New technologies for wheat crop monitoring on the Eyre Peninsula

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RESEARCH

Looking for answers

Location
Paul Schaefer
Pinkawillinie
Rainfall
Weather station: Buckleboo (018172)
2017 Total: 357 mm
2017 GSR: 180 mm
Yield
Potential: 2.4 t/ha
Actual: 3.8 t/ha
Paddock History
2016: Medic pasture
Soil Type
Clay loamy sand
Plot Size
20 m x 20 m x 3 reps, with each plot split into subplots (10 m x 20 m)

Location
Jordan Wilksch
Karkoo
Rainfall
Weather station: Yeelanna (018007)
2017 Total: 358 mm
2017 GSR: 227 mm
Yield
Potential: 4.0 t/ha
Actual: 4.0 t/ha
Paddock History
2016: Canola
Soil Type
Loamy sand
Plot Size
20 m x 20 m x 3 reps, with each plot split into subplots (10 m x 20 m)

Location
Ben Pope
Warramboo
Rainfall
Weather station: Kyancutta (018044)
2017 Total: 309 mm
2017 GSR: 155 mm
Yield
Potential: 2.2 t/ha
Actual: 2.6 t/ha
Paddock History
2016: Wheat
Soil Type
Sand
Plot Size
20 m x 20 m x 3 reps, with each plot split into subplots (10 m x 20 m)

Key messages

- **Soil moisture capacitance probes are a valuable tool for continuous monitoring of soil moisture throughout the soil profile.**
- **The soil moisture probe moisture follows the same pattern as APSIM extractable soil water, suggesting that the moisture probes are a good measure of the moisture in the soil at the paddock scale.**
- **Visible-near infrared spectroscopy is a rapid, cost-effective solution that can be used to predict plant and soil nitrogen, plant biomass, and soil particle size.**
- **Infrared spectroscopy can be used to assist with crop management decision making (e.g. N applications).**

Why do the trial?

The aim of this project was to assess the usefulness of new technologies to support crop management decisions on the Eyre Peninsula. The technology evaluated as part of this project included recently installed soil moisture probes and an infrared spectroradiometer.

Wheat grain yields are subject to high annual variation as a result of many factors, particularly the availability of water and nitrogen resources in rain-fed cropping systems in semi-arid environments such as South Australia [1,2]. Within season and within paddock variability can contribute to uncertainty associated with crop potential and cropping inputs resulting in the need for continuous crop monitoring, including soil moisture content and crop nitrogen status.

There are many new tools such as soil moisture capacitance probes and infrared spectroscopy that can be utilised to collect and analyse crop performance data that are rapid, cost effective and non-destructive strategies. Other tools, e.g. APSIM, utilise a simulation model-based approach and rely on a range of input information (e.g. sowing date, nitrogen inputs) to predict various crop information, e.g. soil moisture and yield.

Soil moisture capacitance probes have recently been installed on the EP and are an attractive tool as they are of low-cost, time-efficient, require little attention once installed, and provide continuous data on soil moisture throughout the soil profile. These instruments will also have the ability to compare data with previous years and once enough data has been collected, may aid in crop choice decisions by assessing pre-sowing plant available water, potentially provide increased confidence in sowing time by assessing soil moisture reserves, and possibly assist with informed input decisions with the aim of lowering inputs in years of low moisture and increasing yield potential when favourable seasons occur [3].There is however, the question of whether a single probe can be relied upon for field-scale interpretations due to potentially large variability across the paddock and the distance from the probe that it is able to measure [4]. There are limited examples of the use of soil moisture probes in dryland cropping systems in South Australia, but interest and awareness in this technology is increasing.

