Farming to Soil Potential on the Upper Eyre Peninsula: How Accurate was In-season Yield Prediction in 2009?

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RESEARCH
EXTENSION

Almost ready

Location: Mudamuckla, near Ceduna, Peter Kuhlmann.
Paddock N1 at Minnipa Ag Centre, Mark Klante

Rainfall
Mudamuckla
Av. Annual: 293 mm
Av. GSR: 219 mm
2009 Total: 292 mm
2009 GSR: 229 mm
MAC
Av. Annual: 325 mm
Av. GSR: 242 mm
2009 Total: 421 mm
2009 GSR: 333 mm

Yield
Potential 2009 Mudamuckla: 3.04 t/ha (W)
Potential 2009 MAC: 5.2 t/ha (W)

Soil Type
Constrained sandy loam, Mudabie heavy (APSOIL#379)
Unconstrained grey calcareous sandy loam, Mudabie loam (APSOIL#374)
Constrained grey calcareous sandy loam, MAC heavy (APSOIL #353)
Unconstrained red light sandy clay loam, MAC loam (APSOIL#354)

Key messages

- **Using crop growth models to quantify the season to season yield performance on different soil types and predict in-season potential yield can be a very useful tool for managing risk and inputs.**
- **Given the high spatial variability in soils and grain yield, mapping paddocks into zones of similar soil and yield potential enables farmers to better target input levels as well as understand crop yield potential in different seasons.**
- **Information about the capacity of a soil to hold water, the water and mineral N levels at sowing are the basic information needed to use Yield Prophet - given this information, grain yield can be accurately predicted.**

Why do the trial?

Managing high levels of climatic variability and business risks on farms with highly variable soil types and conditions pose difficult challenges to most farmers in the lower rainfall regions of Eyre Peninsula. The responsive farming systems approach adopted by the latest GRDC EP Farming Systems 3 project aims to build resilience into EP farms by understanding the interactions between soil potential, climate and management. By running lower risk flexible systems that are more responsive to seasonal indicators such as commodity pricing, weather forecasts etc, farmers are more likely to make better decisions more often. At the focus sites at Mudamuckla and Minnipa, we tested whether knowledge of soil potential, soil variation and in-season predictions of grain yield with Yield Prophet could be useful to improving management.

How was it done?

Zoning and characterising the focus paddocks

Mudabie: Paddock 8 was zoned into areas of good, medium and poor performing areas based on several years of yield maps (cereal yields in 2002, 2004, 2005, 2007, 2008) and an elevation map. Soil samples from 4 points within each zone were taken in increments (0-10, 10-20, 20-40, 40-60, 60-80, 80-100 cm) to depth to determine soil moisture prior to sowing (4 May 09). Soil chemical analysis was also undertaken on these soils to 60 cm depth. Several soils had been previously characterised at Mudabie, with 2 profiles from an adjacent paddock (#10) selected to represent soils within the poor (constrained sandy flat - APSOIL#379) and good zones (grey calcareous sandy loam - APSOIL#374) of the 2009 focus paddock (Paddock #8). (APSOIL is a database of over 500 soil profiles characterised for water holding capacity for use in APSIM modelling - www.apsru.gov.au.)

MAC: Paddock N1 was zoned into areas of good, medium and poor performing areas based on several years of yield maps and an elevation map. Soil samples from 4 points within each zone were taken in two depth increments (0-10, 10-60 cm) to determine soil moisture prior to sowing (4 May 09). Soil chemical analysis was also undertaken on these soils to 60 cm depth. Soil characterisation on this paddock had been undertaken in previous work with a MAC heavy (grey calcareous sandy loam - APSOIL #353) representing an average soil in the poor zone and a MAC loam (red light sandy clay loam - APSOIL#354) representing an average soil in the good zone.

Paddock trials

Wheat was sown on 6 May 2009 at both sites (Mudabie cv. Gladius and at MAC cv. Yitpi). At Mudabie, the seeding rate was 35 kg/ha on the poor zones and 50 kg/ha on the medium and good zones with phosphoric acid applied at sowing at 0, 4 and 8 kg/ha of P/ha to the poor, medium and good zones, respectively. No other fertiliser was applied at this site.

