The Yield Prophet – how did it perform in 2003?

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Key Words

Crop simulation, production, climate risk

Take Home Messages

- APSIM, as a crop simulation model, can accurately estimate actual crop yield.
- The Yield Prophet builds on output tools based on APSIM simulations.
- Inputs returns that can be modelled to build a likely profit profile based on probability functions
- Climate risk (hence production risk) can be modelled to project forward the likely seasonal outcome

Yield Prophet – the concept:

The Yield Prophet is a program designed to assist grain growers in making best bet risk management decisions. The management decisions focussed on are:

- inputs (especially N fertiliser - applied either pre-sowing or post-emergent)
- operation timing and crop/variety selection
- risk in relation to soil water stored and in crop rainfall
- risk in relation to seasonal conditions and forecasts (primarily using the SOI signal)
- expected yield and protein
- gross returns and margins

The Yield Prophet uses APSIM to simulate crop growth during the season.

APSIM: APSIM stands for **A**gricultural **P**roduction **S**ystems s**IM**ulator. It is a computer simulation model developed by APSRU (CSIRO-Toowoomba). The model simulates the production of a crop at any time from sowing to harvest - its primary output is a yield prediction based on a scenario of inputs.

How does APSIM work?

The computer model simulates the growth of a crop based on the initial conditions at sowing, the inputs provided and current weather conditions. The model uses a daily time step and all parameters of crop growth are modelled (ie. growth stages, root growth, dry matter, grain yield etc). At each stage during the season the model calculates a predicted outcome based on a probability function. The probability function is calculated using actual climate data for the last 100 years.

For example, if a model run was done on a paddock on July 1, 2003 it would:

- model the crop growth from the day it was sown (allowing for inputs etc) up to July 1 using daily rainfall (usually obtained from the farmer) and other weather conditions (temperature etc) from the nearest MET bureau site.

It would then:

- estimate the yield presented as a probability function based on running the model over 100 years of local historical rainfall from July 2 to the end of the season. For example, in this case the model would use the rainfall from July 2 to harvest for 1903, July 2 to harvest 1904 etc until it has completed 100 simulations, then present the data as a probability distribution curve (see Figure 3).

The ability to present a yield estimate as a probability function on what would have happened with local historical rainfall is one of the most powerful tools of this model. Besides a yield estimate based on current inputs you could also ask the question of what would happen if you applied 50, 100 etc kg N/ha – the result would again be presented as a probability function.

Yield Prophet in 2003

The BCG-WFS have been working with APSRU and DPI in Victoria for several years modelling some of the trials undertaken by the group. In 2003 the BCG-WFS saw an opportunity to work with APSRU to assess whether the model could be used as an in-paddock management tool. We termed this the Yield Prophet. For validation we ran the model on twenty-nine wheat paddocks in the Victorian Wimmera and Mallee plus the three main BCG-WFS trial sites. The crops were monitored from sowing to harvest to 'paddock test' the APSIM model.

Soil measurements

At all 32 sites soil water and available nitrogen were measured along a 300m transect to a depth of 1.3m prior to sowing, at the end of tillering (GS30), flowering (GS65) and at harvest. In addition, at about half the sites the Soil Drained Upper Limit (DUL) and Crop Lower Limit (CLL) were determined using ponded sites (for DUL) and rainfall exclusion tents (for CLL) (see Figure 1). The DUL, CLL and bulk density data from the measured sites were then used to estimate the DUL and CLL for other sites with similar soil types for which these measurements were not done. In 2003, there was no rain during harvest and for most sites the harvest soil moisture was taken to be the equivalent to the CLL value.

Soil samples from 5 depths (over the 1.3m) were also analysed for chemical characteristics with particular emphasis on possible sub-soil limitations (ie. Electrical conductivity (EC), Boron (B), Exchangeable Sodic Percentage (ESP)).