Location Jason Burton Rudall **Rainfall** Weather station: Rudall (018174) 2017 Total: 293 mm 2017 GSR: 190 mm **Yield** Potential: 2.2 t/ha Actual: 2.7 t/ha **Paddock History** 2016: Wheat **Soil Type** Sand **Plot Size** 20 m x 20 m x 3 reps, with each plot split into subplots (10 m x 20 m)	

Location Jamie Phillis
Ungarra
Rainfall
Weather station: Ungarra (018088)
2017 Total: 379 mm
2017 GSR: 240 mm
Yield
Potential: 3.9 t/ha
Actual: 3.4 t/ha
Paddock History
2016: Lentils
Soil Type
Sandy clay loam
Plot Size
20 m x 20 m x 3 reps, with each plot split into subplots (10 m x 20 m)

Infrared technology measures the wavelengths of light that are reflected from a particular surface (e.g. soil or crop canopy) and is similar to GreenSeeker/NDVI technology, except that it measures a wider range of light wave lengths. The use of infrared spectroscopy has been widely used in laboratories as a rapid, non-destructive and low-cost option for predicting plant and soil properties such as nitrogen and water stress [5,6], however it has had little application in field studies. This tool could be used to capture paddock variation throughout the paddock-scale to provide a better estimate of yield-driven variables, and also yield itself [1,7].

APSIM is a computer based crop simulator that is available commercially as Yield Prophet through BCG that enables crop paddock simulation and monitoring based on various input information (e.g. nitrogen inputs, sowing date, crop type, cultivar, sowing rate) [8,9].

By combining all three of these tools there is opportunity to improve the accuracy in decision making of in-crop N applications with measured soil moisture conditions on the EP.

How was it done?

Five replicated field experiments were set up across the Eyre Peninsula in wheat paddocks as close to the soil moisture probes as possible. Each trial had three plots (20 m x 20 m) that were separated into subplots (10 m x 20 m). The locations were: Warramboo (B. Pope), Pinkawillinie (P. Schaefer), Rudall (J. Burton), Karkoo (J. Wilksch), and Ungarra (J. Phillis). The crop details for each site are presented in Table 1.

Soil physical and chemical properties and gravimetric water content were measured pre-sowing. Each site in this project had a soil moisture capacitance probe and a weather station that were used to monitor soil moisture and to obtain site-specific rainfall information throughout the season. The probes utilise telemetry systems that allow the data collected to be accessed via mobile devices or computers through the Eyre Peninsula Agricultural Research Foundation (EPARF) website (https://eparf.com.au/). Biomass cuts were taken at Z3.1 (stem elongation), Z6.5 (flowering) and Z9.4 (maturity) and were dried, ground and sent to the laboratory for N analysis. An infrared spectroradiometer (Spectral Evolution, SR-3500, USA) was used on a weekly basis on crop canopy and the soil surface in the field from Z3.1 to Z6.5 and on the dried and ground biomass and pre-sowing soil profile samples. Soil and canopy property prediction models were developed using the spectra in the range of 350–2500 nm and analysed using partial least squares regression (PLSR) in the Unscrambler (CAMO version 10.3) program. APSIM was used to develop crop simulation models to assess the predicted soil moisture content in relation to the moisture probes.

Cereals

Table 1. Crop details and sowing nitrogen applications in 2017.

Locality	Crop	Variety	Sowing date	Sowing rate (kg/ha)	N applied (kg/ha)	Mineral N @ sowing (kg/ha)	GSR (mm)	PAW (ext.) @ March 2017	Grain yield (t/ha)
Rudall	Wheat	Mace	16 May	65	5	39	170	105	2.72 – no N 2.62 + 46 kg/ha N
Ungarra	Wheat	Mace	1 July	80	11	11	240	76	2.79 – no N 3.42 + 46 kg/ha N
Warramboo	Wheat	Mace	30 May	75	75	9	170	9	2.37 – no N 2.61 + 46 kg/ha N
Pinkawillinie	Wheat	Scepter	7 May	60	12	84	140	84	3.29
Karkoo	Wheat	Trojan	21 April	75	41	67	186	55	3.68 – no N 4.02 + 46 kg/ha N

The soil moisture capacitance probes provided continuous uncalibrated monitoring of soil moisture throughout the soil profile to a depth of 1 m. The information collected illustrates the location of roots in the soil profile and where the soil moisture is being extracted as indicated by the 'stepping' in Figure 1. The summed soil moisture in relation to rainfall events, plant water use and evaporation is also presented (Figure 2).

The summed soil moisture generated by the probe was plotted in conjunction with the APSIM predicted extractable soil water (esw) using the same rainfall data collected from the weather stations at each location (Warramboo, Pinkawillinie and Karkoo). The plots illustrated that the probe moisture and esw follow a very similar pattern (Figures 3, 4, 5) indicating that the moisture probes may be a good estimation of soil moisture at paddock scale.