At the MAC N1 paddock 3 treatments (seeding and fertiliser rates) laid out in strips across the entire paddock were imposed at planting in 2008 (Frischke et al, EP Farming Systems Summary 2008, p 77-80). This was repeated on the same strips with seeding rates of 40, 50 and 55 kg/ha and DAP fertiliser rates of 60, 40 and 0 kg/ha on the low, standard and high treatments, respectively in 2009 (Paterson et al, 'Responsive Farming Using Variable Rate Sowing'). An application of liquid N was applied to the crop on 23 July at rates of 0, 10 and 20 kg/ha N to the low, standard and high treatments, respectively. At both sites, plant cuts at early tillering, anthesis and maturity were taken to determine biomass at all 4 soil sampling points. On the final maturity cut, grain was threshed from the samples to determine grain yield. While there was a small plot header used to collect a larger grain sample from around these points as well as commercial header yield monitoring, the hand plant cuts were used as the reported grain yield in this article.

Predicting potential yield through the season with Yield Prophet®

APSIM is a crop-soil model that simulates the major processes that occur while crops and pastures grow. These include the nitrogen and carbon dynamics in soil, soil water balance (including evaporation, drainage, leaching and runoff), crop growth and interactions with daily temperature, radiation and rainfall. Yield Prophet is an on-line crop production model (based on APSIM) designed to provide grain growers with real-time information about the crop during growth. To assist in management decisions, growers enter inputs at any time during the season to generate reports of projected yield outcomes showing the impact of crop type and variety, sowing time, nitrogen fertiliser and irrigation. Using Yield Prophet for the poor and good soil types, crop reports were generated several times during the growing season to provide predictions of potential yield.

What happened?

Zones and soils

Mudabie: The areas of the paddock that had performed consistently poorly represent about 15% of the paddock and are dominated by heavy flats. Rooting depth is shallow on these soil profiles due to high concentrations of salt, boron and/or rock (Table 1) and as a consequence, the plant available water capacity (PAWC) is small (37 mm, Fig. 1a).

The areas zoned medium cover about 45% of the area and are located mostly in the midslope areas. The soils in these zones were not characterised for PAWC and it is assumed that the PAWC of these soils would fall between the heavy and good soil types.

The good zones represent 40% of the paddock and contain the best sandy soils (PAWC=50 mm, Fig. 1b), low sub-soil chemical constraints (Table 1) with roots able to reach 70 cm depth.

