Realtime soil tests in the field – Science fiction or just over the horizon?

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Realtime soil tests in the field – Science fiction or just over the horizon?

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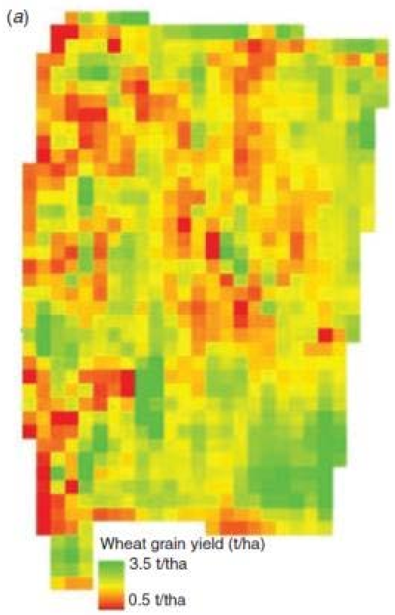
Real time soil tests – key messages

- Not science fiction, but still *just* over the horizon
- Reliant on cheap, robust sensors - new sensor technology coming on line every year
- Electrochemical, infrared and gamma sensors appear to have the most application – IR the most promising to date
- Sensors require careful evaluation before adoption – don't believe the marketing material
- Success with the big four – N, P, K, S – still elusive

Why do we need more soil information?

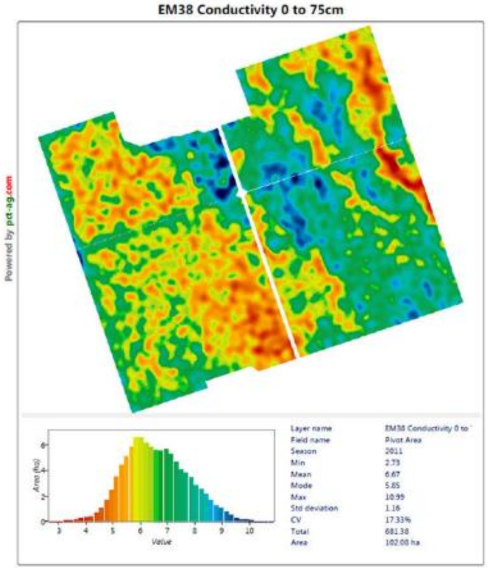


Dang et al. 2009

Wheat grain yield variability across a paddock due to……..

Crop/equipment issues
Topography/water?
Variability of topsoil characteristics?
Variability of subsoil constraints?

What do we have at the moment?



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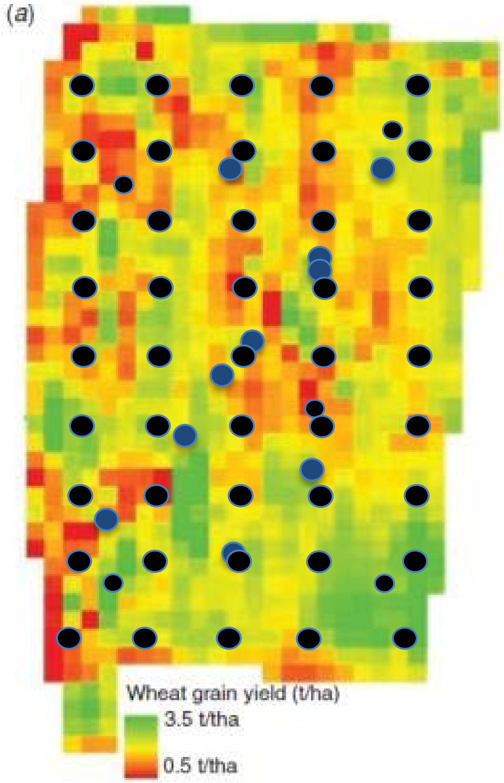
Soil sampling and analysis – Strategies



Dang et al. 2009

Laboratory analytical cost ~ $90-120 per sample for full analysis

Targeted plan
1) 5 x $100 = $500 analytical cost (one depth – topsoil only)
2a) 1 x $100 = $100 analytical cost (one depth – topsoil only)
2b) 5 x $100 = $500 analytical cost (one depth – top soil only)

Precision plan
45 x $100 = $4,500 analytical cost (one depth – top soil only)

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Sensors – getting (more) soil information more easily

A wide range of sensors now available as hand-held or on-the-go devices – how good are they?

On the go soil pH

X-Ray Fluorescence (XRF)

Near-Infrared (NIR)

Mid-Infrared (MIR)

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Comparison of hand-held infrared sensors – NIR/MIR

