Yield gaps – how much yield potential is left behind?

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AT A GLANCE…

- Average wheat yields between 2000 and 2014 for the Liverpool Plains (2.6 tonnes per hectare) are 2.3 tonnes per hectare below the water-limited yield potential for dryland wheat. On average, this is costing growers $575 per hectare.
- A national survey of 232 growers included 45 respondents from the Liverpool Plains. Of the 45 Liverpool Plains respondents, only three fell into the lower half of the national relative yield group, confirming the high standing of growers from the Liverpool Plains.
- At Quirindi, applying 45 kg N per hectare resulted in a 36 per cent yield gap. Failure to control weeds during the summer fallow could account for up to 14 per cent yield loss and low seedling density for a nine per cent yield loss. Even at 90 kg N per hectare, a 14 per cent yield gap remains.
- An emerging practice of sowing early (April 26) with a late maturing variety and flexible N fertiliser application is expected to have the potential to increase the yield frontier by 19 per cent.
- This emerging best practice has the potential to increase financial returns in the Liverpool Plains from about $1260 per hectare to about $1930 per hectare. While proven in other regions, this emerging practice defies local convention and deserves to be investigated in local fields by growers, consultants and researchers.

IT is well known that Australia's grain growers are among the best in the world. But there is a lot of variability between farms in terms of yields produced. This is the case even in the more favourable cropping areas such as the Liverpool Plains of NSW.

So why is the yield gap in the Liverpool Plains 47 per cent of the yield potential? Between 2000 and 2014 average annual wheat yield was 2.6 tonnes per hectare while the water–limited yield potential was 4.9 tonnes per hectare.

This means that there is a yield gap of 2.3 tonnes per hectare or $575 per hectare (at $250 per tonne) that is not realised.

We ask why such a substantial yield gap exists and why some growers achieve their yield potential while others do not. We examined this in three different ways:

- A grower survey that investigated how farms with large yield gaps differ from farms with low yield gaps by relating yield gaps to grower characteristics, farm characteristics and farm management practices.
- A simulation study that examined the impact of sub-optimal management practices at 50 weather stations spanning the Australian grain zone.
- An economic (risk-adjusted profit) analysis that explored the results from the simulation study.

National grower survey

The national survey aimed to comprehensively examine farm management practices as well as farm and farmer characteristics that may contribute to the wheat yield gaps in Australia. Using the GRDC customer relation database we conducted telephone interviews of 232 wheat producers from 14 contrasting local areas (roughly equivalent to a shire) in the Australian grain zone (Figure 1).

The relative yield of wheat (per cent of water-limited yield potential) is indicated by the red-yellow colour gradient. The white borders shows the GRDC sub-regions of the Australian grain zone The average participants' age was 51 years old (ranging from 20 to 89 years in age), with an average of 31 years of experience in growing crops. Among the participants, there were only 10 female producers (four per cent).

Seventeen participants (seven per cent) identified as corporate farms while the rest identified as family farms. Thirty-three participants (14 per cent) owned or managed other farms in locations more than 50 km apart. The average cropping land area was 2149 hectares.

The total area cropped by participants was 0.5 million hectares, or about two per cent of Australia's cropped area.

Each farm's yield gap was calculated by comparing their reported wheat yield in 2016 against the water-limited yield potential, simulated under best management practices for their three dominant soil types, using weather data from all stations in their postcode. All farms were ranked according to their relative yields.

The median relative yield was 64 per cent and this value was used as a cut-off for dividing the respondents into two equal sized groups – the high relative yield group and the low relative yield group.

An average yield gap of 49 per cent exists between these two groups.

FIGURE 1: Locations of surveyed local statistical areas with contrasting average relative yields