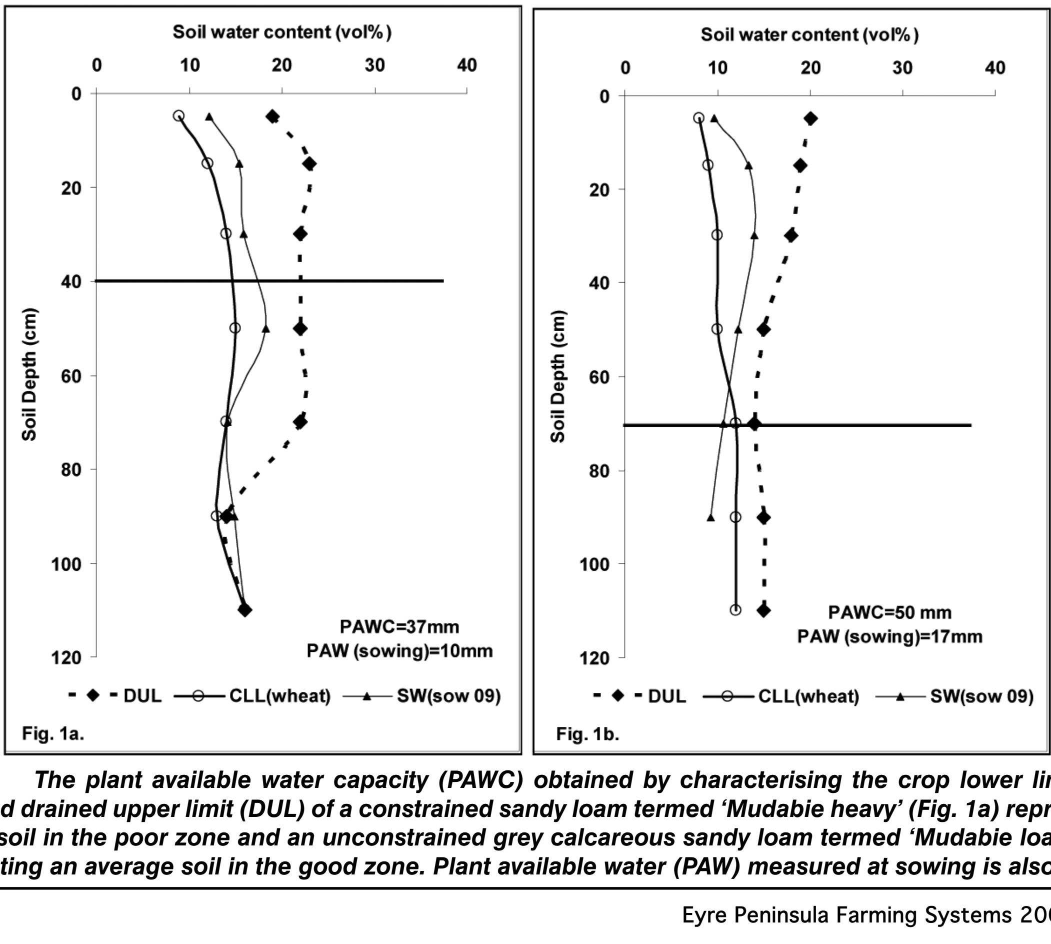


***Figure 1** The plant available water capacity (PAWC) obtained by characterising the crop lower limit (CLL) of wheat and drained upper limit (DUL) of a constrained sandy loam termed 'Mudabie heavy' (Fig. 1a) representing an average soil in the poor zone and an unconstrained grey calcareous sandy loam termed 'Mudabie loam' (Fig. 1b) representing an average soil in the good zone. Plant available water (PAW) measured at sowing is also plotted.*

MAC: The areas of the paddock that performed consistently poorly represent about 25% of the paddock are dominated by heavy flats. Again rooting depth is shallow on these soil types due to high concentrations of salt, boron and/or rock (Table 2) and as a consequence, the PAWC is small (47 mm, Fig. 2a). The areas zoned medium cover about 20% of the area and are located mostly in the midslope areas. The soils in these zones were not characterised for PAWC and it is assumed that the PAWC of these soils would fall between the heavy and good soil types. The good zones represent 55% of the paddock and contain red light sandy clay loam soils referred to as MAC loam with a PAWC of 93 mm (Fig. 2b). The rooting depth of the MAC loam is approximately 60 cm with similar toxic concentrations of salt below this depth as displayed in the MAC heavy soils (Table 2).

Soil moisture and available nutrients at sowing time

Mudabie: Sowing took place on 6 May after 17 mm of rain fell in the last week of April. This rainfall, and the contribution of 46 mm rain that fell in March resulted in 11 to 17 mm of plant available water (PAW) stored in the profile at sowing, depending on the soil type (Fig. 1a and 1b). Soil mineral N measured on soil cores was very high in all zones (Table 1) reflecting a history of good medic pastures and 3 previous years of cereal yield below 0.5 t/ha. As expected, salinity (EC), boron and chloride reached very high readings at depths grater than 40 cm in the soil of the poor zone.