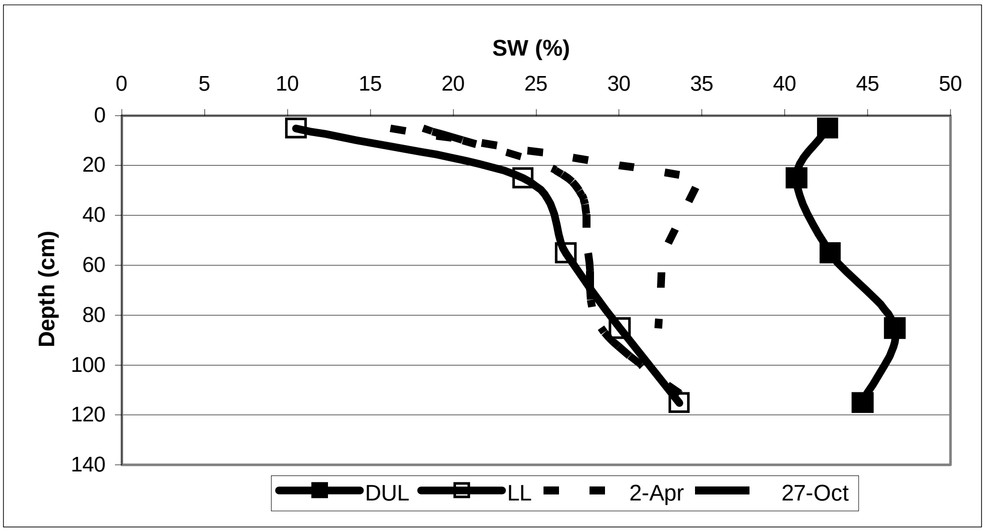

Figure 1. Soil water characteristics for a Yield Prophet paddock on a Wimmera self mulching grey clay (pre-sowing and flowering; the harvest soil moisture was very similar to the CLL values at this site and is not presented for ease of reading the figure).

Crop monitoring and records

Variety sown, sowing date and N inputs at sowing and during the season were all recorded and used to set up the initial parameters for APSIM. Crop growth parameters (emergence, growth stages, diseases, weeds etc) were recorded and used to identify any possible problems associated with the crop during the season. Daily rainfall and severe weather events such as frosts or hot days were recorded by the farmers.

Harvest

The crop on the transect was harvested and weighed with a weigh bin, or a yield map was used to work out the yield – sub-samples of grain were collected and analysed for protein and screenings. Dry matter cuts were taken from most of the paddocks.

Yield Prophet during the season

The inputs required to run APSIM were updated every month and the farmers who hosted a Yield Prophet paddock received a monthly fax outlining:

- updated yield estimate (based on a probability function)
- N fertiliser requirement
- yield risk assessment based on the likely rainfall outcome for the season (SOI based)

APSIM validation

After harvest the actual paddock harvests were compared to the updated APSIM yield estimates (Figure 2) (updated APSIM using the new DUL and CLL soil information for each site) and daily rainfall for the site and other weather parameters from the nearest MET bureau station.

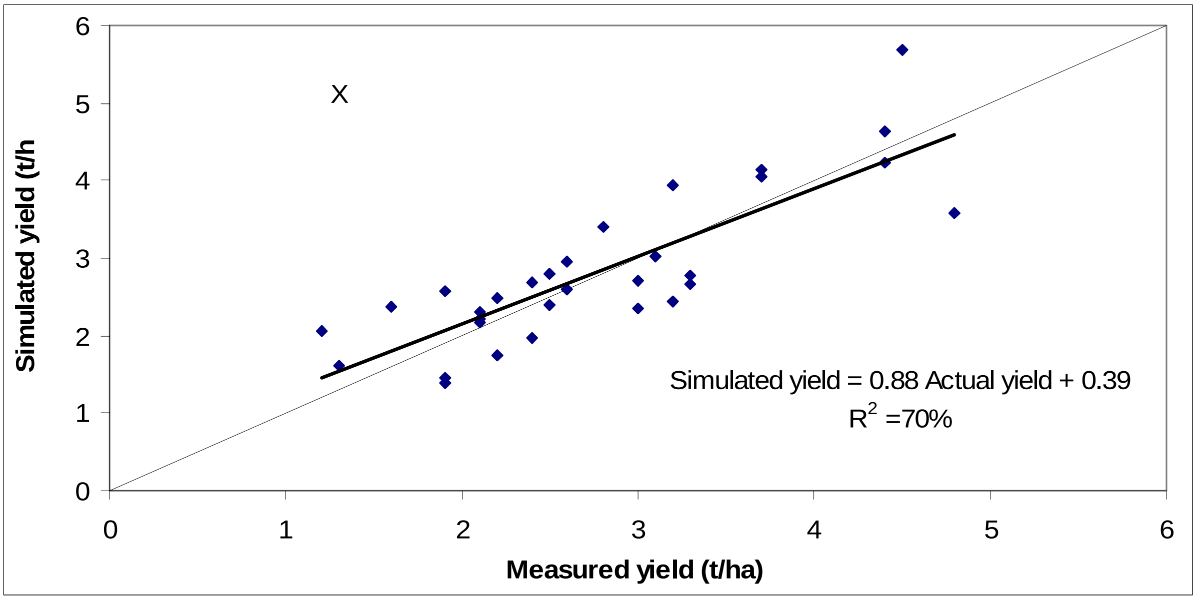

Figure 2. Actual paddock yields versus APSIM modelled yields.

One site was excluded from the correlation analysis: a potentially high yielding site marked as X on Figure 2 was severely frosted and yielded only 1.4t/ha but produced a dry matter yield at harvest of 12.1 t/ha, indicating that the potential crop yield would have been at least 4.5 t/ha.