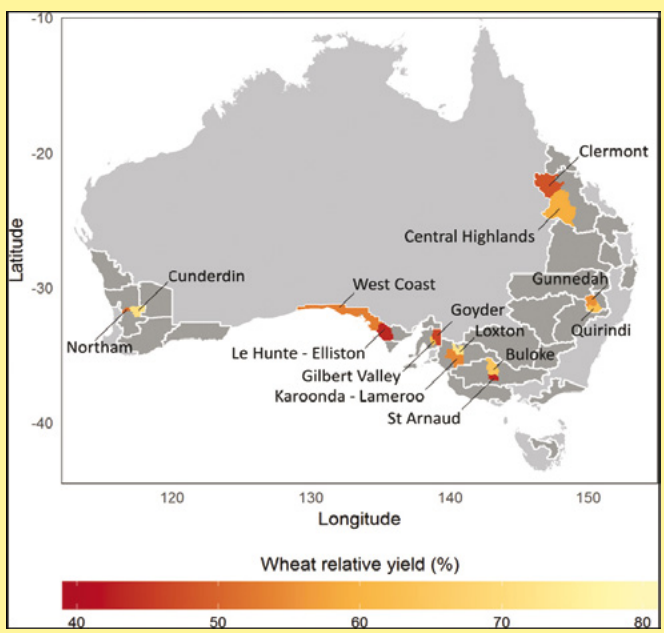
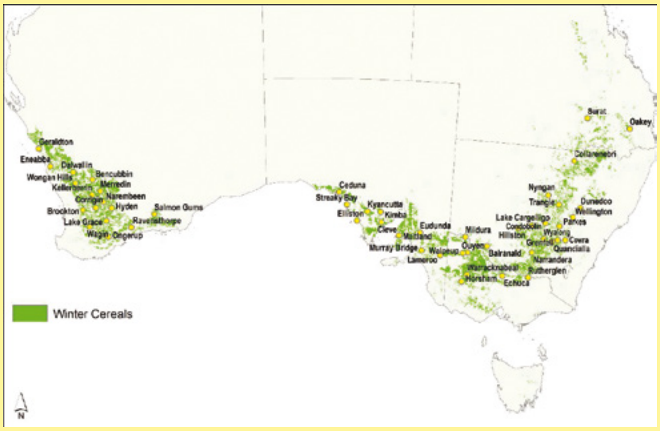


FIGURE 2: Fifty high quality weather stations and their distribution in Australia's cropping zone



All survey responses were analysed to determine if there were significant differences in how the high and low relative yield groups responded.

The results revealed significant differences between farms with smaller yield gaps and those with greater yield gaps in relation to farming management, farm characteristics, and grower characteristics.

Australian farms with smaller yield gaps (high relative yield) are more likely to be smaller holdings (mean size of 1886 hectares) growing less wheat on more favourable soil types.

These growers are more likely to apply considerably more N fertiliser to their wheat crop (Table 1), to grow a greater variety of crops, to soil-test a greater proportion of their fields, to have less area affected by herbicide-resistant weeds, and to be early adopters of new technology.

They are less likely to grow wheat following either cereal crops or a pasture (Table 1). They are more likely to use and trust a fee-for-service agronomist, and to have a university education.

TABLE 1: Preceding crops before wheat crop and average nitrogen applied

	% of farms		Nitrogen application	
	High relative yield group (%)	Low relative yield group (%)	High relative yield group M (SD) (kg N/ha)	Low relative yield group M (SD) (kg N/ha)
A cereal crop	37***	65***	79 (51)*	57 (42)*
A canola crop	44	48	116 (146)**	58 (45)**
A pulse crop	62	53	75 (61)***	42 (34)***
A pasture phase	22***	44***	64 (58)**	30 (33)**

Note: The asterisk symbol indicates the statistical significance level of the differences between high and low relative yield groups, * $p < .05$, ** $p < .01$, *** $p < .001$.
D = Standard Deviation.

Farms from the Liverpool Plains sub-region (Gunnedah and Quirindi) were massively overrepresented in the high relative yields group with only three of the 45 respondents falling into the low relative yield (high yield gap) group. But the large gap between highest and lowest yields reported for 2016 in the Liverpool Plains sub-region indicate that a significant yield gap still exists.

Even in relatively favourable regions, such as the Liverpool Plains, there are large gaps in crop yield potential.

Simulation study

We conducted a simulation study on the impact of sub-optimal management practices at 50 weather stations that span the whole grain zone (Figure 2). A benchmark "best management practice" was defined by:

- Zero tillage with clean fallows and stubble retained;
- A non-limiting supply of nitrogen to the crop; sowing at 150 plants/m² was activated between April 26 and July 15 when there were 30 mm of plant available water (PAW); and,
- A 15 mm cumulative rain event occurred over any three consecutive days.

