National Paddock Survey - closing the yield gap and informing decisions

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Key messages

- **Intensive monitoring of soils and crops over a rotation sequence has identified why crops do not achieve their potential yield.**
- **Reviewing paddock performance at the end of the season and using paddock records is essential for sustained improvement in agronomic performance.**
- **Preliminary analysis indicated that insufficient nitrogen was the main cause for the yield gap in wheat and barley crops grown on the EP. Frost and heat shock were also likely to be responsible for some yield penalty. Diseases, weeds and insects also contributed, but were less severe in impact.**

Background?

The yield gap is the term applied to the difference between achieved and potential yield, where potential yield is estimated from simulation models. On average, Australia's wheat growers are currently achieving about half their water-limited potential yield (Hochman *et al*. 2016, Hochman and Horan, 2018). Previous research with individual growers in the Wimmera/ Mallee in Victoria determined that the long-term yield gap for those farmers was approximately 20% (van Rees *et al*. 2012). For a National overview of the Yield Gap see www.yieldgapaustralia.com.au.

The National Paddock Survey (NPS) is a four-year (2015 to 2018) GRDC-funded project designed to quantify the yield gap on 250 paddocks nationally and to determine the causes for the yield gap. Further, its aim is to establish whether management practices can be developed to reduce the yield gap to benefit farm profitability. The project aims to provide growers and their advisers with information and the tools required to close the yield gap.

How was it done?

250 paddocks nationally, 80 in each of WA and N NSW/Qld, and 90 in S NSW, Vic and SA, were monitored intensively over a four-year rotation (2015 to 2018). Consultants and Farming Systems groups undertook the monitoring. Two zones in each paddock were monitored at five geo-referenced monitoring points along a permanent 200 to 250 m transect. Each monitoring point was visited four times per season (pre- and post-season soil sampling and in-crop at the equivalent crop growth stages of GS30 and 65). Yield map data was obtained for each paddock which enabled the yield of each zone to be determined accurately. Table 1 lists the annual monitoring undertaken in each zone.

All paddocks were simulated with APSIM (Holzworth *et al*. 2014) and, during the season, Yield Prophet was available to all consultants and farmers.

The data set (four years x 500 paddock zones) is being analysed by Roger Lawes, CSIRO for factors primarily responsible for the yield gap in each of the three GRDC regions (Lawes *et al*. 2018).

This paper outlines the results of nine paddocks on the Eyre Peninsula monitored by George Pedler. The results are discussed as a paddock specific yield gap analysis over four seasons focused on outcomes for the farmer and consultant.

Results are presented as the modelled APSIM simulations in which:

- Ya=Actual Yield (as determined for each zone from yield map data)
- Ysim=Simulated Yield (for the same conditions as those in which the crop was grown)
- Yw=Simulated water limited, nitrogen unlimited yield (for the same conditions as those in which the crop was grown, but with N supply unlimited). Yw is considered the potential yield for the crop.

Note: APSIM currently accurately simulates wheat, barley and canola. We have not attempted to simulate the other crop types grown (lentil, chickpea, vetch, field pea).

The Yield Gap is calculated as the % difference between Yw and Ya ((Yw-Ya)/Yw).

Data was entered via the NPS website and stored in a purpose-built SQL Server database.

What happened and what does this mean?

Examples of individual paddock results

Data for two paddock zones in different locations on the EP are presented as examples of outputs as informed by the paddock monitoring.