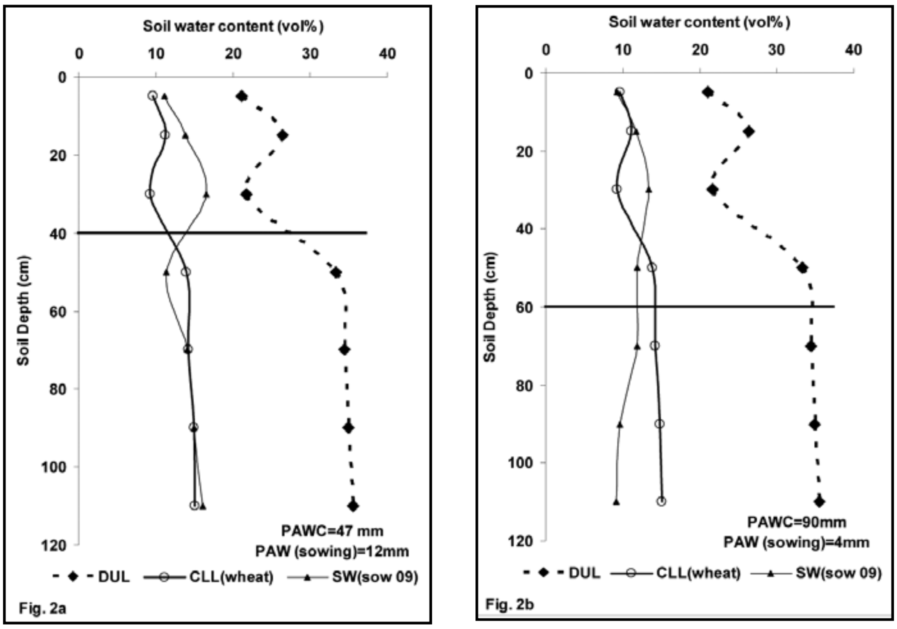


Figure 2 The plant available water capacity (PAWC) of a constrained grey calcareous sandy loam termed 'MAC heavy' (Fig. 2a) representing an average soil in the poor zone and a red light sandy clay loam termed 'MAC loam' (Fig. 2b) representing an average soil in the good zone. Plant available water (PAW) measured at sowing is also plotted.

Table 1 Soil chemical analysis on paddock 8 at Mudabie on soils sampled May 5 (the average of 4 soil cores within each zone)

Zone	Depth	Nitrate N	Ammonium N	Total mineral N	P	EC	pH	Boron	Chloride
		(mg/kg)	(mg/kg)	(kg/ha)	(mg/kg)	(dS/m)	(pH)	(mg/kg)	(mg/kg)
Poor	0 - 10	44	1.3	59	43	0.61	7.9	2.3	730
	10 - 20	32	1.8	44		0.54	8.1	4.8	612
	20 - 40	26	1.5	71		0.87	8.1	12.9	1059
	40 - 60	21	1.3	59		1.26	8.5	21.1	1457
		Total mineral N (0 - 60)		231					
Med	0 - 10	27	1.8	38	41	0.32	7.8	1.5	264
	10 - 20	25	1.0	34		0.39	8.0	2.3	366
	20 - 40	16	1.0	43		0.49	8.1	4.5	481
	40 - 60	15	1.3	43		0.65	8.1	7.1	711
		Total mineral N (0 - 60)		158					
Good	0 - 10	25	1.3	33	33	0.16	7.8	1.1	40
	10 - 20	24	1.5	33		0.21	7.9	1.4	66
	20 - 40	12	1.8	36		0.24	8.0	1.9	155
	40 - 60	14	1.5	40		0.45	8.1	5.0	447
		Total mineral N (0 - 60)		142					

MAC: Sowing took place on 6 May after 25 mm of rain fell in the last week of April. This rainfall, and the contribution of 62 mm rain that fell in March resulted in 12 mm of plant available water (PAW) stored in the profile of the poor soil at sowing (Fig. 2a), but only 4 mm of plant available water (PAW) stored in the profile of the good soil at sowing (Fig. 2b). Soil mineral N measured on soil cores was very high in the poor and medium zones (Table 2), and moderate in the good soil.

Yield Prophet Prediction for 2009 - Mudabie

The first YP reports for good and poor soils were generated on 9 July corresponding with GS30-31 (Figure 3). For both soils, the range of possible yield outcomes was wide ranging from 0.6 to 5 t/ha with the available soil N reserves. Subsequent reports up to and including the 24 August report indicated that the lowest yield likely based on historical weather records was about 1.4 t/ha for the good soil (1.1 t/ha for the poor soil) with the highest yield being around 3.7 t/ha (3 t/ha for the poor soil). Between 24 August and 2 September, the highest potential yield decreased by over 1 t/ha on both soils due to high water stress during mid to late August corresponding with flowering and the start of grain fill. The 30 September report indicated a final yield prediction of 2.1 and 1.6 t/ha for the good and poor soils, respectively. These predictions were close, but just below the observed paddock yields (Table 3) of 2.47 and 1.68 t/ha on the good and poor soils respectively.

Yield Prophet Prediction for 2009 - MAC N1

The YP reports generated on 22 July corresponding with GS 32 indicated that yield was severely limited by available N in the soil profile of the good zone (Figure 4) i.e. the comparison between the solid and non N limiting dotted line. Because there was a high probability of an economic response to additional N application (YP also provides N profitability reports to test such scenarios), additional N was applied on 23 July. The simulations below do not include this topdressing. Due to high soil N available in the profile of the poor soil, there was very little difference between the yield outcome with the actual N and the simulated yield outcomes with unlimited N (similar to the Mudabie grain yield outcomes in Figure 3). In the period between 21 August and 15 September, there was low rainfall (22 mm) and the crop experienced high water stress in the early to mid Sept period on both soil types. In the good soil, this resulted in 60% of seasons with unlimited N now yielding in the range of only 2.1 and 2.5 t/ha and less than 10% of seasons yielding greater than 3 t/ha. The grain yields predicted at maturity (mid October) were all in the best 5 to 10% of seasons corresponding with the decile 9 rainfall received during the growing season at Minnipa.