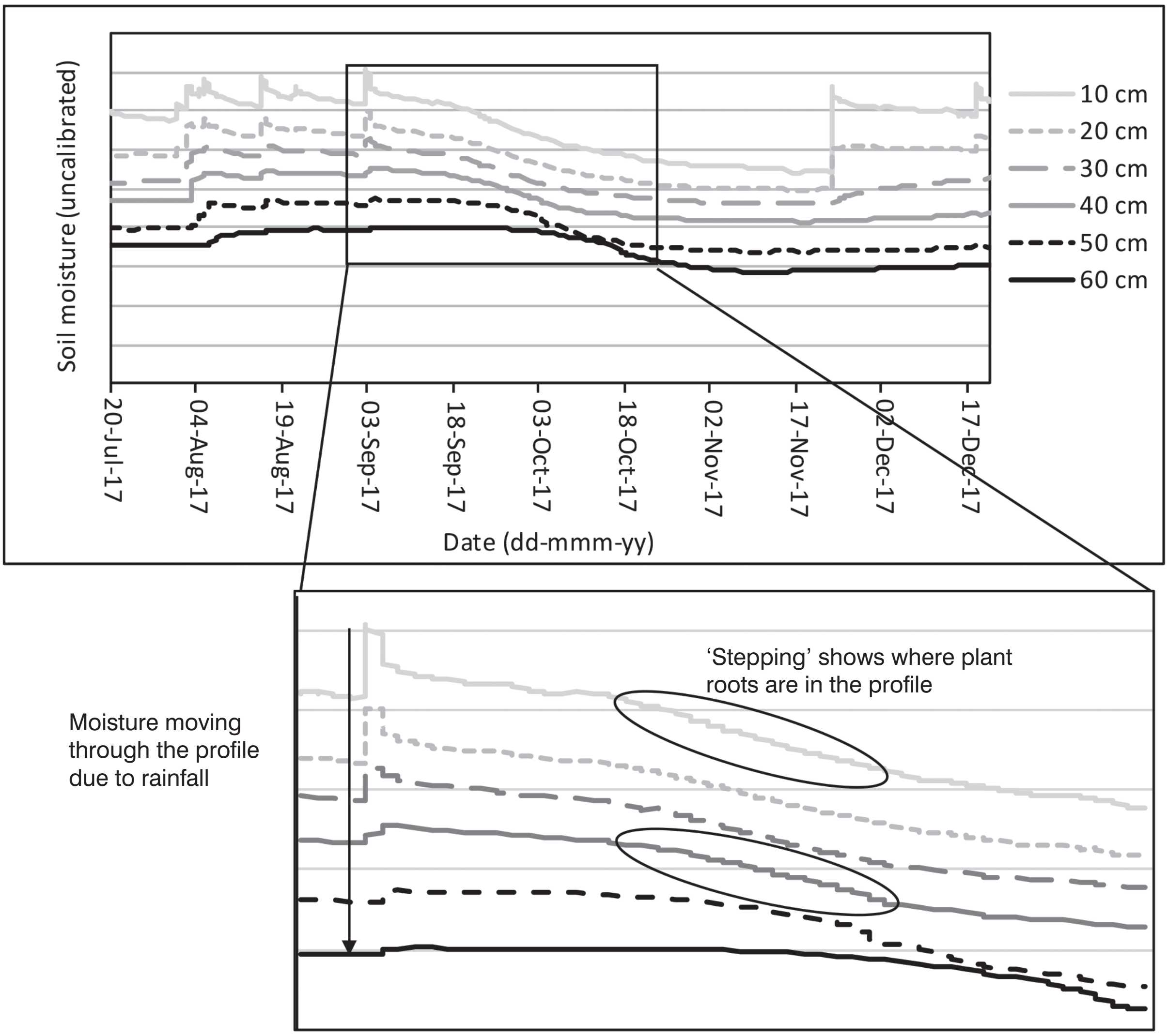

Figure 1. Stacked soil moisture graph of the soil profile at Ungarra using the data collected from the soil moisture capacitance probe.

