on 12 October 2018, prior to and mechanical harvesting on 26 October 2018. A visual assessment of ground cover (%) was also recorded at various times throughout the fallow.

Soil water

Gravimetric soil samples were taken at cover crop establishment, cover crop termination, wheat planting and wheat harvest to a depth of 1.5m. Subsequent volumetric soil moisture values were used to calibrate Neutron Moisture Meter (NMM) count data and EM38 values taken throughout the trial. Aluminium access tubes were installed post-planting of the cover crop, and removed for wheat planting then re-installed. A hydroprobe NMM and EM38 were then used at two to four week intervals through the cover crop development, fallow period and wheat crop to monitor the dynamics in soil water. Soil water values are reported as change in volumetric water content over time from the initial sampling date (ie $\Delta PAW = Vol_i - Vol_t$).

Table 1 Cover crop treatments at the Bungunya site

Treatment	*Cover Crop*	*Termination Time*
1	Control (Bare)	
2	Millet (White French)	Early-sprayout
3	Millet (White French)	Mid-sprayout
4	Millet (White French)	Late-sprayout
5	Millet (White French)	Late-sprayout + rolled
6	Sorghum	Mid-sprayout
7	Lablab	Mid-sprayout
8	Multi-species (millet, lablab, radish)	Mid-sprayout

Results

Biomass and ground cover

Biomass of the millet cover crop treatments ranged from 1533 kg DM/ha for the early-termination, up to 4737 kg DM/ha for the late-termination. The lablab and multi-species treatments produced less dry matter than the cereals, and also broke down faster (**Error! Reference source not found.**).

Delaying termination of the millet crops provided more ground cover, and this cover persisted for longer (**Error! Reference source not found.**). The radish in the multi-species provided the fastest ground cover, but the high C:N ratio meant this treatment, along with the lablab and early-sprayout millet, degraded quickly over the fallow period to be less than 30% when the wheat crop was planted. The late-sprayout millet and the sorghum collapsed across the inter-row after sprayout, so increased ground cover later in the fallow (Figure 2).

Soil water

Average volumetric soil water at the initial sampling was 526 mm (~130mm PAW).

The water cost of growing the millet cover crops, relative to the Control treatment in the early stages of the fallow was ~50mm for the early-termination, ~40 mm for the mid-termination and ~60 mm for the late-termination (Figure 3). The mid-terminated lablab treatment also cost ~60 mm to grow, relative to the Control treatment (Figure 4). These results reflect additional rainfall and different rates of infiltration achieved by the different sprayout timings. Rainfall between the key soil-water measurements of the mid-sprayout treatments was:

- Planting of cover crops to Mid-termination, 86 mm in four events (11/10/17 to 22/11/17)
- Mid-termination to planting of wheat crop, 205 mm in 11 events (22/11/17 to 1/5/18)
- Plant to maturity of wheat crop 41mm in 3 events (1/5/18 to 10/10/18)
- Maturity to post-harvest soil sample 72mm in 7 events (10/10/18 to 5/11/18)

Between mid-termination and 28 February 2018, 175 mm of rainfall had fallen in ten events, and the millet treatments all recovered the PAW used, to have similar soil water as the Control, except the late-terminated and rolled millet, which had 19 mm more PAW than the Control (Figure 3).

When the subsequent wheat crop was planted on 1 May, the mid-terminated millet had 13 mm more PAW than the Control treatment. Similarly the late millet had 15 mm more, and the late millet that was rolled had 31 mm more soil water than the Control at this time (Figure 3, Figure 6). Interestingly, water extraction by the wheat crop was also greater from all of the millet cover crop treatments than the Control, which had lower yields; perhaps due to, or resulting in less root development.