Measured vs predicted wheat growth

Mudabie: The biomass measurements made at early tillering were very low and reflected the high stress conditions following germination (low rainfall and hot winds) that affected the crop during its first 6 weeks of growth (Table 3). At this time, the biomass predicted by Yield Prophet were more than 1 t/ha higher than measured and indicate that the simulation failed to recognise the water stress during this time. Predicted biomass continued to be higher than measured at the next two sampling times but grain yield was somewhat lower than measured, resulting in very low harvest index. The modelled crop growth was unable to represent the effects seen in the sown crop resulting from water and heat stress and consequently low tillering and biomass.

Table 2 Soil chemical analysis on paddock N1 at MAC on soils sampled 23 April (the average of 4 soil cores within each zone)

Zone	Depth	Nitrate N (mg/kg)	Ammonium N (mg/kg)	Total mineral N (kg/ha)	P (mg/kg)
Poor	0 - 10	33	2.0	35	37
	10 - 60	40	1.8	208	
		Total mineral N (0 - 60)		244	
Med	0 - 10	23	1.8	25	40
	10 - 60	35	1.8	186	
		Total mineral N (0 - 60)		211	
Good	0 - 10	11	2.0	14	33
	10 - 60	19	1.4	103	
		Total mineral N (0 - 60)		117	

Figure 3 Predictions of grain yield outcomes for Mudabie for soils in the good and poor zones (Wheat cv. Gladius sown May 6)