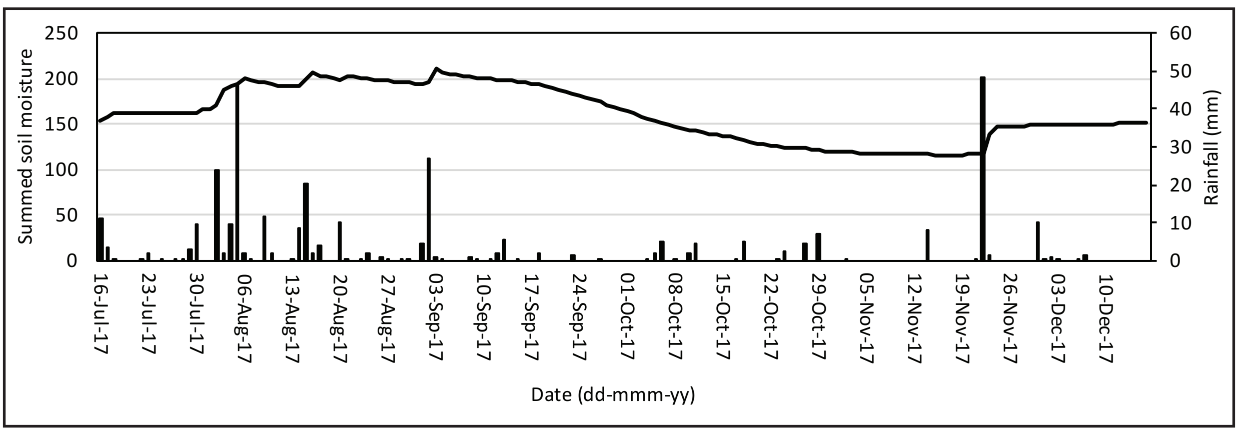

Figure 2. Summed soil moisture and rainfall (mm) data from the Ungarra soil moisture probe.

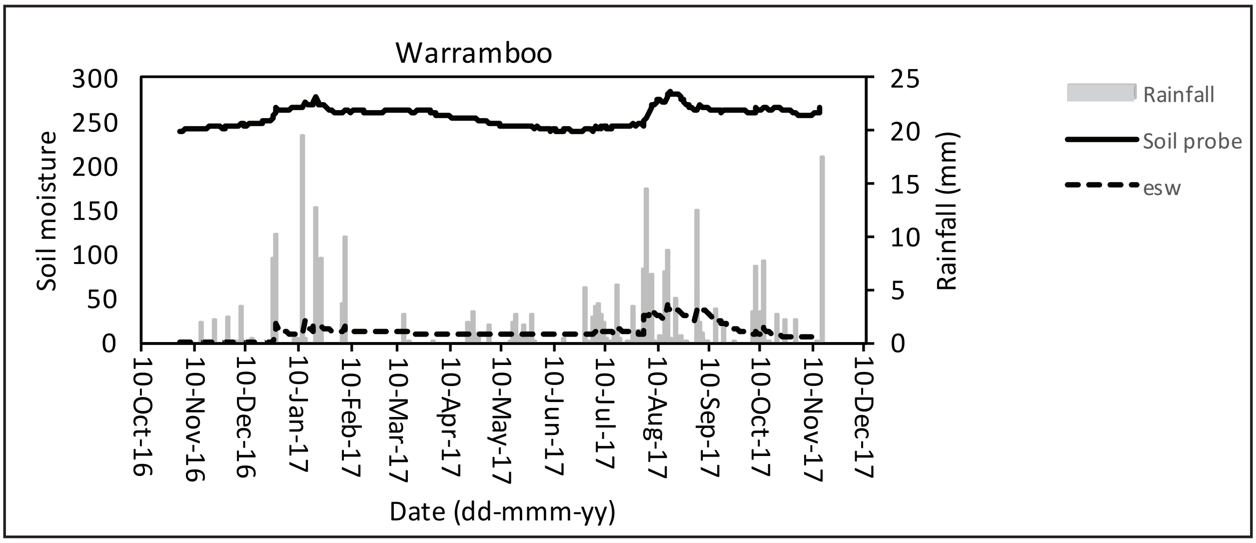

Figure 3. Warramboo summed soil moisture, extractable soil water and rainfall. Extractable soil water based on an estimated starting soil moisture of 0% using APSIM.

