Yield Prophet[?]: An online crop simulation service

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Abstract

Yield Prophet[?] is a simplified web interface for the crop production model APSIM. It is a subscription service that is delivered to growers and farm consultants Australia wide. Yield Prophet provides dry land and irrigation grain growers with up-to-the-minute, real-time information about their wheat and barley crops during growth, and the likely impact of management events on crop yield and quality. Its primary output is a forecast of yield probabilities based on the simulation of crop production from pre-sowing until harvest.

Grain growers are using Yield Prophet to match inputs such as irrigation water and nitrogen fertiliser to crop requirements, manage climate and soil water risk, forecast yield (forward selling, storage and insurance), target protein for desired grain quality and assess likely impact of sowing time and variety selection on yield. 2005 was the third year of Yield Prophet's commercial delivery with 338 paddocks subscribed to the service. Subscriptions directly involved 236 growers, 38 agronomic consultants, 8 government extension and research officers and 8 grower groups. Subscribers used Yield Prophet to generate 6813 APSIM simulations from 5 April to 1 December 2005, with most demand experienced during August and September, the decision making time for nitrogen top-dressing for most subscribers.

Key Words

Yield Prophet, APSIM, crop simulation, online

Introduction

APSIM (Agricultural Production System Simulator) is a modular model of crop production developed by CSIRO and its APSRU partners over 15 years (Keating et al., 2003). Research by CSIRO through the FARMSCAPE program demonstrated the relevance of APSIM simulations to farm management (Carberry et al., 2002), and that there was a market demand from farm managers for access to paddock specific APSIM simulation output. In order to meet this demand BCG and CSIRO collaborated to develop Yield Prophet. In 2003 Yield Prophet initially took the form of a monthly fax-out service to subscribers from BCG's membership catchment area in the Wimmera-Mallee region of north-west Victoria. In 2004 the Yield Prophet web interface (www.yieldprophet.com.au) was developed which automated much of the simulation data entry and outputs in a series of reports, and created the capacity to service a large number of users. 2005 saw the rapid expansion of the service to all major grain growing regions of Australia.

Initial applications of Yield Prophet related to impact of varying initial nitrogen and sub-soil moisture on likely yield. This soon expanded to incorporate the likely impact of seasonal forecasts and different nitrogen and irrigation application scenarios on likely yield. In 2005 reports were created delivering model output that returned likely impact on yield of sowing date and variety scenarios, and reports on yield and gross margin response to timing and quantity of nitrogen fertiliser. Initially wheat was the only crop type available in Yield Prophet, with barley and sorghum added in 2005. Canola is being tested in 2006, and pulse crops are being investigated. Yield Prophet now stands as an integrated production risk and monitoring decision support tool with multiple applications relevant to farm management.

This paper describes the current operational design of Yield Prophet as an interface to APSIM, and the output which users obtain from it. It also presents data on national use of Yield Prophet, and the accuracy of its simulations in comparison to observed paddock yields.

Methods

Subscription

Users register online for subscription to Yield Prophet in early autumn. They provide the names of the paddocks that will grow the crop that they wish to simulate, and the distance and direction of each paddock to the nearest town (this information is used to ensure that relevant soil types and climate data is available). Upon subscription, users are provided with a list of the soil data inputs required by Yield Prophet and must organise their own soil sampling and analysis. Prior to the commencement of the growing season users are provided with log in details which gives them access to their 'paddocks' on the Yield Prophet website, where they enter the results of their soil tests and nominate a weather station from the SILO patch-point data set (Australian Government Bureau of Meteorology, 1997) that is climatically most relevant to each of their paddocks. As the season progresses, users update agronomic management details and paddock specific rainfall.