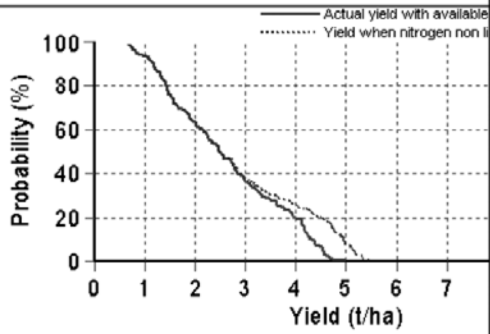
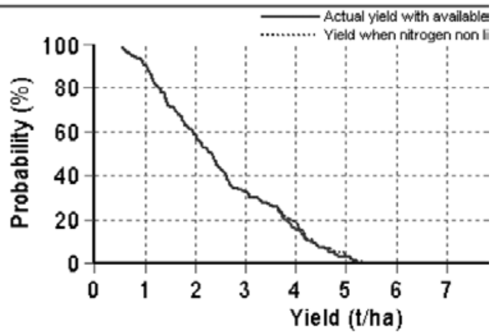
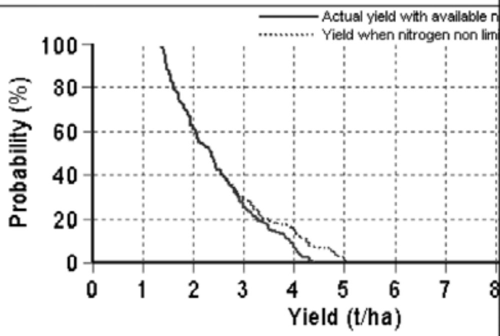
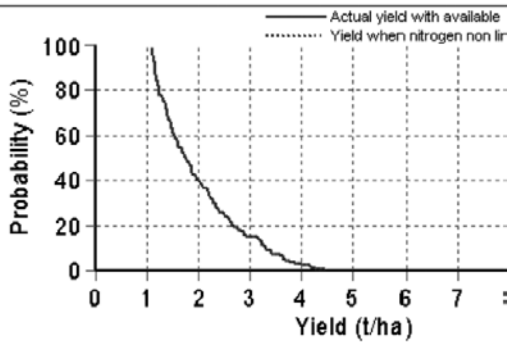
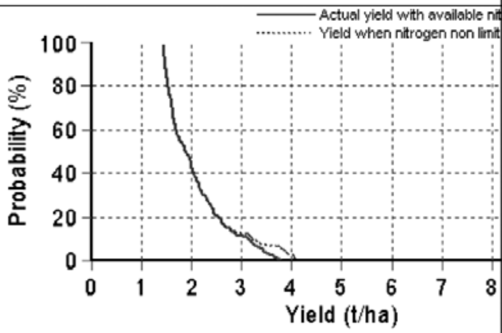
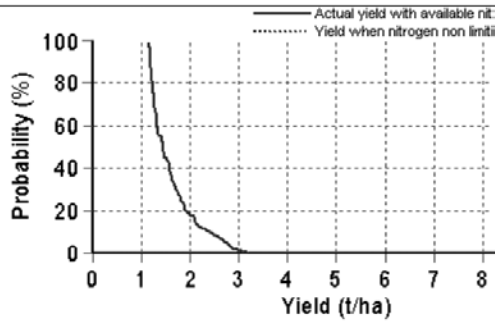
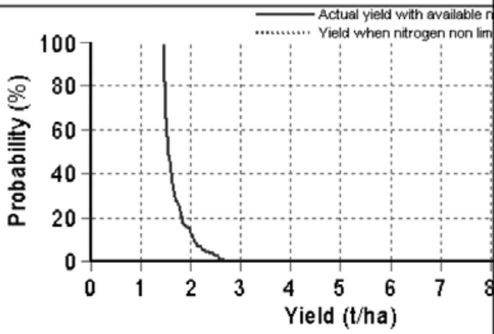
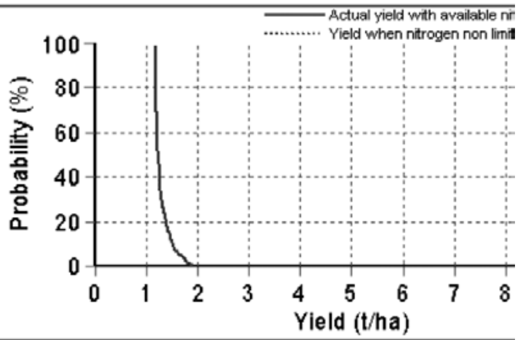
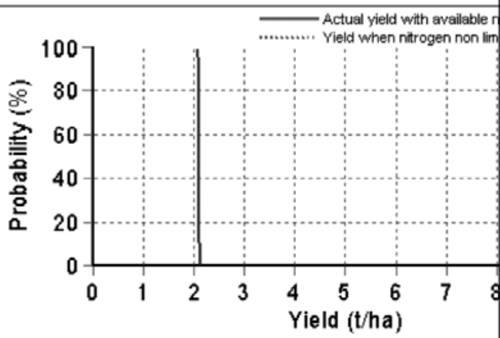
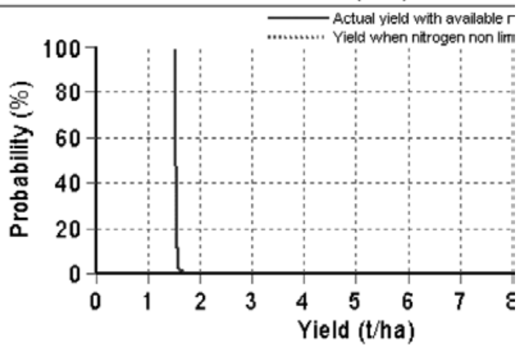
Date of report/ Growth stage/ GSR (from May 6)	Good zone	Poor zone
9 July GS31 - 1st node GSR 60 mm		
6 Aug GS45 - mid boot GSR 123 mm		
24 Aug GS65 - anthesis GSR 134 mm		
2 Sept GS75 - mid dough fill GSR 143 mm		
30 Sept Maturity GSR 193 mm		

Figure 4 Predictions of grain yield outcomes for MAC N1 for soils in the good and poor zones (Wheat cv. Yitpi sown May 6)