SciO- $1k - NIR

Texas Instruments
NIRScan Nano - $1k

Agilent Exoscan – MIR $60k

Spectral Evolution - NIR $80k

Agilent Flexscan – MIR $60k

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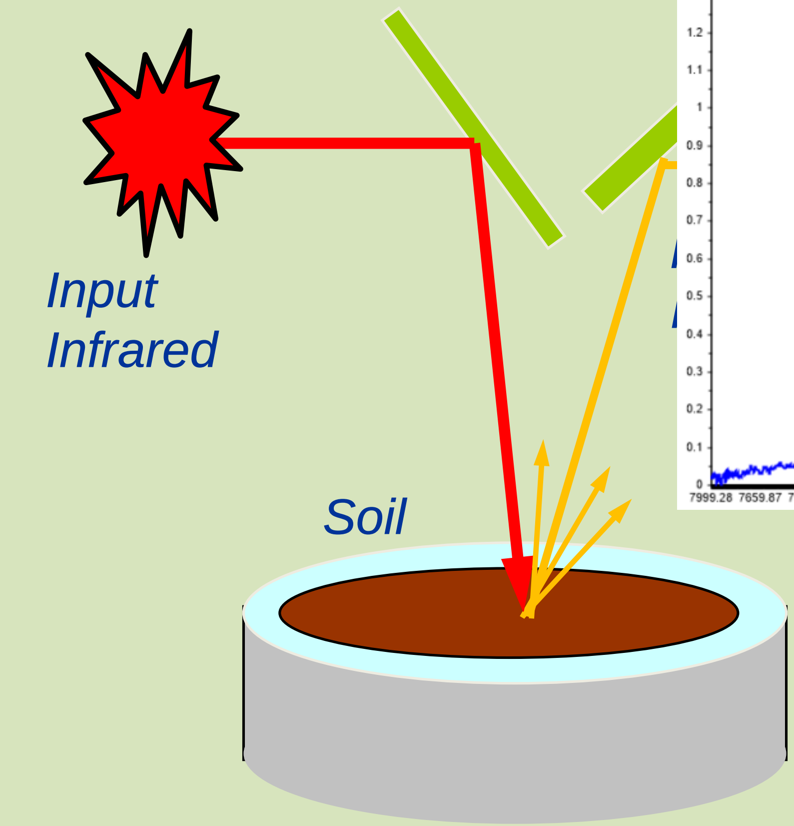
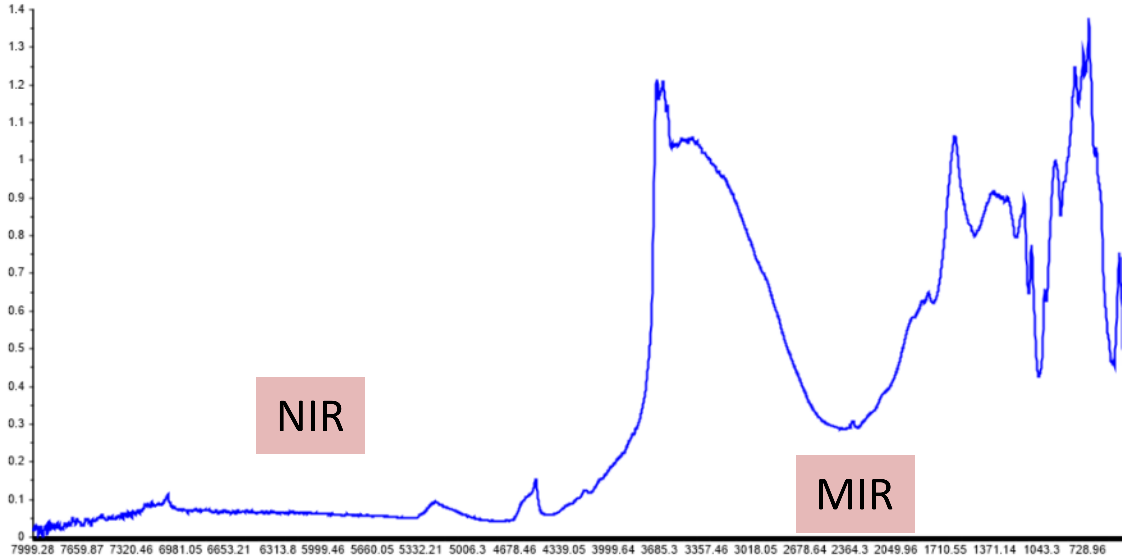
How does IR work?

Note: It measures surface characteristics, does not penetrate sample





- IR focused onto soil surface
- Infrared radiation absorbed by soil
- Characteristic spectra measured

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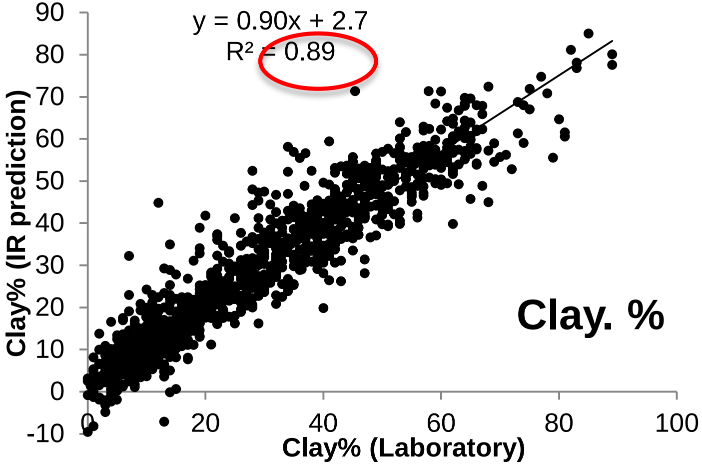
Assessing sensor performance?

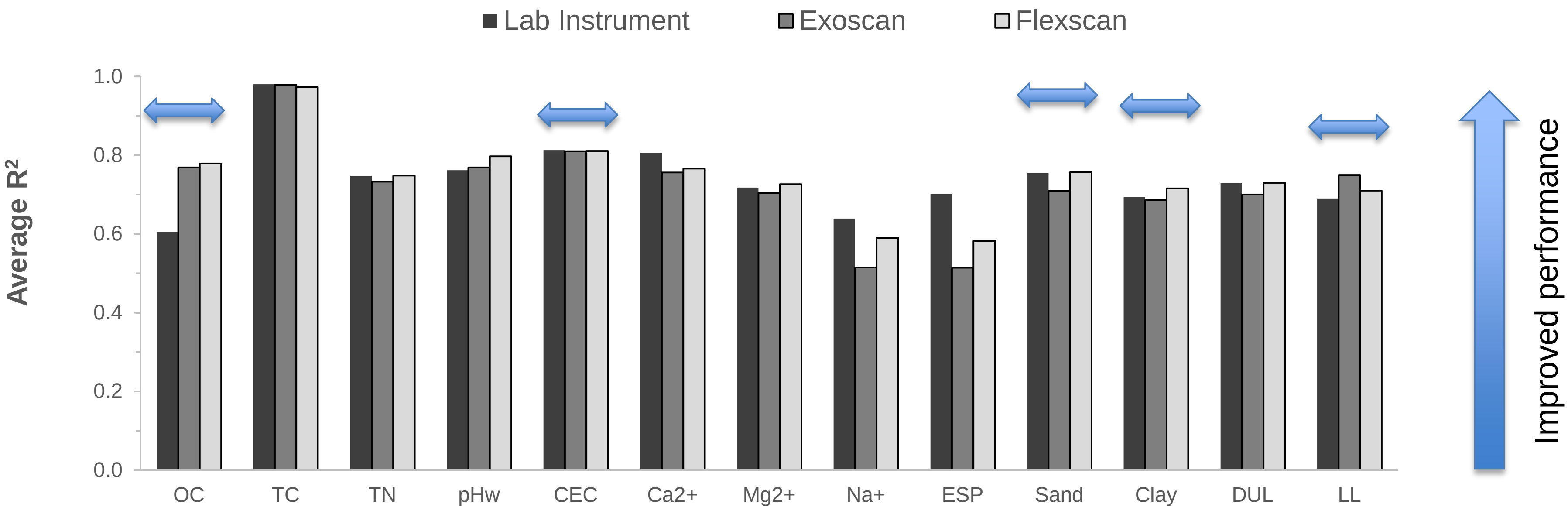
- 80 soil profiles (458 soil samples) from the APSIM database used
- Wide range of soil properties measured in the laboratory
- Soils scanned with all **hand-held** instruments and compared to a **“reference” laboratory** IR instrument
- Predicted properties compared against laboratory chemical measurements



