Is there a better way to present simulation data and probabilities?

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Abstract

Increasingly, simulated outputs from models such as APSIM are being used to facilitate and assist farmers in making decisions. Generally the output is summarised as a graph or series of graphs that present distributions of yields for various amounts of starting water or levels of nitrogen, and the position of a specific value on the curve or in the box relates to the probability of the yield being achieved. We have extended this approach and created a different form of presentation that considers the probability of achieving two variables. The rainbow chart allows the user to look at what probability a crop has of achieving a specific yield when sown on a specific soil moisture profile or how much soil water is required to have a high probability of achieving a specific yield. We have used the rainbow chart in workshops with over 40 consultants who believe the simple colour-related probabilities will help when discussing yield probabilities at sowing with their clients.

Key Words

Risk, simulation modelling, stored soil moisture, planting decisions

Introduction

The southern Queensland cropping region, which is dominated by summer rainfall, combines adequate winter rainfall and heavy clay Vertosols to produce both summer and winter crops. The key to winter crop production is the capture and storage of water during the summer. The plant-available water capacity (PAWC) of soils in the region varies between 100 and 300 mm. This stored water can carry crops between the unpredictable winter rainfall events. The more soil water stored during the summer, the greater the probability of a good crop yield. Planting on inadequate soil water increases the risk of poor yields, as the crops must rely on sporadic unpredictable rainfall events.

For over a decade the value of stored soil water and methods of soil water measurement have been advocated to farmers in southern Queensland (Dalgliesh et al. 2009; Carberry et al. 2009). As a result of this work, farmers and advisors are acutely aware of the importance of fallow rainfall and storage for grain production within the region (Darbas and Lawrence 2010; Freebairn et al. 2006). However, a recent series of drought years and crop failures in the region has provoked concern that the message on the importance of stored soil water has been lost. A study of consultants and farmers within the region concluded that the message had not been lost but there was a need for greater use of probabilistic information in planting decisions (Darbas and Lawrence 2010).

The use of simulation models to produce probabilistic outcomes is becoming common in Australian agriculture. The use of Yield Prophet (www.yieldprophet.com.au; Hunt et al. 2006; Hochman et al. 2009) has built on the success of FARMSCAPE (McCown 2009) to deliver probabilistic outcomes specific to individual paddocks for many farmers. However, despite the success of these two programs only 3 consultants surveyed by Darbas and Lawrence (2010) regularly used this type of information. Is this because the information is difficult to obtain? Or is it that farmers, consultants and researchers have conflicting views on the interpretation and value of this information?

This issue was discussed within the southern Queensland farming systems project by team members and its steering committee of local farmers and consultants. The conclusion was to try to develop a field-based generic method of converting soil water content to crop yield and estimating the probability of achieving this yield. Our aim was to take the power of simulation models and capture their output in a series of simple figures that could be used in the field by farmers and consultants when making planting decisions.

Probabilistic information has generally been presented in two ways, box and whisker plots (Tukey 1990; Figure 1) or cumulative distributions and their inverse, probability of exceedence plots (Figure 2).

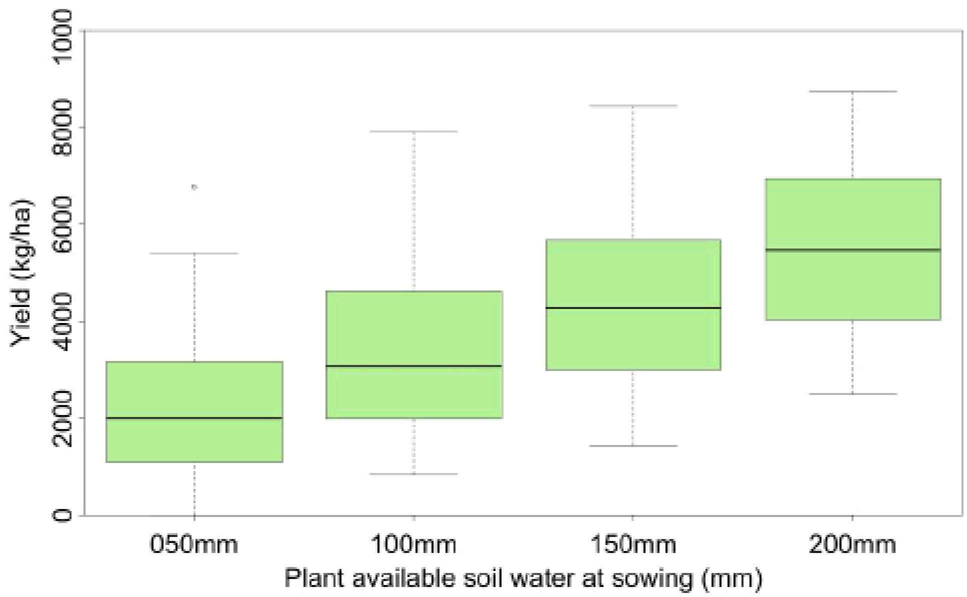

Figure 1. A box and whiskers plot showing the simulated outcomes for a September sorghum planting at Dalby for four different sowing water conditions.

