MIXED COVER CROPS

FOR SUSTAINABLE FARMING

# Multi Species Demonstration Trials

# Soils & Agronomic Analysis

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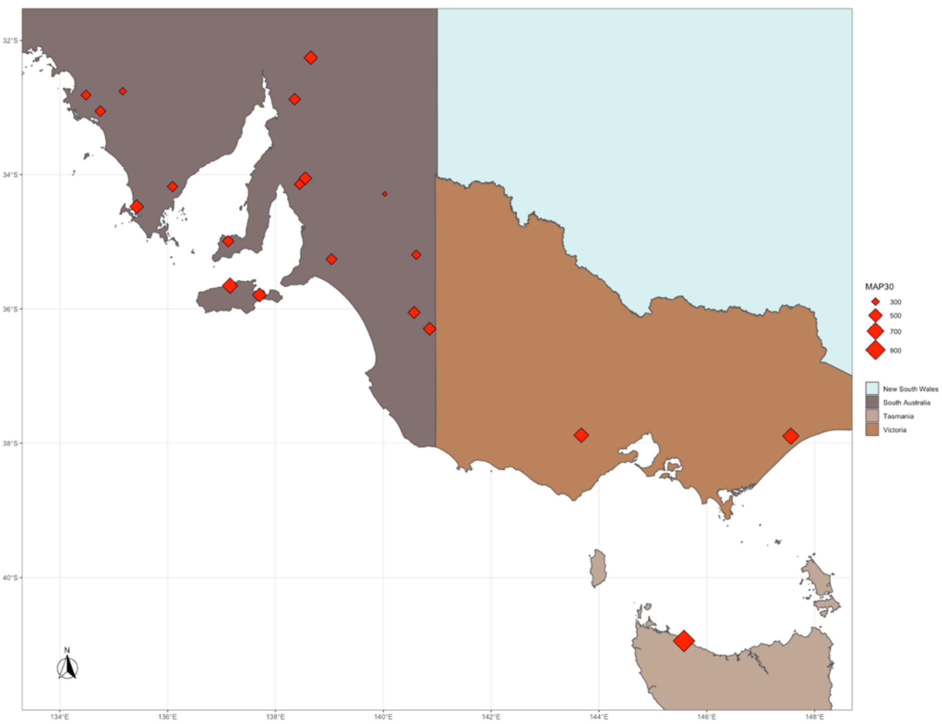
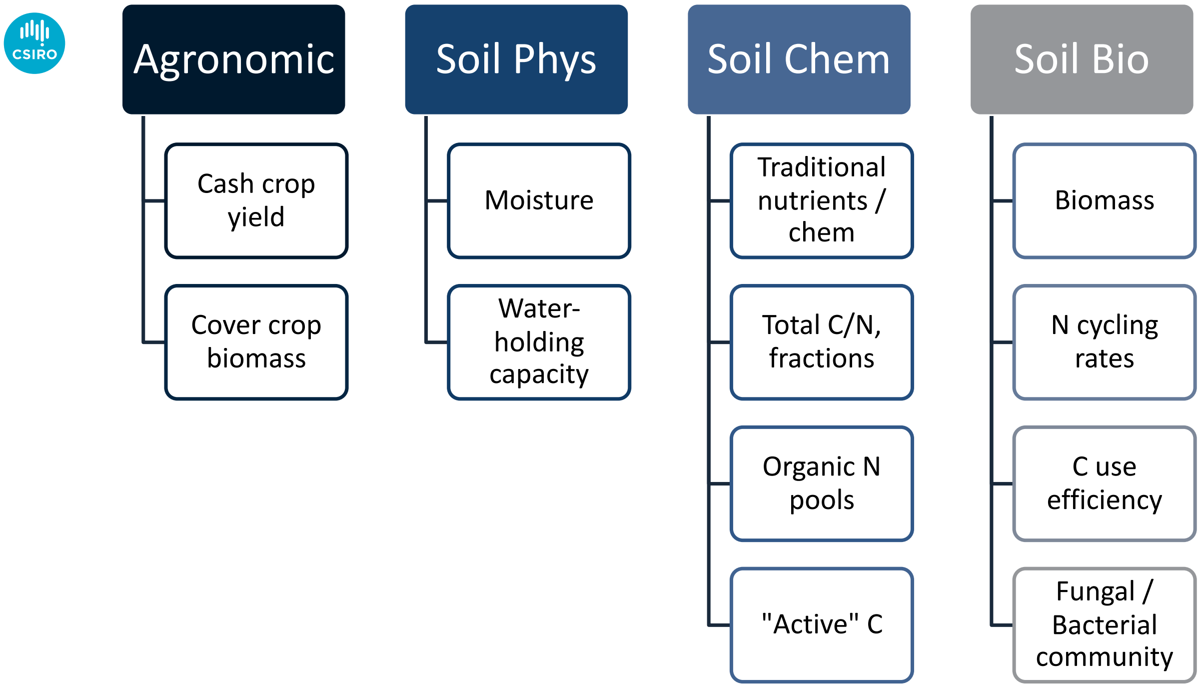
## Sample analysis conducted