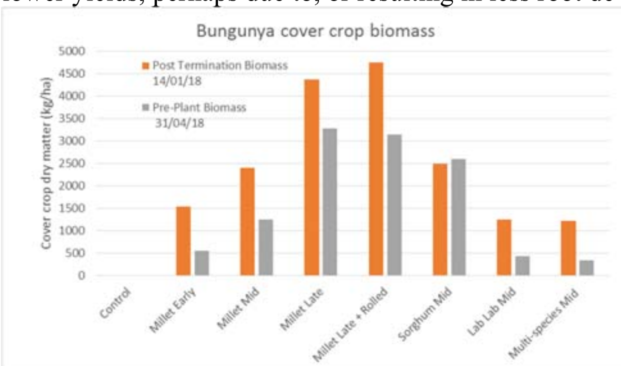

Figure 1 Cover crop biomass measured after termination and at the end of the fallow period

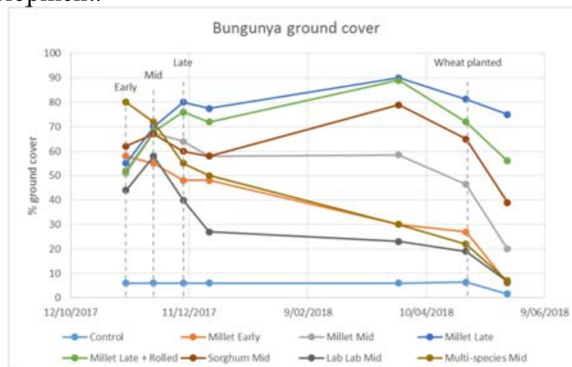

Figure 2 Visual assessment of % ground cover

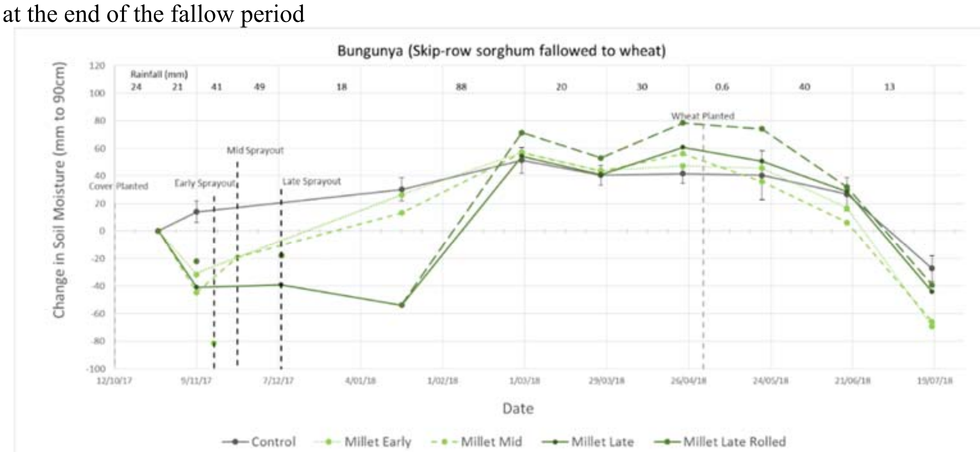

Figure 3 Soil water dynamics of White French millet cover treatments, from calibrated NMM readings, relative to the initial gravimetric soil samples at cover crop emergence, with rainfall (mm) between each assessment.

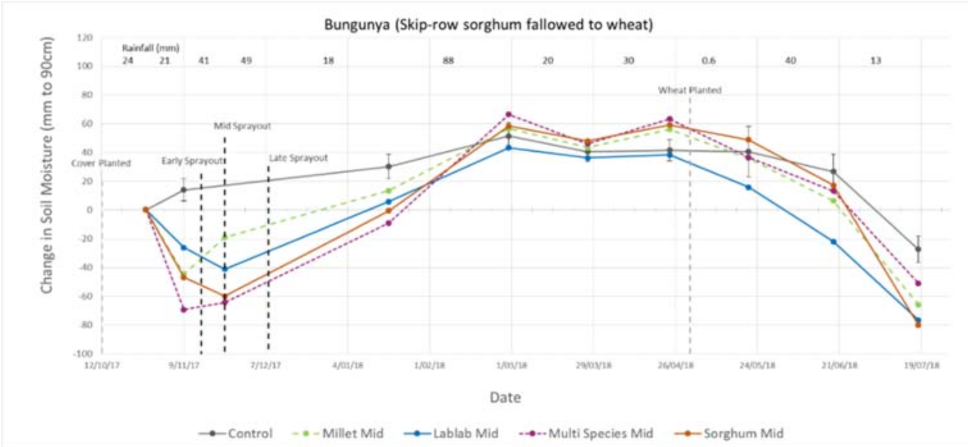

Figure 4 Soil water dynamics of cover crop species terminated at the mid-sprayout timing, from calibrated NMM readings, relative to the initial samples taken after cover crop emergence, with rainfall (mm) between each assessment.