Table 1 Overview of monitoring and data collected per zone for each NPS paddock

Monitoring	Timing	Monitoring	Timing
Deep soil test 4 depths (0-100 cm)	Pre-sow	Paddock yield and yield map data	Post-harvest
PredictaB (0-10 cm)	Pre-sow	Crop density, weeds, foliar diseases, insects (/m^2)	GS30
Deep soil test 4 depths (0-100 cm)	Post-harvest	Cereal root sample to CSIRO	GS30
Crop and Cultivar		Weeds, foliar diseases, insects (/m^2)	GS65
Sowing date and rate		Cereal stubble/crown for Fusarium	Post-harvest
Fertiliser, herbicide type, rate, date		General observations	
Temp buttons (1 per paddock)	GS60-79		

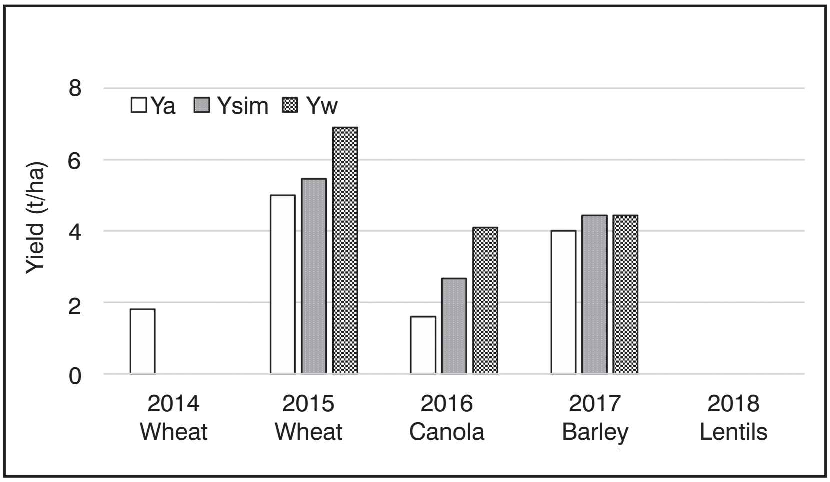

Figure 1 Example a. (EP NPS 3246) sandy loam over clay

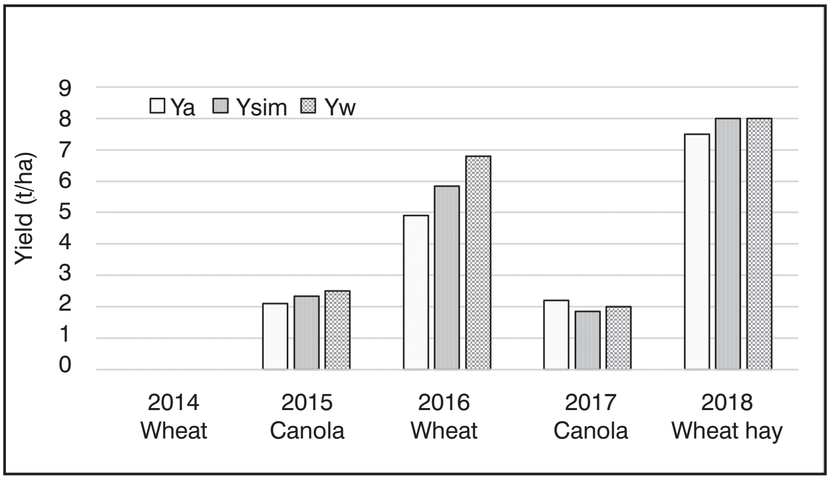

Figure 2 Example b. (EP NPS 3268) sandy loam over clay

Example a.

2014: setup year and no in-paddock measurements were taken, the paddock yield was 1.8 t/ha.

2015: Wheat Ya<Ysim<Yw there was 1.4 t/ha difference between Ysim and Yw which is attributed to insufficient N being available to the crop. The 0.5 t/ha difference between Ya and Ysim is attributed to abiotic and/or biotic stresses. Three days with temperatures above 34°C were recorded during GS60 to 79. The PredictaB soil test showed moderate levels of YLS and Rhizoctonia; Rhizoctonia was also recorded on the roots at GS30 (61% of the roots had a low level of Rhizoctonia), there were no crop diseases, insects or weeds recorded at GS65.