This section of the project consisted 20 field sites stretching from Maryvale (near Streaky Bay, SA) to Sisters Creek in NW Tasmania. I designed the experiments and assisted with any queries regarding their implementation. Each site had three treatments (business as usual control, single-species cover crop, multi-species cover crop), which were replicated four times, resulting in 12 experimental plots at each of the 20 sites. In many cases, summer active cover crops were sown to augment existing rotations, but in particularly rainfall-limited systems, cover crops were used in the winter phase.

Explicitly designed as a “light touch” means of testing the incorporation of single- or multi-species cover crops into southern Australian grain-growing systems, implementation was not overly prescriptive. Cover crop treatments were requested whenever feasible within the cropping (and on occasion, grazing) sequence, and only expected prior to the final cash crop season that fell within the project window. This means that the project tested realistic comparisons, rather than mandating successive cover crop rotations where the prevailing season likely limited success. The location of the sites is shown below, with point size indicating long-term mean annual precipitation (smaller = lower):



In total, 1106 soil samples were collected and analysed from five depths of the 12 plots across the 20 sites. This is slightly lower than the expected due to both limited soil depth at some sites, and issues with the experimental design protocol being followed by the land-holder at one site meaning that there were fewer plots to sample. Sampling was mostly carried out in accordance with agreed protocols by the collaborators, with samples arriving in the CSIRO laboratories in a timely manner. Over the following period of several months, these samples were subjected to a large number of analyses outlined below:




Taken together, these analyses were selected to both test relevant and innovative soil health and biological parameters such as nitrogen cycling pathways and microbial community structure, and place these in the context of more traditionally understood agronomically-important soil properties

**Data Analysis**

Due to the structured design of the project (same experimental design across 20 sites), we were able to consider the project as a single experiment along a rainfall gradient, moderated by soil type. This has enabled us to work towards developing a systematic understanding of the effects of cover crop incorporation across the whole of the southern grain-growing region.

Noting that in many cases there has only been 1-2 seasons of cover cropping at the sites, informal visual analysis of trends was selected as the most appropriate form of data interpretation in the first instance. This is because it is well known from areas where cover crops are known to be successful (cool/temperate regions in the USA and Europe), statistically significant responses often take 5-10 years to manifest themselves. To reduce bias in this more subjective approach, all variables of interest were plotted in exactly the same way, enabling comparisons between treatments across the sites.

For variables known to be especially dynamic (e.g., microbial community structure), or in situations where very clear apparent treatment effects were observed, formal statistical hypothesis testing as carried out either using univariate mixed linear models (e.g., soil organic C at one site), or multivariate permutational analysis of variance (PERMANOVA; e.g., fungal community structure).

Following this interrogation of the data, a ranking for each variable of interest at each site was conducted, with positive scores where the cover crop had improved the variable of interest, and negative scores where there had been a deterioration. Neutral results were scored zero. For the most important variables (cash crop yield and soil organic C), these were more heavily weighted. This approach enabled a clear picture to emerge which illustrates not only which situations favoured or were negatively impacted by the adoption of cover crops, but also which variables drive this assessment.