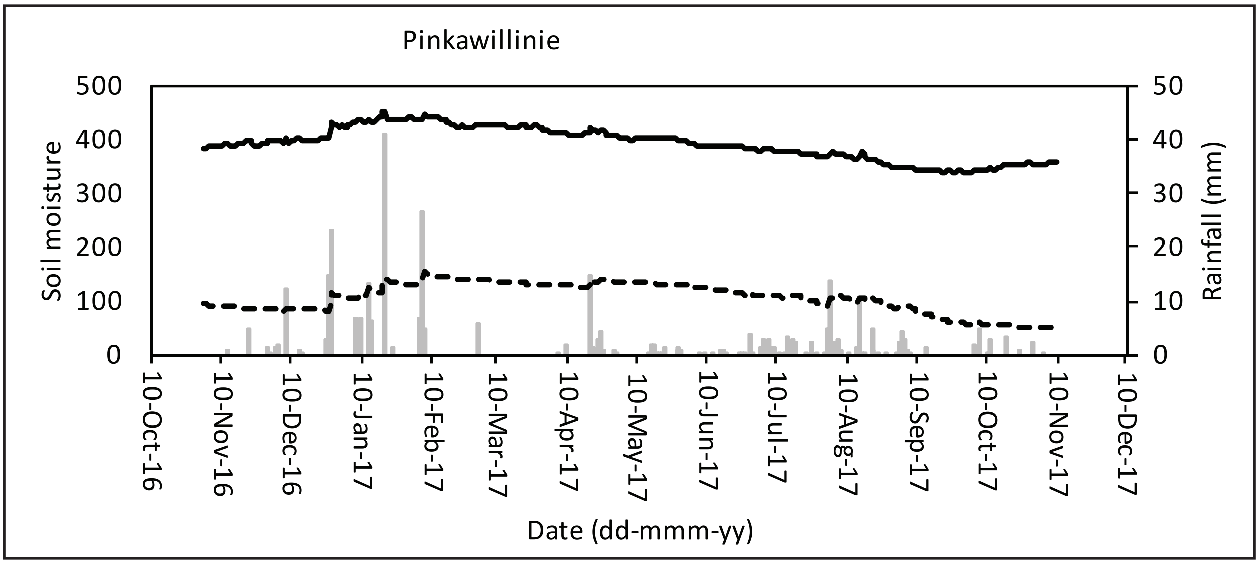

Figure 4. Pinkawillinie summed soil moisture, extractable soil water and rainfall. Extractable soil water based on an estimated starting soil moisture of 30% using APSIM.