Soil properties assessed

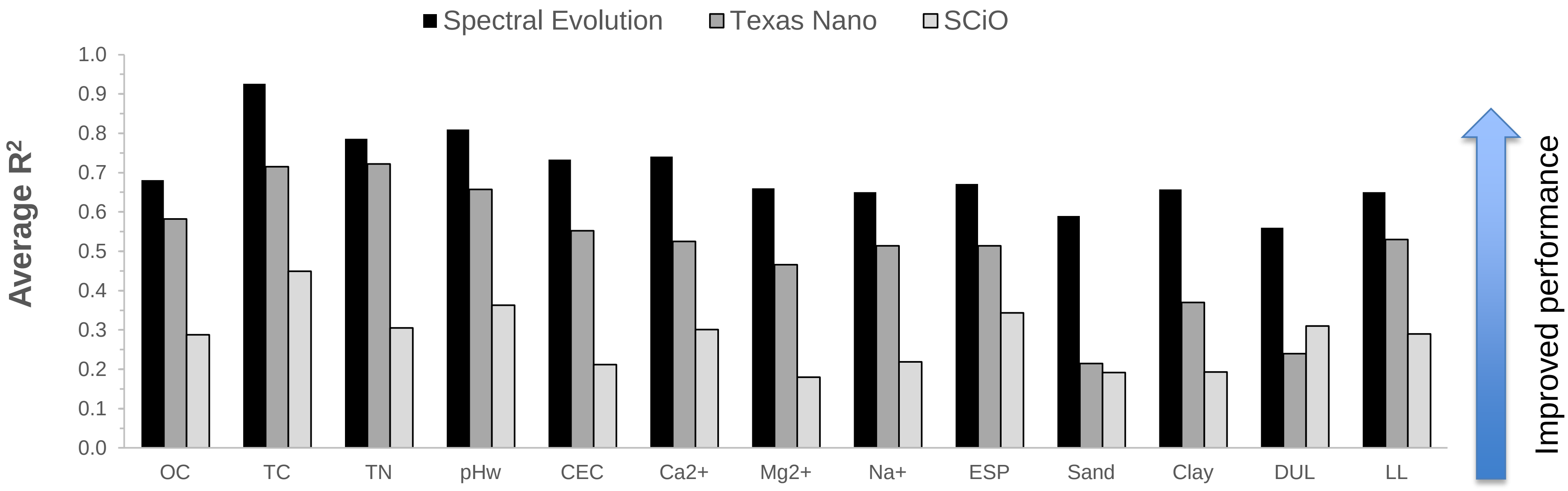
- pH
- EC
- Sand, silt, clay
- Exchangeable cations and CEC
- Exchangeable Na percentage (ESP)
- Total and organic C and N
- Water – drained upper limit (DUL) and lower limit (LL)
- Boron
- Chloride

Instrument performance – MIR instruments



Hand-held MIR instruments as good or better than laboratory instrument

Instrument performance – NIR instruments



Smaller (cheaper) hand-held NIR instruments performed poorly

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Miniature IR instrument sensor conclusions

- Miniaturisation does not necessarily lead to loss of performance – smaller MIR instruments were excellent in predicting soil properties
- The cheaper NIR instruments performed poorly, mainly due to a restricted range of wavelengths used in the instruments
- Hand-held instruments that performed well still cost >$50k – this will likely limit adoption to specialist consultants

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Real-time or field soil tests – the gaps?

- Sensing available nutrient concentrations in soil is a real gap – P, N, K, S
- Real-time or field sensors for these nutrients are either not robust, not accurate, not fast, or not cheap

Two in-field examples of using NIR/MIR

1) Ability to paddock map in terms of Phosphorus Buffering Index (PBI)

2) In field determination of crop N content

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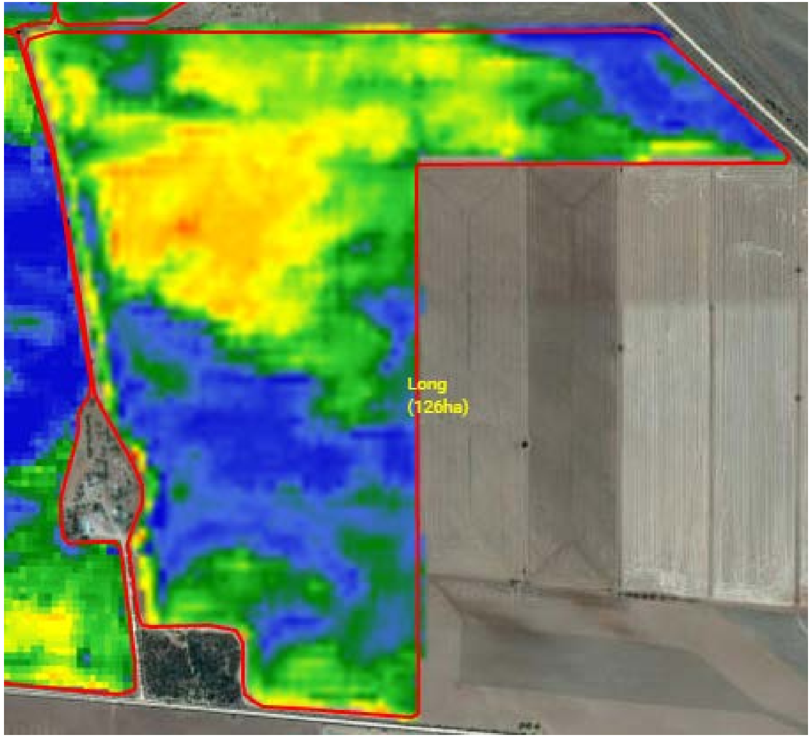
1) Ability to paddock map in terms of Phosphorus Buffering Index (PBI)