Soil characterisation

An appropriately measured soil characterisation - specifically plant available water capacity (PAWC) is an essential input for Yield Prophet to simulate crop growth, yield and protein accurately. Users must select a soil type from a 'library' of soils for which the soil inputs required by APSIM have been measured or estimated. Variation in soil type, the major cause of within-paddock yield variation, requires some consideration in use and interpretation of Yield Prophet. Yield Prophet's simulation is based on one soil type nominated for each paddock, and initial soil resource data that is usually sampled from a limited number of points within a paddock and bulked to give a single sample seen as representative of conditions in that paddock. Where differences in soil type are obvious and growers treat each soil type as a different management zone, each zone can be set up as a different 'paddock' in Yield Prophet with appropriate soil types nominated. Where growers are aware of soil type variation, but do not consider it of sufficient importance to manage, output from Yield Prophet provides a good guide to likely yield outcomes within the paddock, but should not be seen as a definitive paddock result.

Yield Prophet System Structure

Yield Prophet is an online interface for APSIM. It simplifies the inputs required and outputs generated by APSIM to those relevant to agronomic management. The inputs which Yield Prophet requires are listed in Table 1. After users enter these inputs through the Yield Prophet website, they are saved by the website to a Microsoft Access database.

Table 1. Inputs required by Yield Prophet.

Paddock Attribute	Input Data
Soil (attributes sampled in specified layers from the soil profile 0-10, 10-40, 40-70 and 70-100cm depth)	▪ Pre-sowing gravimetric water content ▪ Pre-sowing nitrate and ammonium concentration ▪ Organic carbon content ▪ Electrical conductivity ▪ pH ▪ Chloride concentration ▪ Estimate of maximum rooting depth

Climate	▪ Nearest weather station with available patch-point dataset from SILO ▪ Daily rainfall
Management	▪ Sowing date ▪ Variety ▪ Nitrogen application date and rate ▪ Irrigation application date and rate

When a user requires output from an APSIM simulation, they request a report. When a report is requested, the paddock specific information is e-mailed from the database to a 'run machine' computer. The run machine queues the report to a cluster of 26 dual processor computers, which patch the paddock specific parameters into a template APSIM simulation in which all other model parameters are optimised for Australian temperate broad-acre cropping. Climate data for the current season and the last one hundred years as recorded by the weather station most relevant to the paddock are automatically obtained online from SILO. APSIM simulates the soil water and nitrogen processes in the paddock from the start of the current growing season, and crop growth from the user nominated sowing date, up to the present. It then simulates crop growth and resource availability from the day on which the report was generated to crop maturity using historical climate data. It does this one hundred times using each of the last one hundred years of climate data from the nominated weather station. The output from these simulations that is returned to the user is determined by the type of report that the user requests. The output specific to the requested report type is graphed and then converted to an image file by the run machine to create the report, which is then e-mailed to the database where it can be viewed by the user. An e-mail is also sent to the user notifying them that their requested report is ready for viewing. As an image file, reports can be saved, printed or e-mailed as required by the user. Report generation takes from five to fifteen minutes.

Output from the one hundred simulations (principally grain yield and protein) is presented to the user in probabilistic terms (Figure 1a). The range of probabilities narrows as the season progresses and components of yield become more certain. This is the main output of Yield Prophet, and its value is increased by incorporating seasonal forecasts, in this case the Southern Oscillation Index (SOI) phase system. In this case, instead of yield results for the last one hundred years, Yield Prophet selects the years out of the last one hundred in which the SOI phase was the same as in the current year. This creates another probability curve which growers can use to ascertain the impact of the current phase of the SOI on yield (Figure 1b).