### Interpretation and main findings

The main finding of the soils and agronomy analysis on the cover crop demonstration trials is that whilst expectedly climate driven (the most successful sites generally had the highest rainfall, and the least successful had the lowest). The table that follows illustrates this. Sites are arranged in order of increasing annual precipitation as rows, with columns detailing many of the soil characteristics measured, as well as yield and cover crop biomass. The final column is the total for each site, and the final row is the total for each variable. In the first block, negative trends are detailed (green being an apparent negative effect). In the second block, positive results are shown (green being an apparent positive impact). The extra row and column on the outside of this second block is the balance of these two matrices, with dark red been strongly negative overall, and dark green being strongly positive overall.

Whilst it is clear that at several of the lower-rainfall sites there was a negative impact on crop yield, this was not observed at the majority of sites, and indeed yield increases (where data was available) were observed at a similar number. Whilst it is clear that growing a summer cover crop likely utilises some soil water which may impact eventual yield, reduced soil moisture did not appear to impact yield at most sites in what was mostly a reasonable growing season in 2021.

The main biogeochemical finding we observed was a decrease in nitrate-N at many of the cover crops sites, accompanied by an increase in both dissolved organic N (DON) and microbial biomass N (MBN), as well as proteolysis and amino acid uptake. Taken together, these findings suggest that cover cropping has reduced the concentration of the most lossy form of plant-available nitrogen (nitrate), whilst also increasing the amount of N that is potentially available (DON + MBN), and its rate of delivery (proteolysis and amino acid uptake). Assuming that cover crops can be integrated into systems without imparting either a yield penalty or excessive monetary cost, this finding suggests that they may act to reduce N losses, retaining N in an easily mineralisable form, and increasing the rate of that mineralisation.

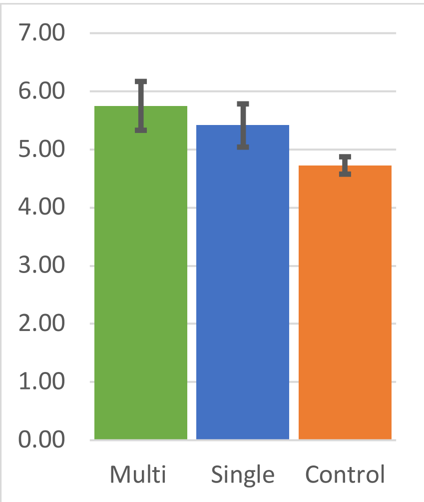
| Negative | Biomass | Yield | MC | WHC | P | NO3 | DON | POXC | SOC | CUE | MBN | Prot | Aaup | BacR | FunR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| "DEM_07" = "Waikerie, ML", | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| "DEM_12" = "Minnipa, UEP", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| "DEM_08" = "Parilla, ML", | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 6 |
| "DEM_10" = "Maryvale, UEP", | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| "DEM_16" = "Balaklava, MN", | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 |
| "DEM_04" = "Ungarra, LEP", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 |
| "DEM_09" = "Langhorne Creek, ML", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| "DEM_14" = "Honiton, YP", | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| "DEM_20" = "Booleroo Centre, UN", | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| "DEM_06" = "Sherwood, USE", | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| "DEM_05" = "Pine Hill, USE", | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 4 |
| "DEM_15" = "Hoyleton, MN", | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| "DEM_13" = "Belalie East, UN", | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| "DEM_03" = "Coulta, LEP", | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| "DEM_01" = "Haines, KI", | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| "DEM_17" = "Rokewood, CD (Vic)", | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| "DEM_02" = "Stokes Bay, KI", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| "DEM_19" = "Bairnsdale, EG (Vic)", | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| "DEM_18" = "Sisters Creek, NWC (Tas)" | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 2 | 8 | 9 | 4 | 1 | 7 | 1 | 2 | 2 | 3 | 1 | 3 | 1 | 3 | 2 | 49 |