- *Why is PBI important? It can control P availability*



NDVI map – Warm colours = poor growth (Source: Sam Trengrove)

Paddock	Description	PBI	DGT P ug/L	Colwell P mg/kg
Home	High yielding	47	100	39
Home	Low yielding	110	8	38

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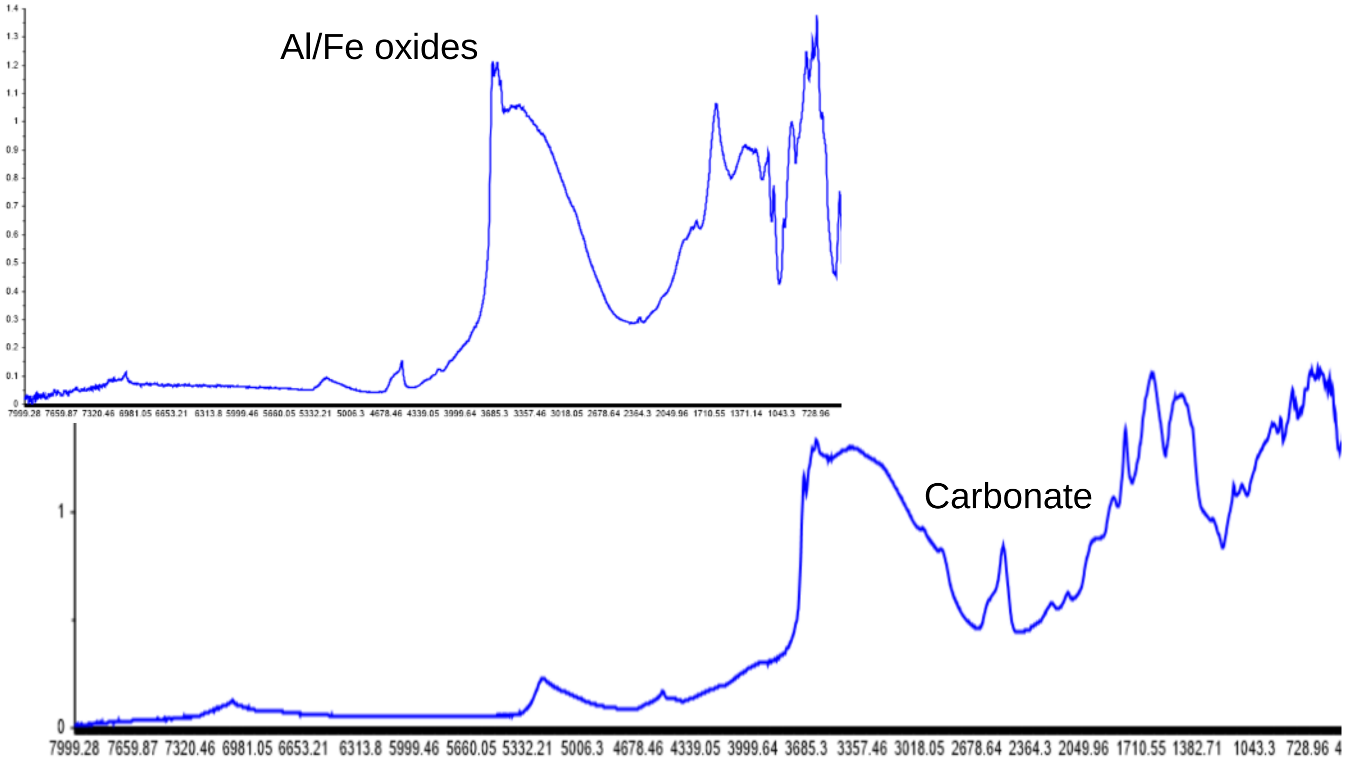
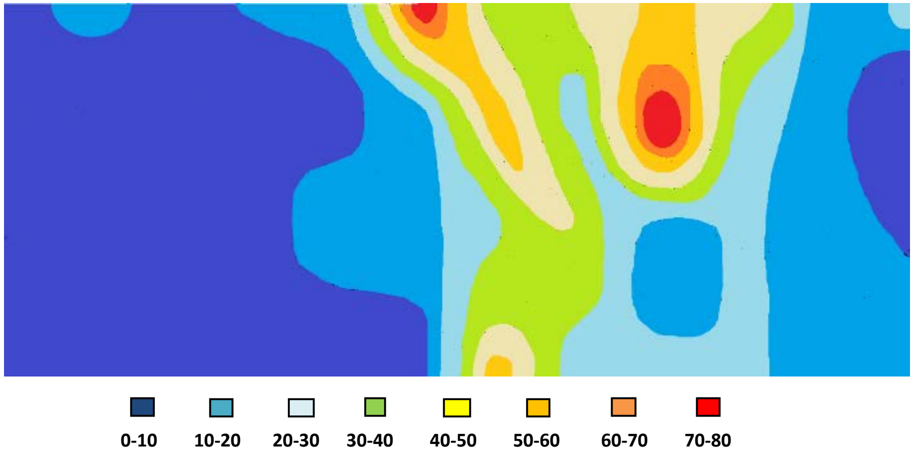
1) Ability to paddock map in terms of Phosphorus Buffering Index (PBI)