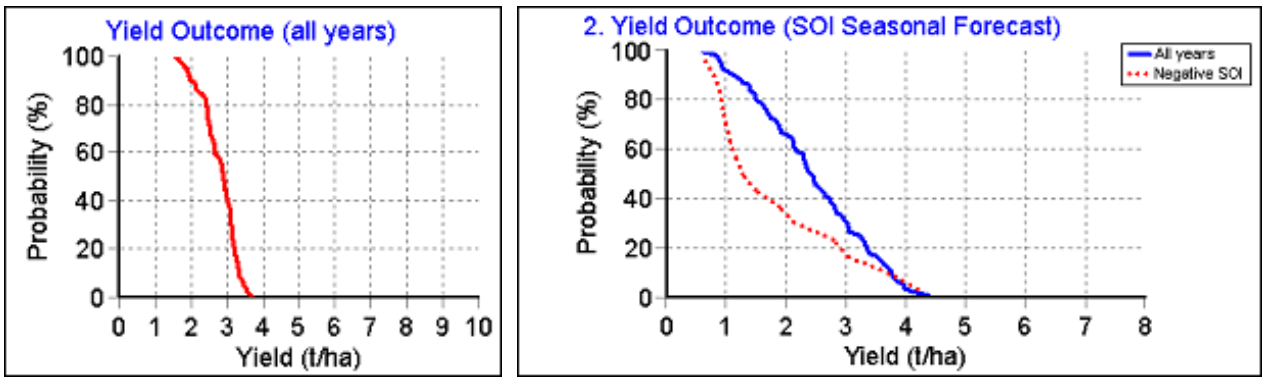


Figure 1. a) A yield probability curve, the main output from Yield Prophet. b) Yield probability curve generated using season finishes for the last hundred years of climate data (solid line), and only those years in which the SOI phase was the same as the current phase at the time the report was generated (dotted line).

The likely impact of different management decisions (sowing date and variety, irrigation and nitrogen applications) can be determined by simulating different management 'scenarios'. APSIM simulates yield

outcomes for three different scenarios nominated by the user, and this is presented by Yield Prophet as a set of up to 3 probability curves, each representing one scenario.

Adoption and Results

Yield Prophet as a web-based service first went online in 2004 to 47 growers primarily from BCG's catchment region in north-west Victoria. In 2005, subscription was broadened to include all major grain growing regions of Australia, and the service was delivered to 236 growers, 38 agronomic consultants, 8 government extension and research officers and 8 grower groups. That year subscribers generated 6813 reports from 5 April to 1 December 2005, with most demand experienced during August and September, the decision making time for nitrogen top-dressing for most subscribers. Regional growth of Yield Prophet is presented in Figure 2.

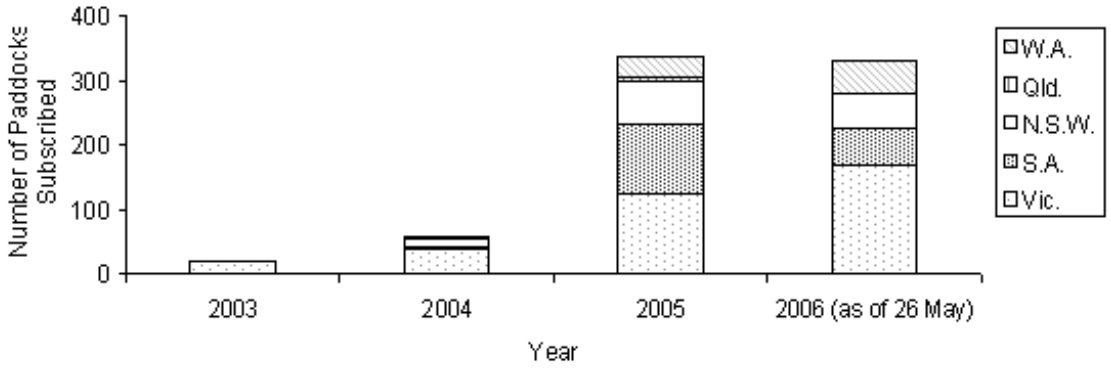
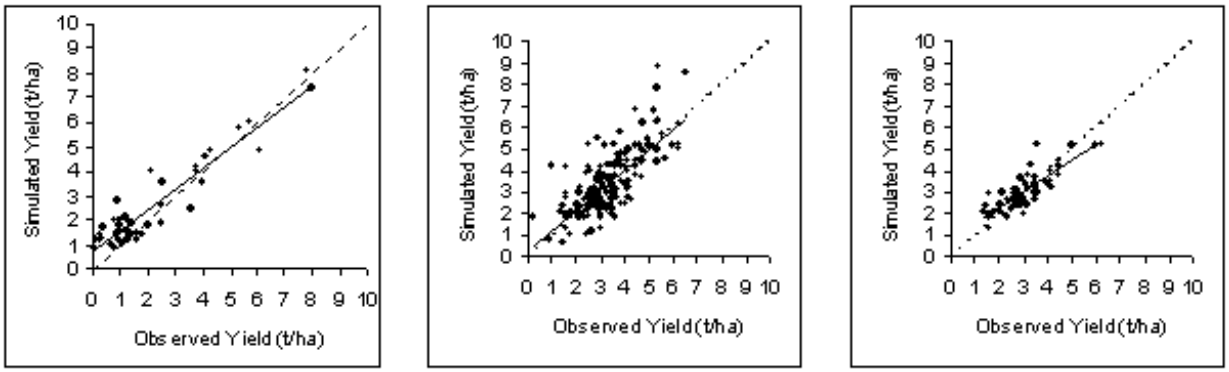