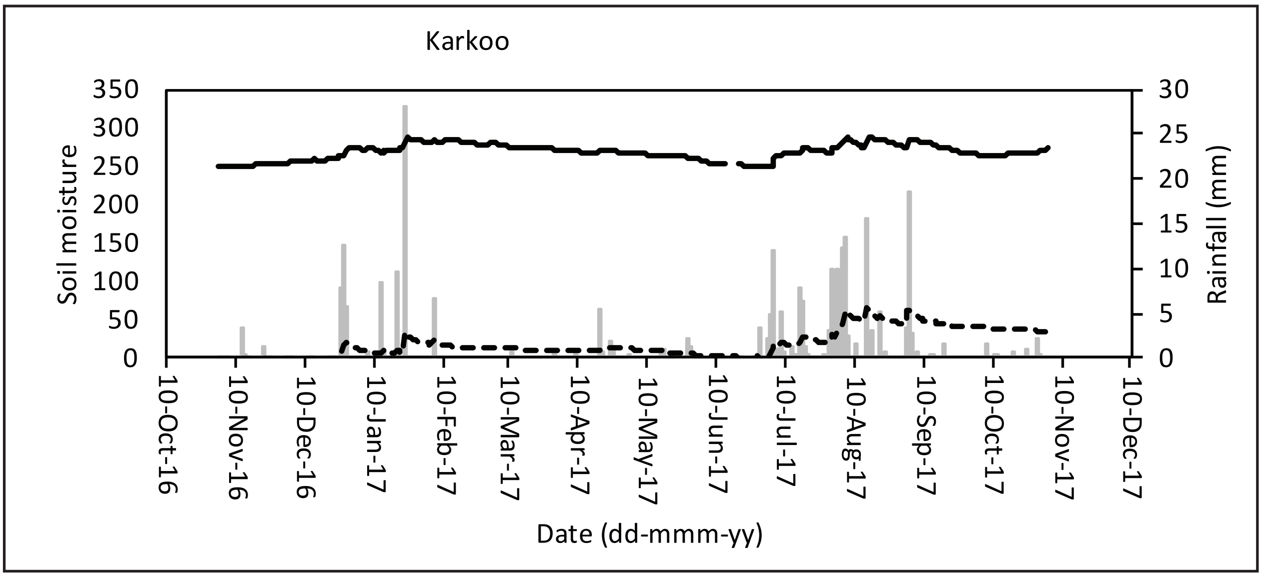

Figure 5. Karkoo summed soil moisture, extractable soil water and rainfall. Extractable soil water based on an estimated starting soil moisture of 0% using APSIM.

The soil moisture capacitance probes used in the EP have demonstrated to be a useful and time-efficient method for monitoring soil moisture throughout the soil profile at low cost (approx. $5000/ probe + ongoing telemetry fee) and may be a good alternative to manual moisture measurements.

Infrared spectroscopy

For this project the Spectral Evolution SR-3500 spectroradiometer was used to assess the ability of the instrument to predict plant nitrogen and biomass, and soil particle size and nitrogen in the Eyre Peninsula.

Using the dried and ground biomass samples, the PLSR model achieved a strong correlation of R^2 0.96 for the prediction of plant nitrogen (%) (Figure 6) using information from Z3.1 (Pinkawillinie, Rudall, Warramboo) and Z6.5 (Pinkawillinie, Warramboo, Rudall, Karkoo, Ungarra) in the lab. When using field data, the model for Z6.5 achieved the highest correlation for plant N (R^2 0.70) (Figure 7). The models that combined earlier growth stages also presented strong relationships between the reference and predicted data (Table 2). The correlation between laboratory reference and field predicted biomass (kg) was the strongest when using all of the assessed growth stages (Z3.1, Z4.3, Z6.5) R^2 0.70 (Figure 8).

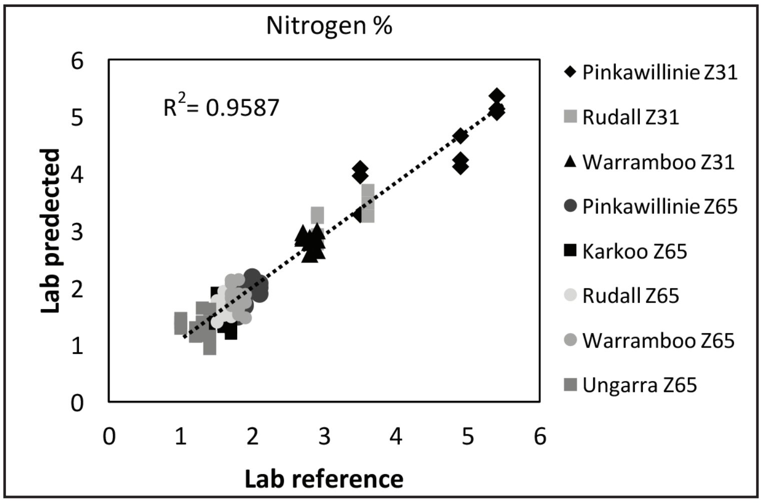

Figure 6. Reference and predicted plant nitrogen content for ground laboratory samples across 3 sites for Z3.1 and 5 sites for Z6.5 using the SR-3500.

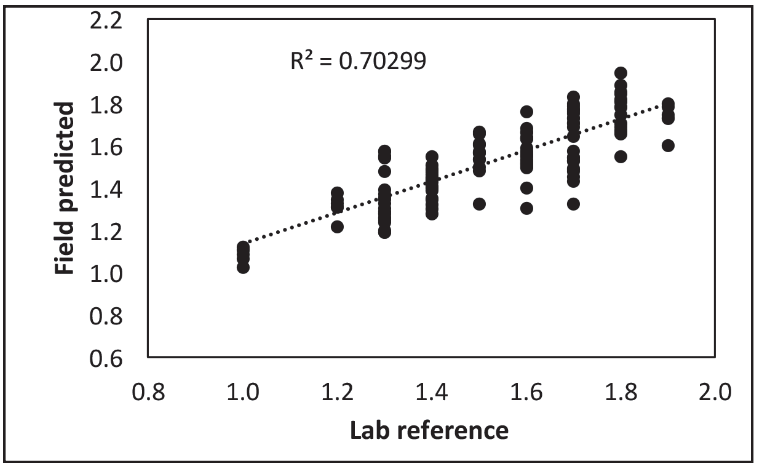

Figure 7. Relationship between laboratory plant nitrogen content and predicted plant nitrogen using the SR-3500 for field measurements at 4 sites at Z6.5. Root mean Square Error (RMSE)=+/-0.120.