- *How does IR predict PBI?*



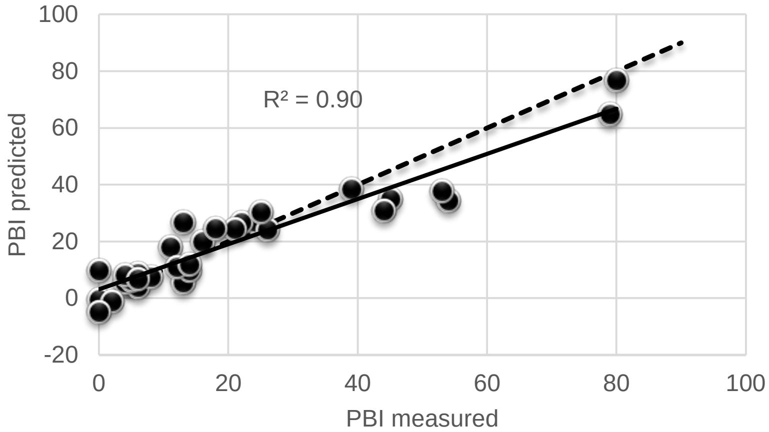
1) Ability to paddock map in terms of Phosphorus Buffering Index (PBI)

80m

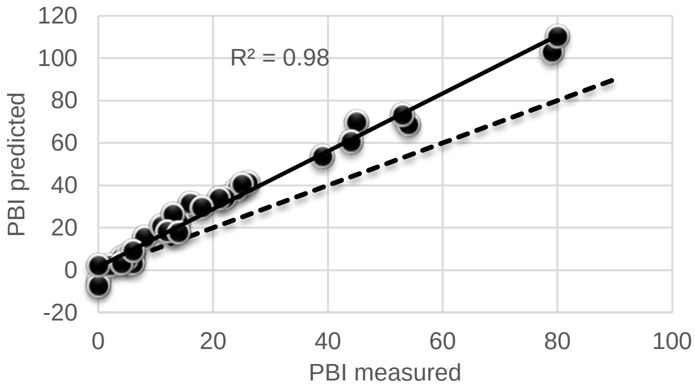


40m

Grid sampling every 10m = 32 samples total



Field moist



Incorporating moisture contents

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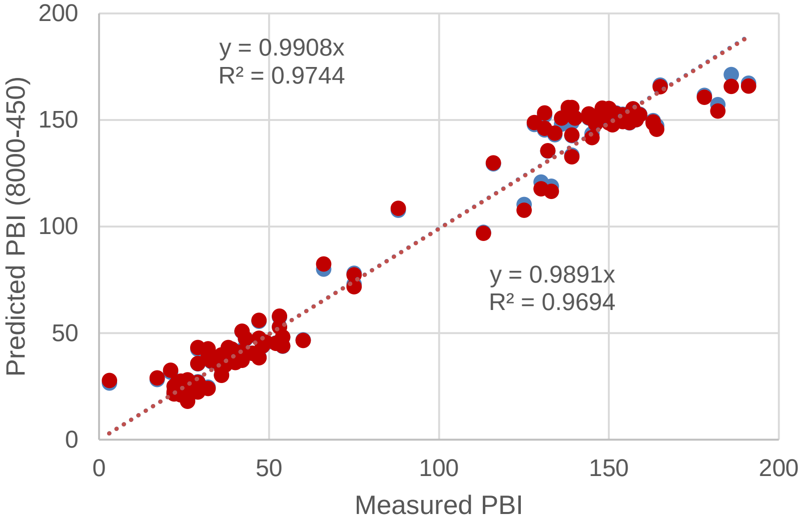
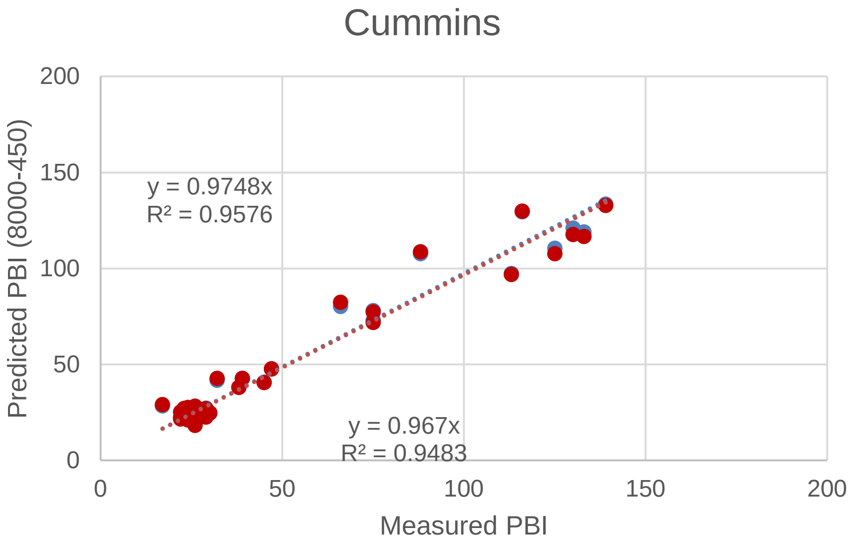
1) Ability to paddock map in terms of Phosphorus Buffering Index (PBI)



Across 6 replicated P response field trials combined



Across 1 replicated field trial (50 x 100m)