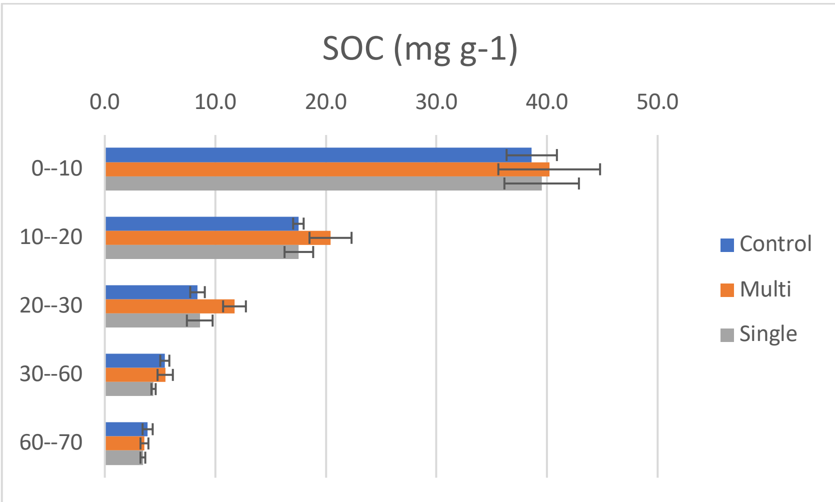
| Positive | Biomass | Yield | MC | WHC | P | NO3 | DON | POXC | SOC | CUE | MBN | Prot | Aaup | BacR | FunR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| "DEM_07" = "Waikerie, ML", | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 4 | 2 |
| "DEM_12" = "Minnipa, UEP", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| "DEM_08" = "Parilla, ML", | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 4 | -2 |
| "DEM_10" = "Maryvale, UEP", | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 5 | 0 |
| "DEM_16" = "Balaklava, MN", | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | -2 |
| "DEM_04" = "Ungarra, LEP", | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 7 | 4 |
| "DEM_09" = "Langhorne Creek, ML", | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 5 | 4 |
| "DEM_14" = "Honiton, YP", | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 6 | 1 |
| "DEM_20" = "Booleroo Centre, UN", | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 |
| "DEM_06" = "Sherwood, USE", | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 |
| "DEM_05" = "Pine Hill, USE", | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | -1 |
| "DEM_15" = "Hoyleton, MN", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 |
| "DEM_13" = "Belalie East, UN", | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -2 |
| "DEM_03" = "Coulta, LEP", | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 8 | 5 |
| "DEM_01" = "Haines, KI", | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 11 | 9 |
| "DEM_17" = "Rokewood, CD (Vic)", | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 7 | 6 |
| "DEM_02" = "Stokes Bay, KI", | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 9 | 7 |
| "DEM_19" = "Bairnsdale, EG (Vic)", | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 2 |
| "DEM_18" = "Sisters Creek, NWC (Tas)" | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 7 | 6 |
| | 10 | 8 | 0 | 4 | 3 | 2 | 9 | 6 | 5 | 2 | 10 | 8 | 9 | 4 | 6 | 86 | 37 |
| | 8 | 0 | -9 | 0 | 2 | -5 | 8 | 4 | 3 | -1 | 9 | 5 | 8 | 1 | 4 | 37 | |

Collectively, sites can be grouped by rainfall into three categories:

1) Low rainfall. These sites will typically not benefit from the integration of summer cover crops unless there is either exceptional summer rainfall to support an opportunistic planting that is carefully monitored for water usage. Cover crops may be suitable (single or mixed) when sown in winter in place of a cash crop. However, if biomass is then harvested for hay or grazed, their positive impact on soil function would likely be reduced (whilst noting their contribution to the fam business through the provision of biomass/fodder). For summer cover crops in these environments there is a risk that spoil health outcomes may actually regress due to excessive water use curtailing growth and carbon input from the following winter cash crop.
2) Medium rainfall. These sites may benefit from either summer or winter cover crops, though care would need to be taken when looking towards growth in the summer season to avoid a water penalty for the following winter crop. Nonetheless, it is apparent that within the context of the short study period this project allowed, there are positive, neutral, and negative outcomes across the medium rainfall sites (Ungarra to Belalie East on the above figure).
3) High rainfall. These sites (found on the eastern side of the LEP, KI, Vic and Tas in the present study) showed the most consistently positive outcomes, with many suggesting an increase in cash crop yield as well as multiple soil health benefits, even after the relatively short time period afforded by the project. Care would still need to be taken regarding excessive water use.

Out of the higher rainfall sites, the site at Stokes Bay (KI) showed most promise, with a 1 t/ha increase in yield of the oats cash crop following 1½ summers of mixed species cover crop (below, left). Notably, even after such a relatively short adoption period, this also resulted in an increase in SOC concentration in the 10-20 cm and 20-30 cm layers, with the lower of these two depths being a statistically significant increase.




Project Proponents

Project Funders