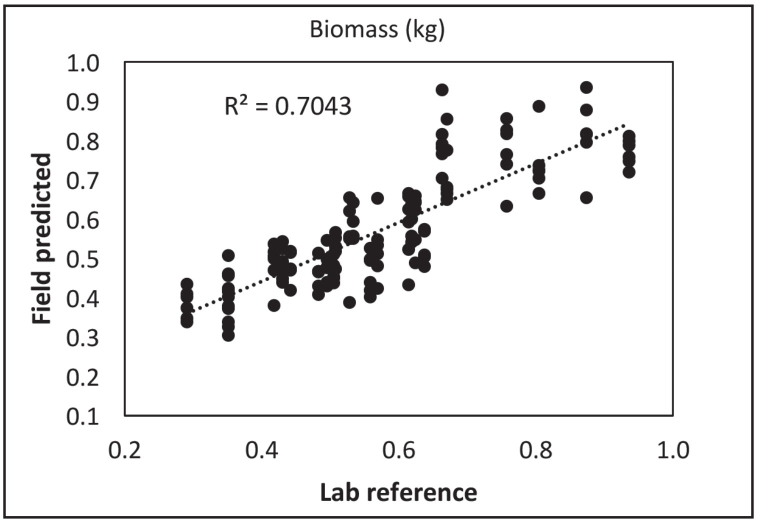

Figure 8. Relationship between laboratory measured plant biomass and predicted biomass using the SR-3500 for 4 sites at Z3.1, Z4.3 and Z6.5. RMSE=+/-0.087.

Table 2. R^2 for relationship between reference and predicted plant nitrogen and biomass for various growth stage combinations using field scans from SR-3500 for the predictive models.

	Growth stage	R^2
Nitrogen	Z3.1, Z4.3, Z6.5	0.69
	Z3.1, Z4.3	0.63
	Z6.5	0.70
Biomass	Z3.1, Z4.3, Z6.5	0.70
	Z3.1, Z4.3	0.60
	Z6.5	0.55

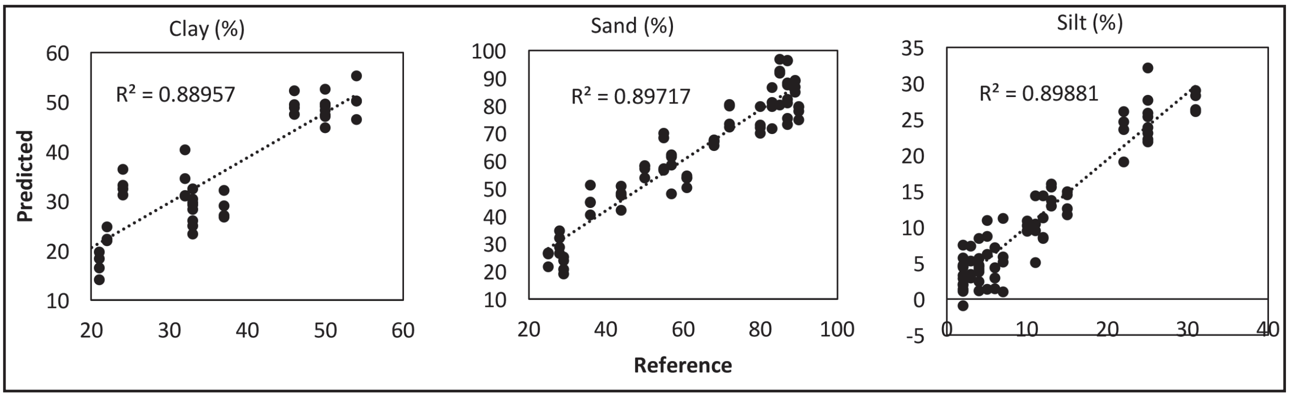

Figure 9. Relationship between laboratory (reference) and predicted soil particle size (%) using the SR-3500. The results are based on the use of dried and ground soil samples from depths 0-10 cm, 10-30 cm, 30-60 cm and 60-100 cm (4 scans for each depth) for Pinkawillinie, Karkoo, Warramboo, Rudall and Ungarra. Clay RMSE+/-=5.19, sand RMSE=+/-7.19, silt RMSE=+/-2.84.