2016: Canola Ya<Ysim<Yw the 1.4 t/ha difference between Ysim and Yw is attributed to N deficiency. The 1.1 t/ha difference between Ya and Ysim is not explainable at this stage – there were no frost or heat shock events recorded, the soil PredictaB test did not show any diseases, and only 10 ryegrass/m^2 were recorded, there were no in-crop diseases or insects recorded.

2017: Barley Ya<=Ysim=Yw. Yw was the same as Ysim indicating N was not limiting. Ysim was slightly higher yielding than Ya (0.4 t/ha) which indicates either simulation variation or some abiotic and biotic stress having a small impact on yield. There was one day of hot weather recorded (+34°C) during flowering and grain-filling, soil PredictaB showed no diseases; no diseases, insects or weeds were recorded at GS65; and the stubble had a low level of Fusarium.

The average yield gap for wheat and barley was 24% in Example a.

Example b.

2014: wheat (no yield data)

2015: Ya=Ysim=Yw. Ya was 0.2 t/ha higher than the simulated yield which is within the error for simulations. There were no crop stresses limiting production. There were no frost or heat shock events recorded between GS60 (start of flowering) to GS79 (end of grain filling). There also were no crop diseases, insects recorded and only a very low level of marshmallow at mid flowering of the crop (3 marshmallow/m^2).

2016: Ya<Ysim<Yw. The 1 t/ha difference between Yw and Ysim is attributed to N deficiency. The 0.9 t/ha difference between Ya and Ysim is attributed to abiotic and/or biotic stresses. There were no frosts or heat shock events recorded, YLS was moderate in the soil PredictaB test, the roots had moderate level of disease and Rhizoctonia was low. The 38% yield gap can be attributed to N deficiency and the rest from low to moderate levels of disease.

2017: Ya=Ysim=Yw the small differences between Ya and the simulated yields (Ysim and Yw) of less than 0.3 t/ha indicates that there were no abiotic or biotic stresses on the crop (no yield gap). YLS was high in the soil PredictaB test, however this disease does not affect canola.

2018: Ya=Ysim=Yw indicates the actual hay yield is the same as the simulated yield (no yield gap). There was no disease recorded in the PredictaB test.

The average yield gap for the crops grown from 2015 to 2018 was 12% in Example b.

Average yield gap for wheat and barley on the EP (2015 to 2018)

The yield gap is defined as the difference between potential and actual yield, where the potential yield is determined through computer simulation. The average yield gap for wheat and barley grown over the 2015 to 2018 project period was 49%. This is preliminary data only – some of the paddock results need verification.

Assessing crop performance: Water Use Efficiency vs Modelling

The first paper on Water Use Efficiency (WUE) was published by French and Schultz in 1984. It was a breakthrough at the time, enabling farmers and agronomists to benchmark crop yield against a target and compare performance against other wheat crops. The French and Schultz WUE equation has since been updated by Sadras and Angus, 2006 and Hunt and Kirkegaard, 2012.

Hunt and Kirkegaard, 2012 calculate Crop Water Available as:

Soil water pre-sowing – Soil water post-harvest + Rainfall during the same period.

WUE is then calculated as Yield (kg/ha) / (Crop water available - 60).

Potential yield is calculated as 22 x (Crop Water Available - 60).

The 2015 to 2018 EP NPS wheat yields are plotted against Crop Water Available in Figure 3. The graph reveals a strong tendency for Ya to increase with Crop Water Available with an upper boundary of yield. The upper boundary is reasonably interpreted as Yw for well-managed crops as available crop water increases. The two lines included on the diagram are the potential yield lines proposed by French & Schultz, 1984 and Sadras & Angus, 2006 - the latter calculated as Potential yield = 22 x (Crop Water Use – 60), with a maximum WUE of 22 kg/ha/mm. For those yield achievements above the S & A line, the most likely explanation is that the crop had access to some water which was not accounted for in the calculation. There were two paddocks which had low WUE (the two most right points in Figure 3) in a very wet season which is not unusual. It is difficult to capitalise on those occasional years of very much above average rainfall, partly because of uncertainty that the good conditions will extend right through to the end of the season. Waterlogging can also occur in these above average conditions which restrict crop performance.