Table 2 shows the average national impact, relative to water-

TABLE 2: Impacts of management factors (treatments 2 to 7) and of frost and heat stress (treatments 9 and 10) on water-limited yield potential (Yw)

Treatment number	Treatment	Mean (t/ha)	SD (t/ha)	CV (%)	Y% (%)
1	Yw (water-limited yield)	4.28	0.92	21	100
2	Seedling density (50 plants/m²)	3.78	1.10	29	88
3	Late sowing (2 week delay)	3.97	1.04	26	93
4	Summer weeds	3.18	1.17	37	74
5	Conventional tillage	2.86	1.08	38	67
6	N fertiliser (45 kg N/ha)	2.57	0.44	17	60
7	N Fertilizer (90 kg N/ha)	3.30	0.96	29	77
9	Frost and Heat	3.15	1.00	32	74
10	Frost and Heat 2 (moderate impact)	3.60	0.95	26	84

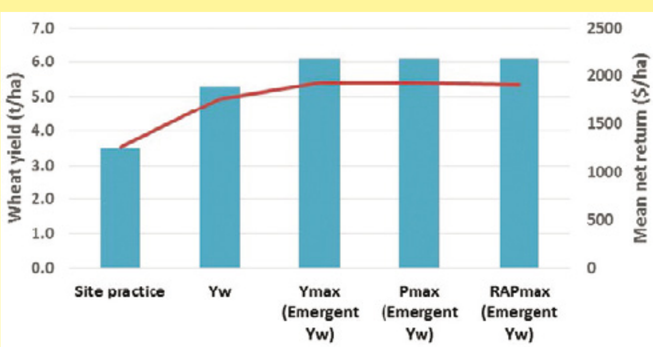
There is room for closing the yield gap by adopting non-limiting fertiliser management.

limited yield potential, of selected sub-optimal management practices.

Nationally, the average rate of N applied to grain crops is 45 kg N per hectare. This one practice is sufficient to account for a 40 per cent yield gap. Even at double that rate, a 23 per cent yield gap remains.

Frost and heat stress accounted for yield losses of between 16 and 25 per cent of water limited yield potential (Yw).

FIGURE 3: Wheat yield (tonnes per hectare) (blue bars) and net returns ($/ha) (red line) achieved by average site practice, water-limited yield potential (Yw) and yield-maximizing (Ymax), profit-maximizing (Pmax) and risk-adjusted profit maximizing (RAPmax) practices that are all emergent Yw treatments at a high yielding site (Dunedoo, NSW)



Failure to control weeds during the summer fallow could account for up to a 26 per cent yield loss; delayed sowing accounted for a seven per cent yield loss and low seedling density for an eight per cent yield loss.

Any grower who is still practising conventional tillage could be missing out on 33 per cent of their yield potential.

Other factors that contribute to the yield gap, not included in simulations, include biotic stresses such as plant diseases, insects and other pests, in-crop weeds and extreme weather events (eg. floods, strong winds and hail).

Despite the practice of late sowing in the Liverpool Plains, we found that the ideal sowing date was April 26 with a late maturing cultivar. This 'emergent Yw' treatment, with a 15 year average yield of 6.0 tonnes per hectare, had a 19 per cent advantage over Yw and should be considered as the new yield frontier.

While frost and heat stress reduce the yield potential of both Yw and the new simulated yield frontier, the advantage of the new treatment is slightly enhanced when frost and heat stress are taken into account.

The advantage of early sowing combined with later maturing (slower developing) varieties is consistent with recently published field and simulation work for sites from Dubbo south to Victoria, and west to SA and WA but will require flexible additional application of N fertiliser to meet N requirements of six to nine tonnes per hectare crops when seasonal conditions are right (for example, 2016).

Risk-adjusted profit

Growers generally do not seek to maximise yield but rather to maximise their profit. But growers are also generally averse to risk, meaning that profits should be adjusted for yield and price risk via a measure of certainty equivalent.

The certainty equivalent represents the smallest amount of certain money a farmer is willing to receive to forgo an uncertain profit, and can be calculated as the difference between average profit and a risk premium.

When typical costs were built in to allow profit and risk-adjusted profit to be calculated for a risk-neutral and a moderate risk-averse context, respectively (Figure 3), we found that, despite the higher costs, both maximum profit and maximum risk-adjusted profit were achieved by the emergent Yw treatment.

To sum up

While wheat growers in the Liverpool Plains are among the most efficient in Australia, there is still room for closing the yield gap by adopting non-limiting N fertiliser practices and controlling fallow weeds.

Simulation analysis suggests that, contrary to current practice, early sowing with slow maturing varieties has the potential to lift the production frontier by 19 per cent and significantly improve risk-adjusted profitability. This finding needs to be fully evaluated in local field experiments.

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