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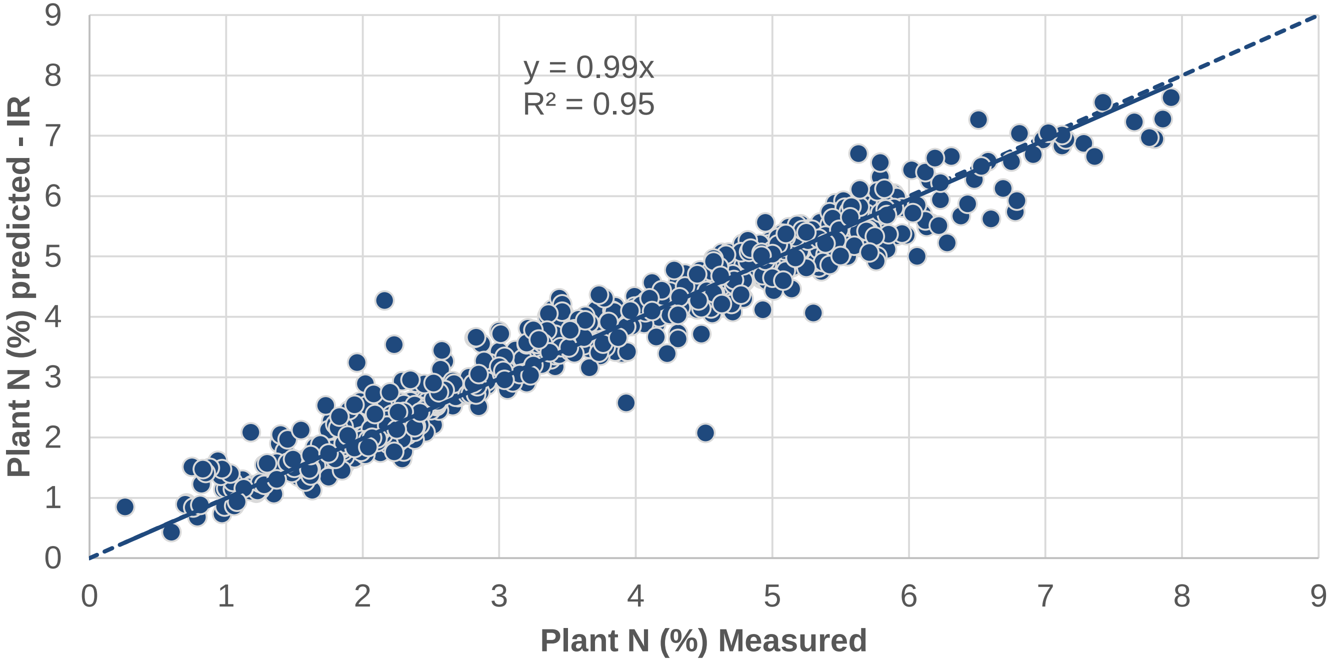
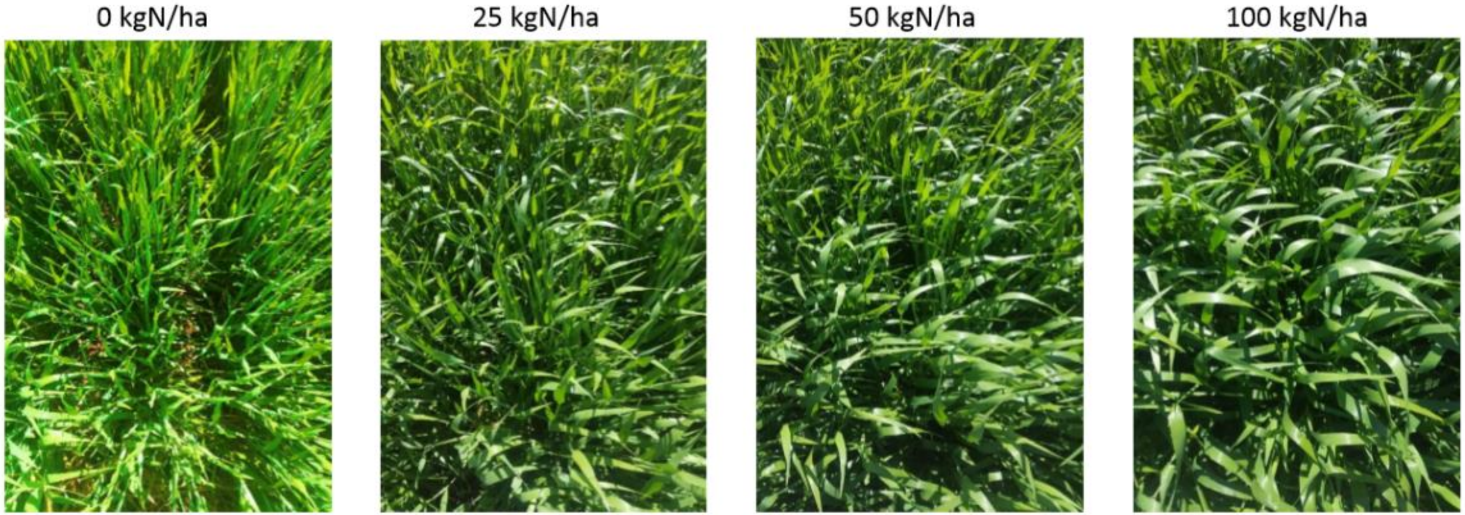
2) Real-time determination of crop N status

Works in the lab does it work in the field?



2) Real-time determination of crop N status

Why use NIR?