Figure 2. National growth of Yield Prophet as number of paddocks subscribed.

At the conclusion of each season, actual paddock yields are compared to Yield Prophet simulated yields and reported to users (Figure 3). Results from 2005 have highlighted the importance of appropriate soil characterisation and input data. In that year 49% of simulated results were within 0.5 t/ha in all paddocks (Figure 3b), compared to 68% in paddocks with appropriate measured soil characterisations (Figure 3c).



a) **b)** **c)**

Figure 3. a) All returned simulated vs. observed yields from Yield Prophet in 2004. A linear function (solid line y = 0.84x + 0.74) was fitted to the data points using least-squares regression (R^2=0.89). b) All returned simulated vs. observed yields from Yield Prophet in 2005. A linear function (solid line y = 0.95x + 0.29) was fitted to the data points using least-squares regression (R^2=0.54). c) Simulated vs. observed yields paddocks with appropriate measured soil

characterisation and segmented soil profile sample inputs for Yield Prophet in 2005. A linear function (solid line y = 0.75x + 0.74) was fitted to the data points using least-squares regression (R^2=0.68).The dashed line in all figures represents y=x, where all data points would lie if the simulated results were perfectly accurate.

Surveys of users' satisfaction and requirements from Yield Prophet are conducted annually at the end of each season. Results from these surveys provide a guide for the level of accuracy that farm managers require from Yield Prophet for it to be useful for support of management decisions, and to the aspects of the service where improvements could be made. User adoption of Yield Prophet has been studied in detail as part of a project relating to adoption of discontinuous technologies (Brennan et al., 2006).

Conclusion

Yield Prophet is a unique and innovative method of making simulation output from a powerful and complex production model available to farm managers. There is abundant anecdotal evidence that it has already made an impact on the way in which grain growers make management decisions, particularly in regard to in-season nitrogen inputs and climate risk. The main limit to its accuracy is appropriate measured soil characterisation suitable for APSIM input. Further capabilities being developed for Yield Prophet include NRM outputs and a greater selection of crop types (canola and pulses) to allow assessment of rotation risk.

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References

Brennan, LE, Hochman, Z, McCown, RL, Darbas, TM, Carberry, PS, Fisher, J, Hall, CA and Dalgliesh, NP (2006) Targeting pragmatist farmers in transfer of simulation-based decision support - A report for the Cooperative Venture for Capacity Building, Rural Industries Research and Development Corporation. RIRDC, Barton ACT

Carberry, PS, Hochman, Z, McCown, RL, Dalgliesh, NP, Foale, MA, Poulton, PL, Hargreaves, JNG, Hargreaves, DMG, Cawthray, S, Hillcoat, N and Robertson, MJ (2002) The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation. *Agricultural Systems,* **74,** 141-177.

Keating, BA, Carberry, PS, Hammer, GL, Probert, ME, Robertson, MJ, Holzworth, D, Huth, NI, Hargreaves, JNG, Meinke, H, Hochman, Z, McClean, G, Verburg, K, Snow, V, Dimes, JP, Silburn, M, Wang, E, Brown, S, Bristow, KL, Asseng, S, Chapman, S, McCown, RL, Freebairn, DM and Smith, CJ (2003) An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy,* **18,** 267-288.

Australian Government Bureau of Meteorology (1997) SILO - Meteorology for the Land. http://www.bom.gov.au/silo/. Accessed 13 June 2006