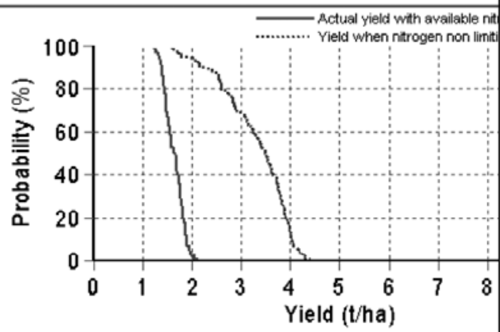
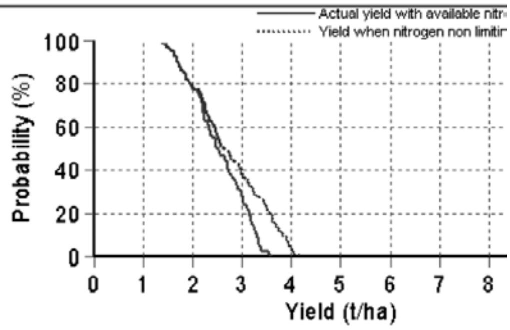
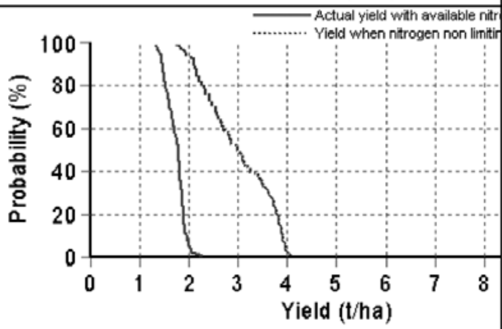
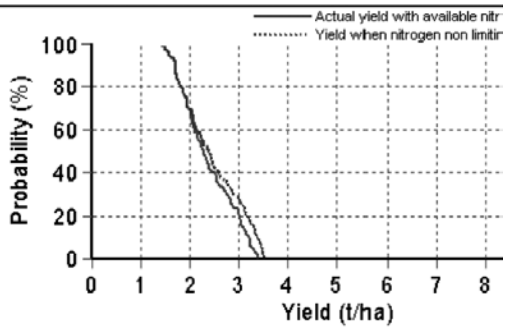
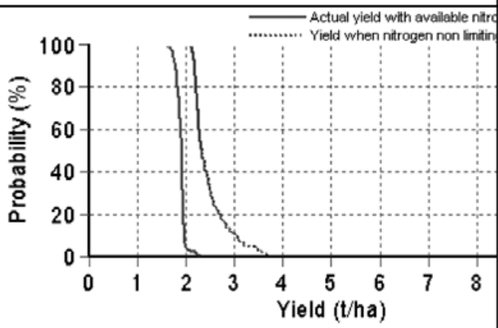
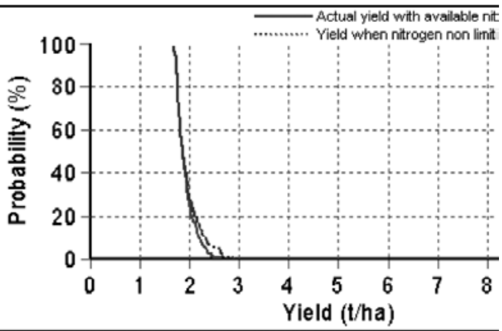
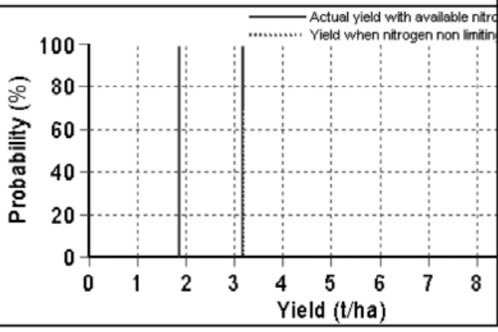
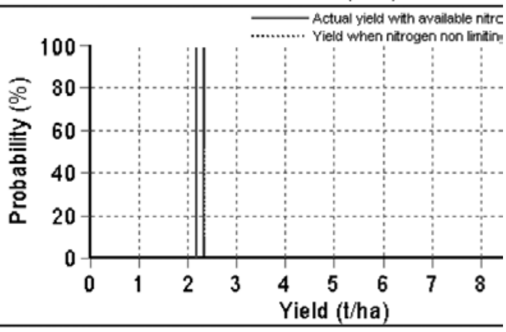
Date of report/ Growth stage/ GSR (from May 6)	Good zone	Poor zone
22 July GS32 2nd Node GSR 192 mm		
21 Aug GS55 mid head emergence GSR 214 mm		
15 Sept GS75 - mid dough fill GSR 236 mm		
20 Oct Maturity GSR mm		

Table 3 Observed dry matter, grain yield and harvest index averaged from 4 sampling points within zones sampled at early tillering, anthesis and maturity and predictions made by Yield Prophet for the good and poor zones at Mudabie