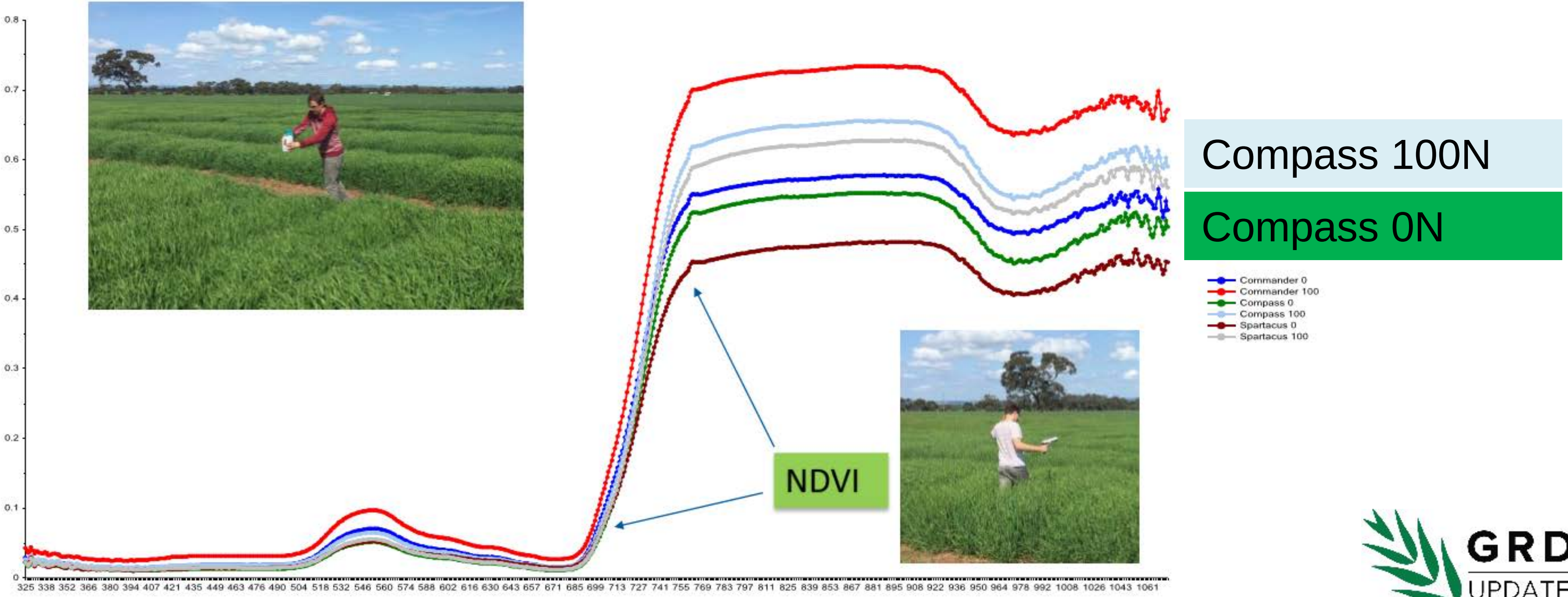


Canopies saturated but differences in greenness remain, NDVI no longer useful but spectral data can build new calibrations for metabolic traits such as N content and WSC which define yield

2) Real-time determination of crop N status

Using ASD Hand-held VNIR ~ $10-15k

In field ASD Spectral data ready for calibration
Roseworthy 2016



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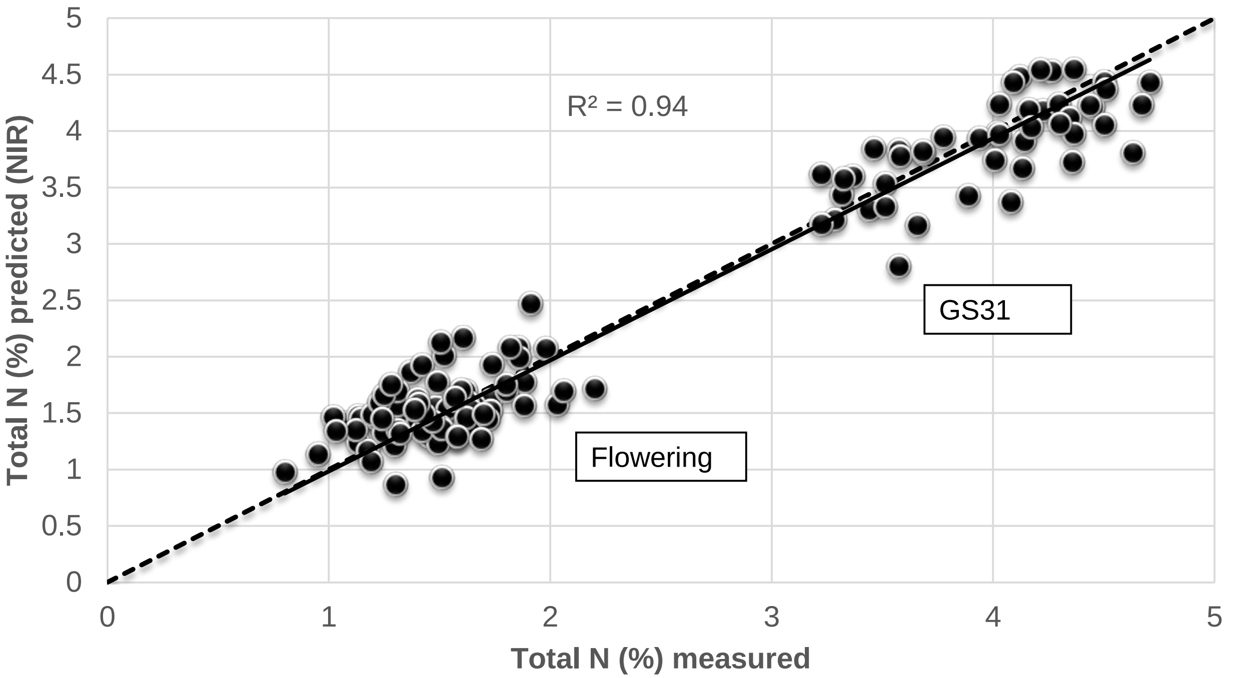
2) Real-time determination of crop N status



Cross validation of measured total N crop values with predicted crop N contents using portable NIR in field spectrometer.

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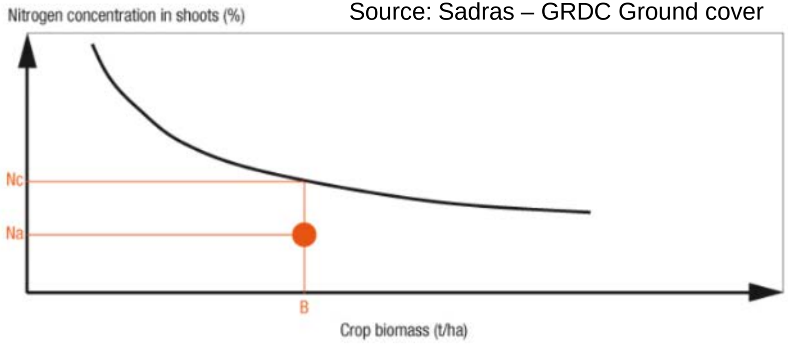
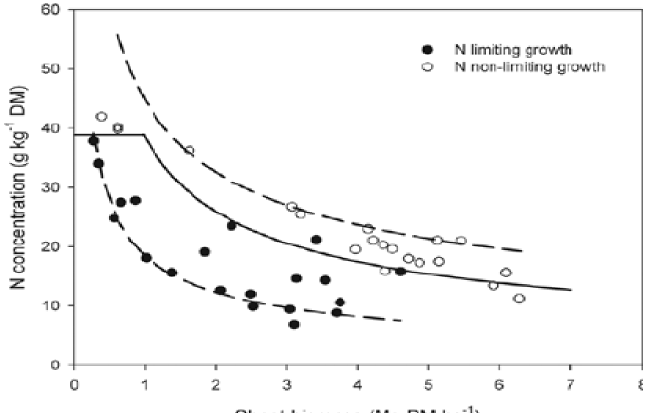
2) Real-time determination of crop N status
Other benefits of knowing crop N content
N dilution curves and N budgets