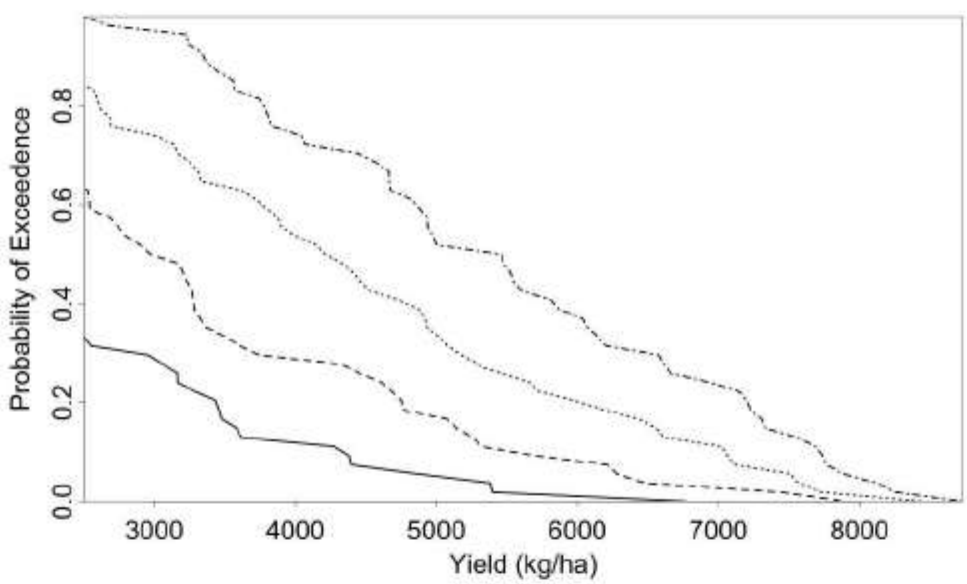

Figure 2. A probability of exceedence plot showing the simulated outcomes for a September sorghum planting at Dalby for four different sowing water conditions. Solid line 50mm PAW at sowing, dashed line 100mm PAW at sowing, dotted line 150mm PAW at sowing and dot dash dot line 200mm PAW at sowing.

We questioned if these methods were the best way to present data for the purpose of making decisions. When making planting decisions, is additional data more informative or are summaries of the key elements more beneficial? A disparity was observed between the ways soil water and soil nitrogen was discussed with farmers. When looking at soil water, exceedence or box plots (Figures 1 and 2) are often used. Box plots focus on the relationship between soil water and yield and the probability is estimated from the median and the size of the box. Exceedence plots concentrate on the yield and probability of achieving it with the different starting conditions being represented by lines; the more starting conditions the more cluttered is the figure. Both methods can adequately represent the probability of achieving a specific yield given a specific starting content of soil water. In contrast, when nitrogen is discussed farmers are asked what yield do you hope to achieve and then the calculation is done to estimate how much nitrogen to apply. The yield estimate for nitrogen is solely based on the farmers' experience and hopes. The probability of achieving these estimated yields is not often considered. To improve the rigour behind yield estimates for nitrogen application while highlighting the consequences of planting on different soil moistures, we devised a 3 dimensional figure (Figure 3) that relates starting soil water to yield and gives the likely probabilities of achieving it, in what we believe to be a more intuitive presentation method.