The reasons for improvement in potential WUE, from 20 to 22 kg/ha/mm since French and Schultz (1984) have been due to improved cultivars (semi-dwarf wheats) and higher atmospheric CO_2 levels.

How useful is WUE compared with computer modelled assessments of potential yield, and what will the future hold?

Figure 3 demonstrates a considerable variation in paddock yield relative to the potential, i.e. a considerable yield gap in many crops. Key questions for farmers and agronomists are what is the cause of the yield gap in each individual case and how can it be alleviated?

There are many possible causes that cannot be identified without careful paddock monitoring of abiotic and biotic factors, as attempted in the present project.

We must remember that WUE to assess yield potential is a bucket approach to a complex problem in a system with many interactions. WUE will not explain the causes of a yield gap, nor can it inform on reasons for favourable outcomes. It may identify the presence of a yield gap but not their cause.

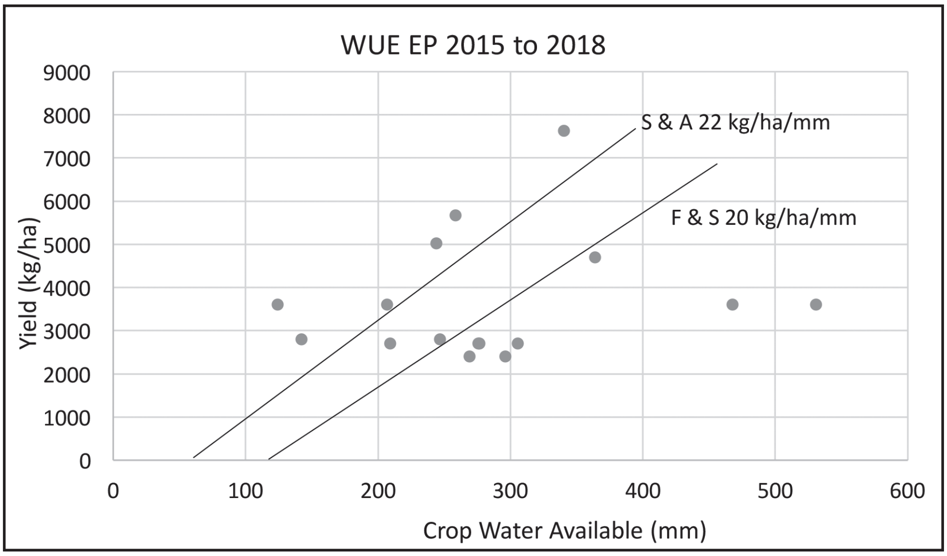

Figure 3 NPS – EP wheat yields (Ya) plotted against available water (2015 to 2018). F & S refers to French and Schultz (1984); and S & A refers to Sadras and Angus (2006).

Causes of yield gaps

Abiotic factors

Variability is a feature of farming in Australia and there are several reasons why crop roots cannot access soil water such as soil type (texture) and physical and chemical limitations. Chemical and physical constraints to root development can have a large impact on potential yield.

Interactions between soil type, available soil water and the amount of water extracted by the growing crop are influenced by crop growth and the distribution and amount of rainfall. If these factors are ignored there is limited predictive capability of yield.

High and low temperatures at critical times of crop development can cause devastating yield loss.

Biotic factors

Crop nutrition appropriate to achieving potential yield (Yw) is relatively well understood and in the case of N, with many examples of successful tactical responses to fertilization. But this is not matched for other nutrients such as P and K, and micronutrients such as Zn.

Major infestations of weeds, pests and diseases can cause dramatic yield loss and less serious infestations may cause greater losses than is commonly appreciated and remain unknown without careful paddock monitoring.

The nature of these biotic causes of yield loss vary greatly from site to site, paddock to paddock and within paddocks.

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