Source: Sadras – GRDC Ground cover





N budgets
1 t/ha dry matter @ 5% N = 50 kg N/ha
75% conversion to grain = 37.5 kg N/ha

4 t/ha dry matter @ 2% N = 80 kg N/ha
75% conversion to grain = 60 kg N/ha

1t/ha grain @ 10% protein = 23 kg N/ha

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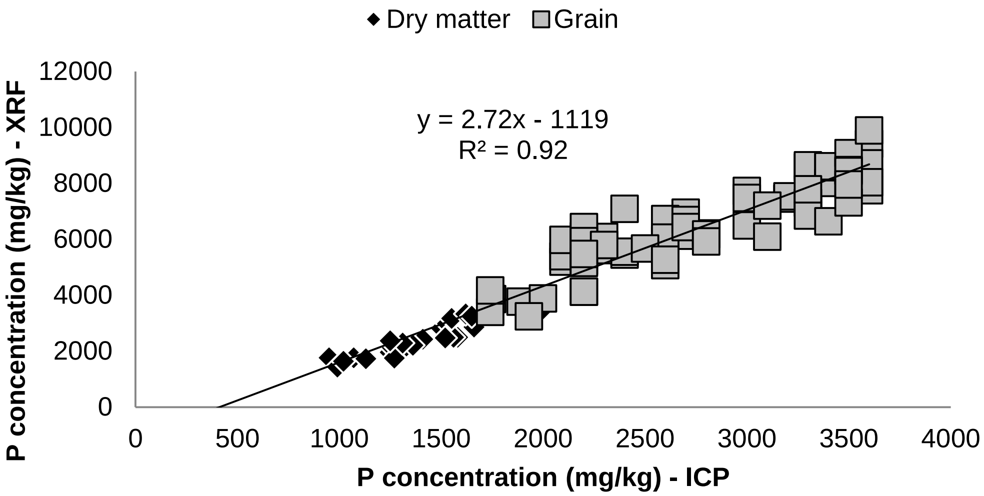
What else is out there?

- X-ray fluorescence – measures total elemental concentrations
- Cannot measure available nutrients or elements such as B, Mg, Na
- ~$80k
- Sample needs to be dry



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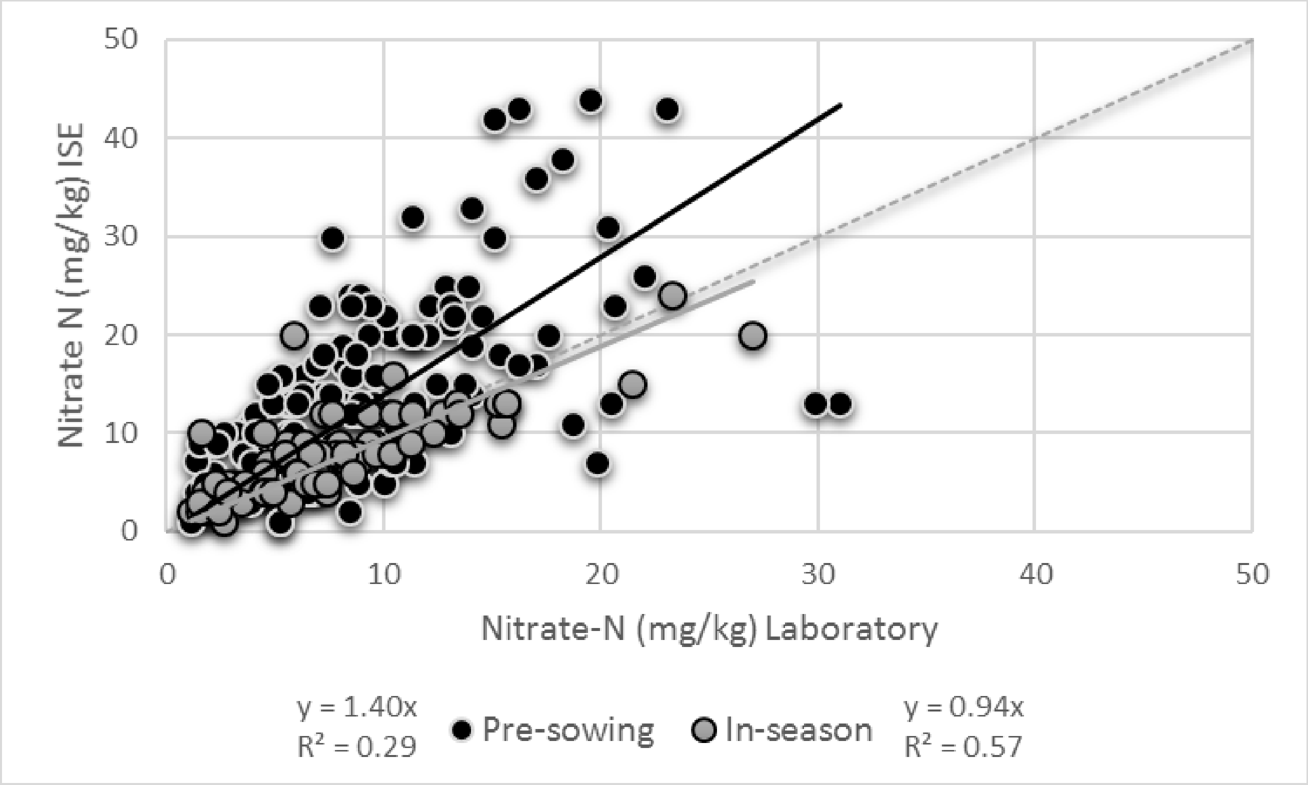
What else is out there?
Electrochemical sensors

http



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Conclusions

- IR technology has significant potential to provide rapid analysis of several soil characteristics and crop N status in the field
- Not a fit for all – need specific skills in order to run spectral data and perform a prediction
- Reliant on cheap, robust sensors - new sensor technology coming on line every year
- Also reliant on continued validation, quality control with a laboratory

- Potential Soil characteristics predicted by IR

pH, OC, TC, TN, Texture, PBI, CEC, $CaCO_3$, DUL, Wilting point

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