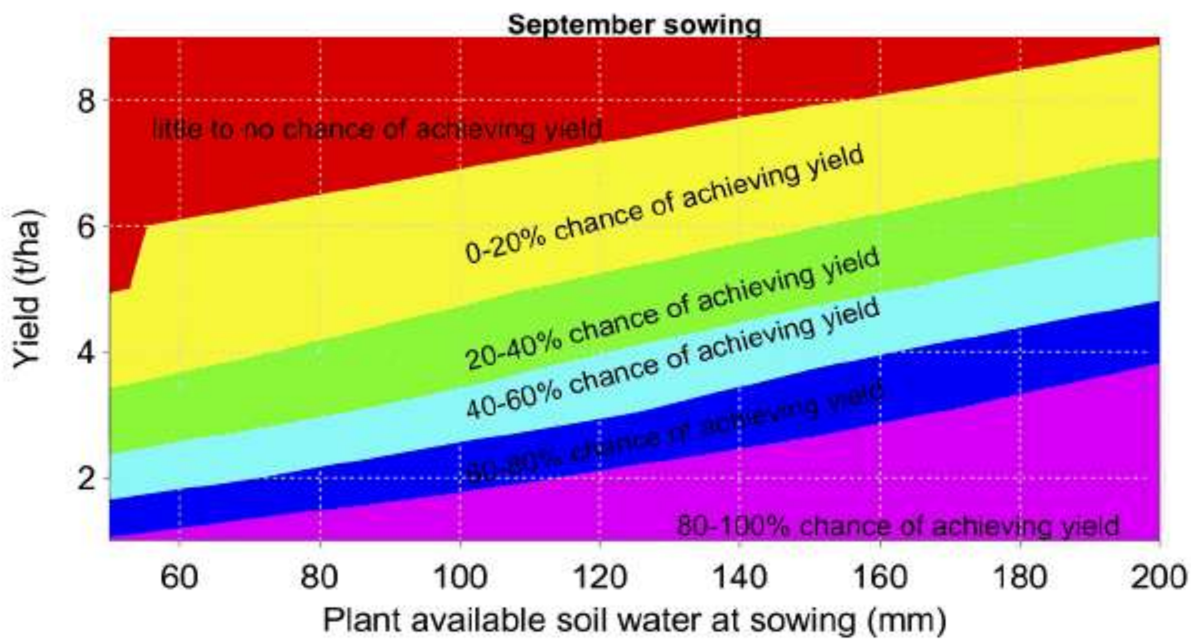

Figure 3. A rainbow chart for a September sorghum sowing at Dalby Qld.

This Rainbow chart was included in a workshop designed for agronomic consultants to explore the importance of soil water at planting. During the workshop probabilistic information was presented in three formats (box plots, exceedence plots and the rainbow chart). The consultants used the charts and estimates of soil water to identify sowing options for a specific paddock. At the end of the process they were asked what tools they felt would be most useful to use when discussing planting options with their clients.

Methods

The initial rainbow charts were developed in the statistical software package R (R Development core team 2007). The chart was created by combining multiple APSIM yield outputs. Specific location simulations were built for a particular sowing date. The simulations were initiated at different sowing conditions from 50mm of available soil water to 250 mm in 50 mm graduations. Each simulation was run for 108 years (1900-2008) making use of location specific rainfall records (Jeffery et al. 2001). The outputs from APSIM were read into R and for each starting condition a cumulative distribution was calculated. A spline was fitted to the distribution and specific yield values and corresponding probabilities recorded in a matrix. This process was repeated for each of the soil starting water conditions, resulting in a probability matrix representing 9 yields by 5 different starting soil water conditions. This matrix was then plotted using the filled contour-plotting feature to produce the rainbow plot. A simpler procedure was recently developed in Excel where stacked contour plots of frequency distributions could produce the same rainbow effect.

The rainbow charts were used as part of a workshop focussing on soil water and planting decisions. Thirteen workshops were conducted across southern Queensland with approximately 120 farmers and consultants attending. The attendees were responsible for the management of approximately 5% of the farming land in southern Queensland (500,000 ha). Both quantitative and unstructured interviews were conducted at the end of the workshop to identify what tools people found useful and if they would use the tools with their clients, when making planting decisions.

Results

The rainbow chart was considered a useful and simple way to present probabilities with 98 percent of the participants agreeing it was a valuable tool to help estimate yields and assessing the chance of achieving these specific yields. Eighty-three percent of participants felt that they would use the graphs when planning for their next crop. When specifically asked about the workshop as a whole and what was their biggest learning feature, participants responded with a positive assessment of the rainbow chart, such as this remark from a Roma consultant "*The rainbow graph was great. It fills in a gap of working out our expected performance from different soil moistures at planting in our area*". When asked what they would do differently after the workshop the responses included "*work out my own PAW on our two main soil types and use the rainbow graphs and my own gross margins to make planting decisions*" and "*use the How-wet tool* (a model to convert rainfall into stored soil water) *and the rainbow graphs before planting*". Requests have been made by consultants to have rainbow charts for major crops in different regions combined in a field book or placed on a web site for easy access by consultants and growers.

Conclusion

The rainbow charts proved to be a simple way of taking complex probability information and converting it into a simple figure that famers and consultants can easily refer to when making planting decisions. The generic nature of the simulations (regional soil type and climate data) used to create the chart is one limitation. However, tools such as Yield Prophet are available to provide more specific targeted information for individual paddocks. The level of soil water precision required for planting decisions depends on the individual, the size of the investment and the individual's acceptance of risk. The use of a generic rainbow chart is a sound first step towards this decision and a good way to encourage people to stop and think about the consequences of a planting decision while the tractor is still in the shed.

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