The correlation of the other 31 paddocks between actual paddocks versus the APSIM modelled yields was quite good in 2003. The relationship between actual and APSIM modelled had an R^2 of 70%. The accuracy of the relationship is good for a highly variable biological system such as farming. Some of the variation between Actual and APSIM modelled yield can be explained by:

- errors in measuring soil water – the model is sensitive to accurate soil water data. Our soils are highly variable and to get a good representative soil water measurement is difficult and time consuming.
- effects of sub-soil limitations. The BCG-WFS is working with Daniel Rodriguez from DPI, Victoria in determining the effect of sub-soil limitations on a range of crop types and what impact this had on modelled outcomes.
- disease and weed competition (monitored in the paddocks but low levels of stripe Rust or other diseases could have had an impact on yield)
- low level frost and variability in the extent of frost across a paddock
- rainfall variability (between where it was measured and the paddock)
- low level herbicide damage, etc

APSIM Output

An example of an APSIM output at sowing for a paddock in the Wimmera (on self mulching clay) is presented in Figure 3. The inputs into the model at this stage were: the soil water characteristics (DUL and CLL);

measured soil water and available N; wheat variety, sowing date, fertiliser inputs at sowing; and daily rainfall from the date that soil water measurements were taken. The model then simulates yield using historical actual rainfall from the day of sowing to the end of the season for each of the last 100 years. This information is presented as a probability function graph (as per Figure 3).

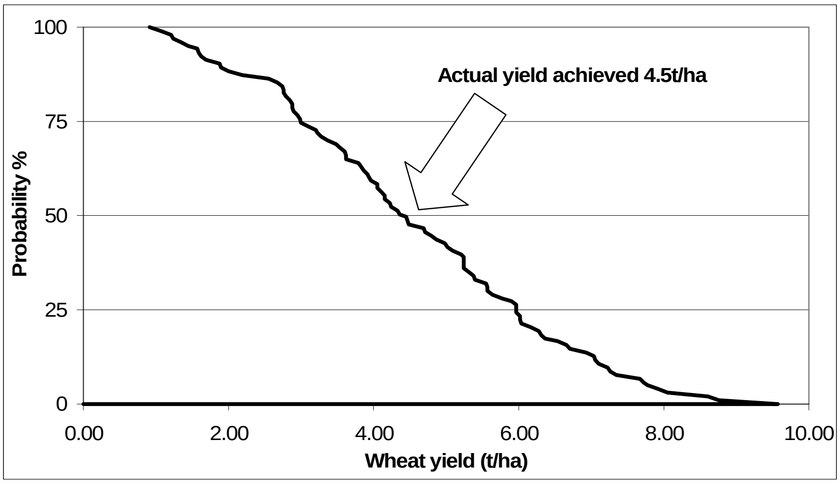

Figure 3. Yield probability function for a paddock in the Wimmera for conditions as set at sowing. The arrow indicates the actual yield achieved in 2003.

Based on conditions at sowing in 2003, the median (50% probability) was for a yield of at least of 4.5 t/ha; in 25% of years an outcome of 6 t/ha should be achievable. These yields should not be read as achievable in any season! They only apply to conditions at sowing in 2003. As the season progresses actual rainfall replaces historical rainfall and the model becomes more accurate.

In this case, the season finished slightly above average growing season rainfall (319mm in 2003, long-term average GSR 300mm) and the actual modelled yield at sowing was at 50% probability.

Risk Analysis

The model is very useful for undertaking risk analysis of particular scenarios:

(i) Inputs. The model enables you to apply Nitrogen fertiliser at different rates and application time. It then calculates the yield response and $ return.

(ii) Climate risk. By selecting the historical years with rainfall in a particular SOI phase you can observe what happened in those years with yield estimates. For example in July 2002 we estimated that yields in the southern Mallee in an El Nino year would likely be in the order of 0.2 to 0.4t/ha (these were not actually achieved with most paddocks not harvestable).

Where to with the Yield Prophet in 2004

In 2004, the BCG will be working closely with APSRU to develop new management tools and commercialise the output of APSIM. In the first stage we are working on developing input screens which make data entry easier and faster and then we will work on automating outputs. New output tools under development are:

- CropRisk – APSIM is being validated for crops other than wheat. When these have been validated, a CropRisk output will outline the risk associated with planting a particular crop based on soil water values at sowing, input requirements, and sowing date effect on yield, variety choice etc.
- Rain Risk – the APSIM outputs are probability based (over a 100 year data set of site rainfall) the climate risk factors based on various climate predictions will be presented (eg. likely outcome for a particular SOI phase)
- N Risk – APSIM models the daily N requirements for a crop which when linked to a yield potential can be used to determine the N fertiliser input requirements
- Profit Risk – APSIM yield estimates will be linked to $ inputs and price projections to calculate likely gross margins

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