Crop performance

All cover crop treatments increased the yield of the final wheat crop (**Error! Reference source not found.**) and saved two fallow weed sprays (~$40/ha). However, the biggest yield increases were from the cereal cover crops, especially the late-terminated millet and the sorghum.

The water differences at planting (end of the fallow) may explain some of the yield difference (Figure 6). Gravimetric measurements taken post wheat planting showed that the cover crops had more water in the 0-10cm layer (Figure 6). This extra surface water has improved establishment of the wheat crop dramatically where cover crops were used, more so where cereals were used but also for lablab. The expected yield increases from the higher fallow water storage alone would typically be ~200 kg grain in wheat (at WUE 15 kg/ha/mm) for the mid-terminated millet (worth ~$50/ha), ~280 kg grain for the late millet (worth $75/ha) and ~540 kg grain for the late +rolled millet (worth $150/ha). These gains would represent net returns of $20/ha, $45/ha and $120/ha respectively. However, the measured yield gains for these treatments were 950 kg/ha, 1461 kg/ha and 1129 kg/ha respectively, representing increase returns of between $250 and $380 /ha.

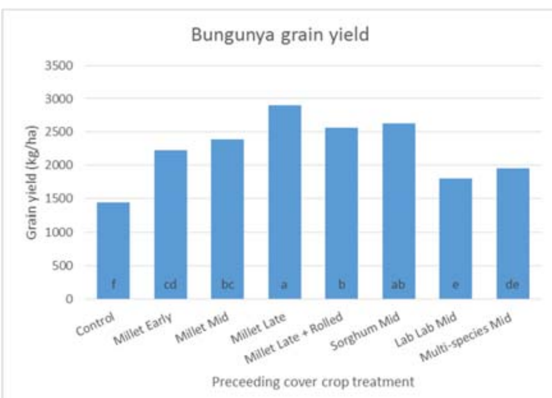

Figure 5 Wheat grain yield following different cover crop options, with PAW advantage over the bare control at wheat planting. Letters show significant difference (p 0.05)

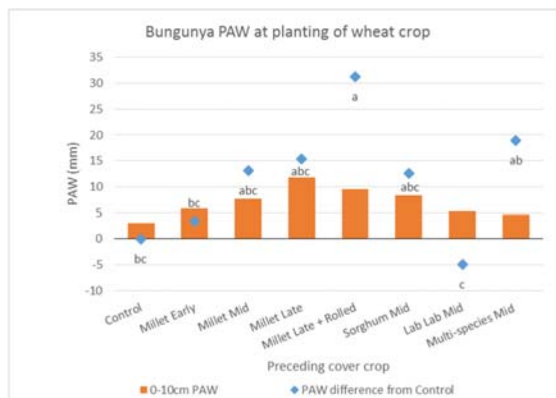

Figure 6 Plant available water present at planting of the wheat crop. Letters relate to the difference in PAW from the control (◆) showing significant difference (p 0.05).

Conclusion

These results shows that cover crops can indeed help increase net water storage across fallows with limited ground cover. How often these soil water results will occur across different seasons will be explored across the rest of the project with further experiments and simulation modelling.

However, more dramatic are the early yield results for the subsequent wheat crop. These yield responses are very large and represent big improvements in returns; far beyond what could be expected from the increases in net soil water storage across the fallows. Similarly Whish et al. (2009) also measured yield benefits greater than could be attributed to PAW. Wheat establishment was dramatically improved in this Bungunya experiment, and there was greater water extraction. How much of the responses can be attributed to these

factors, how often such results might occur, and the contributions of other different factors to these gains remains to be explored.
This site had a long fallow, and so had the greatest benefits were achieved by the later terminated cover crops, which grew more biomass and had more resistant stubble.

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