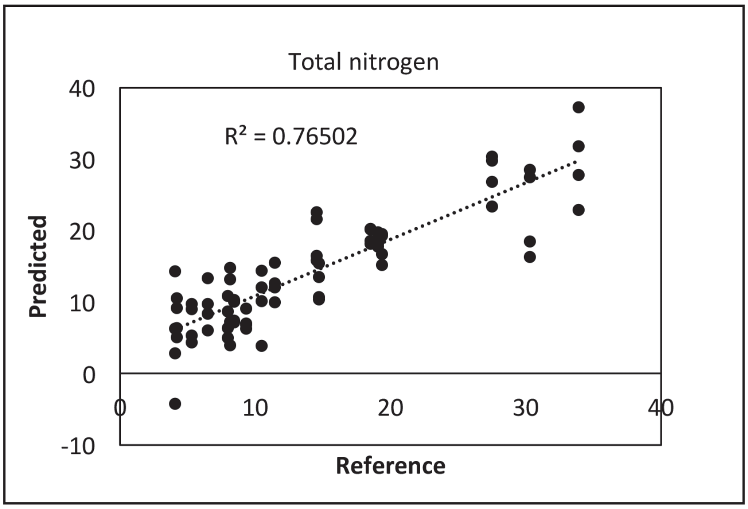

Figure 10. Relationship between laboratory (reference) and predicted soil nitrogen (%) using the SR-3500. The results are based on the use of dried and ground soil samples from depths 0-10 cm, 10-30 cm, 30-60 cm and 60-100 cm (4 scans for each depth) for Pinkawillinie, Karkoo, Warramboo, Rudall and Ungarra. RMSE=+/-4.27.

The models used to predict clay (%), sand (%) and silt (%) all presented a very strong correlation of R^2 0.90 (Figure 9). The SR-3500 is also capable of predicting other soil properties such as total nitrogen (R^2 0.77) (Figure 10).

The SR-3500 is a useful tool for monitoring plant nitrogen and biomass in field conditions as well as using ground and dried plant samples. The spectroradiometer is also a good determinant of soil particle size and total nitrogen using dried and ground samples. This instrument has a high initial cost ($113,000), however there are many cheaper field spectrometers available on the market. This technology can be used in place of sending samples to the laboratory for plant and soil N and soil particle size information and unlimited scans can be taken to capture the variability within a paddock which will save costs in the long run. The information can be used to determine the timing of N applications.

What does this mean?

- Soil moisture probe
  - A useful, time efficient and cost-effective tool for monitoring soil moisture throughout the soil profile at paddock scale. The information provided by the moisture probes may aid in crop choice decisions by assessing pre-sowing plant available water, potentially provide increased confidence in sowing time by assessing soil moisture reserves, and possibly assist with informed input decisions with the aim of lowering inputs in dry years and increasing yield potential when favourable seasons occur through timing of inputs.

- o The soil moisture data should be collected over more seasons to determine reliability in different conditions.
- SR-3500
  - o The infrared spectroradiometer is a good predictor of various plant and soil information on the EP, including plant N in the lab and field at Z3.1, Z4.3 and Z6.5, biomass by combining Z3.1, Z4.3 and Z6.5 into a model, and soil TN and soil particle size using dried and ground samples to any depth.
  - o This information could be used to determine the timing of N applications.
  - o Further research will involve using the SR-3500 to predict yield and assess how early in the season it can be reliably predicted.
- Using a combination of the soil moisture probes, an infrared spectroradiometer and APSIM provides an opportunity to improve the accuracy of in crop decision making on the EP.
- The tools used in this study have the capability of being used in other areas with different conditions (e.g. rainfall, soil type and crop type).

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