		Biomass Early tillering 17 July (t/ha)	**Biomass Anthesis 26 Sept (t/ha)**	**Biomass Maturity 5 Nov (t/ha)**	**Grain yield (t/ha)**	**Harvest Index**
Observed	Poor *SED*	0.13 *(0.03)*	1.66 *(0.25)*	3.21 *(0.88)*	1.68 *(0.42)*	0.52
	Medium *SED*	0.27 *(0.02)*	2.11 *(0.42)*	3.63 *(0.18)*	2.00 *(0.25)*	0.55
	Good *SED*	0.56 *(0.08)*	3.28 *(0.23)*	5.31 *(0.17)*	2.47 *(0.05)*	0.47
Predicted	Poor	1.67	4.98	5.35	1.60	0.30
	Medium					
	Good	1.67	5.96	6.62	2.00	0.30

SED = Standard error of the mean calculated from 4 sampling points

Table 4 Observed dry matter, grain yield and harvest index averaged from 4 sampling points within zones sampled at early tillering, anthesis and maturity and predictions from Yield Prophet for the good and poor zones at MAC

		Biomass Early tillering 17 July (t/ha)	**Biomass Anthesis 14 August (t/ha)**	**Biomass Maturity 16 Nov (t/ha)**	**Grain yield (t/ha)**	**Harvest Index**
Observed	Poor *SED*	0.54 *(0.10)*	4.19 *(0.09)*	4.35 *(0.24)*	1.96 *(0.13)*	0.45
	Medium *SED*	0.37 *(0.04)*	3.65 *(0.44)*	5.38 *(0.39)*	2.63 *(0.18)*	0.49
	Good *SED*	0.38 *(0.05)*	3.78 *(0.37)*	5.90 *(0.23)*	2.94 *(0.10)*	0.50
Predicted	Poor	0.24	4.42	5.46	2.10	0.38
	Medium					
	Good	0.24	5.27	6.65	2.40	0.36

SED = Standard error of the mean calculated from 4 sampling points

MAC: (Table 4) This wheat crop grew in an exceptionally good year (decile 9). The Yield Prophet reports do suggest crop potential was reduced because of moderate water stress experienced in the period between 21 August and 14 September when only 23 mm of rainfall was received. Predicted biomass at maturity was higher than measured while predicted grain yield was similar to measured on the poor zone and 0.54 t/ha under predicted in the good zone.

What does this mean?

The Yield Prophet system is a tool that integrates the multiple drivers of crop growth (soil moisture, soil nutrition, crop stage, seasonal outlook and soil potential) into the prediction of in-season grain yield outcomes. This has been achieved by combining a complex soil-crop simulation model with real time soil, crop and weather information and some seasonal forecasts. Provided that soils are accurately characterised APSIM can accurately predict cereal yields on the upper EP (see Whitbread et al EP Farming Systems Summary 2007 p 95-102). At the 2 sites presented in this article, prediction of crop performance of the good and poor soils was consistent with the measured data, although grain yields were up to 0.54 t/ha under-predicted at MAC. There was also a much lower harvest index resulting from the overestimation of biomass. While additional soil characterisation could improve these predictions, the aim here was to apply Yield Prophet using representative soil characterisations which were modified with additional site specific soil data.

The question posed by this work was whether predicting crop performance in-season could be useful in the management of responsive faming systems. In addition to the grain and hay yield outcomes presented in this article, there is information contained in the Yield Prophet reports such as predicted dates of crop stages, frost and heat risk assessment and yield predictions for years where SOI has an influence on rainfall. This information is useful in planning crop-stage dependent herbicide applications, or understanding the drivers of crop performance for instance.

In highly risky environments, such as the upper EP, predictions made at GS31-32 (first and second node) of crop response to additional N inputs are of limited value as the range of seasonal outcomes from that point forward is still so wide.

The range of grain yield outcomes in the Yield Prophet reports became tighter around anthesis – while this is of limited value in forward selling decisions, it may be useful in making decisions about the application of rust sprays or planning for harvest.

The long term yield performance and season to season yield variation of different soil types is critical information in designing lower risk farming systems. This may include deciding on areas most suitable for various landuses (continuous cereal cropping, season responsive rotations, permanent pastures) and for designing robust paddock zones in precision agriculture applications.

The provision of regular in-season Yield Prophet reports for a range of soil types across several regions of the upper EP may be the most time and cost effective method of using this technology. While the starting soil conditions are not standard and comparable from paddock to paddock, in the low input marginal environments of EP understanding soil potential and seasonal variability is the critical information that farmers should be aware of for their particular farm.

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