Managing risks associated with climate variability on soils with subsoil constraints in the Southern Mallee

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Summary
The APSIM wheat model was adapted and tested for southern Mallee conditions and demonstrated to be a powerful tool to evaluate risk exposure of farmers to climate variability.

The model was tested and found to be reasonably accurate in estimating soil water based on rainfall events and also in relation to being able to simulate historical wheat yields.

From the analysis of historical climate, using data in years after an El Nino event, the model predicts that the chance of a good yields during 2003 is about 50% (this is higher than the 33% that would be expected from the long term average), while the chance for a poor season is about a 20% (this is lower than the 33% that would be expected from the long term average).

Our results also highlight the importance of taking into account soil water at sowing to analyse climate risk exposure in the Birchip area.

Background

Climate variability is inherent to dry-land farming and major droughts have a devastating impact on farm economic performance and social viability. Even though we live in a highly variable climatic zone - can we improve the management of climate risk? Are there tools available which we can use to improve our crop management skills so that we can take greater advantage of the good years whilst minimising our losses in the poor years?

DPI at Horsham (VIDA) has been working with the BCG to evaluate a cropping model named the Agricultural Production Systems sIMulator (APSIM). This cropping model may provide us with the tools to:

- identify the risk associated with crop selection based on stored soil water at sowing
- target inputs such as N fertiliser depending on how the season is progressing
- modify our cropping program according to climate indicators such as the SOI

BCG members are already familiar with this model through the 2002 fax out service named the 'Yield Prophet' in which we regularly updated yield predictions using ASPIM at five sites in the southern Mallee and Wimmera (done in co-operation with APSRU-CSIRO).

In this paper we outline how we have evaluated the model for our conditions, specifically we:

- reviewed the accuracy of the soil water model (how well can the model estimate soil water content during the season based on rainfall)
- compared the predicted model yield against actual farm yields over a 20 year period

We also checked the current yield forecast at Birchip for the 2003 season.

Birchip soils

A good description of the behaviour of a soil, in how it provides a crop with moisture and nutrients, is an essential component of the APSIM model. The model was characterised for our soils by using data collected by James Nuttall for his Ph.D. James found that many paddocks in the region had high levels of salinity, sodicity and boron in the subsoil which had a major negative influence on crop production.

James surveyed 150 sites around Birchip. He found that the concentration and levels of soil salinity, sodicity and boron increased with soil depth, while the values of soil water at wilting point (LL15) varied much less. In more than 50% of the sites, at depths deeper than 0.6m, the values of salinity were higher than the critical value of 0.8 dS m^{-1}; in about 50% of the sites the values of sodicity and boron were above the critical values of 19% and 24 mg kg^{-1} respectively (Rodriguez and Nuttall, 2003). Critical values referred here are values of salinity, sodicity or boron above which the yield of the Frame wheat crop starts to be affected (Nuttall et al., 2003). Functions that take into account these subsoil restraints to moisture and nutrient uptake were built into the model by DPI, Horsham.

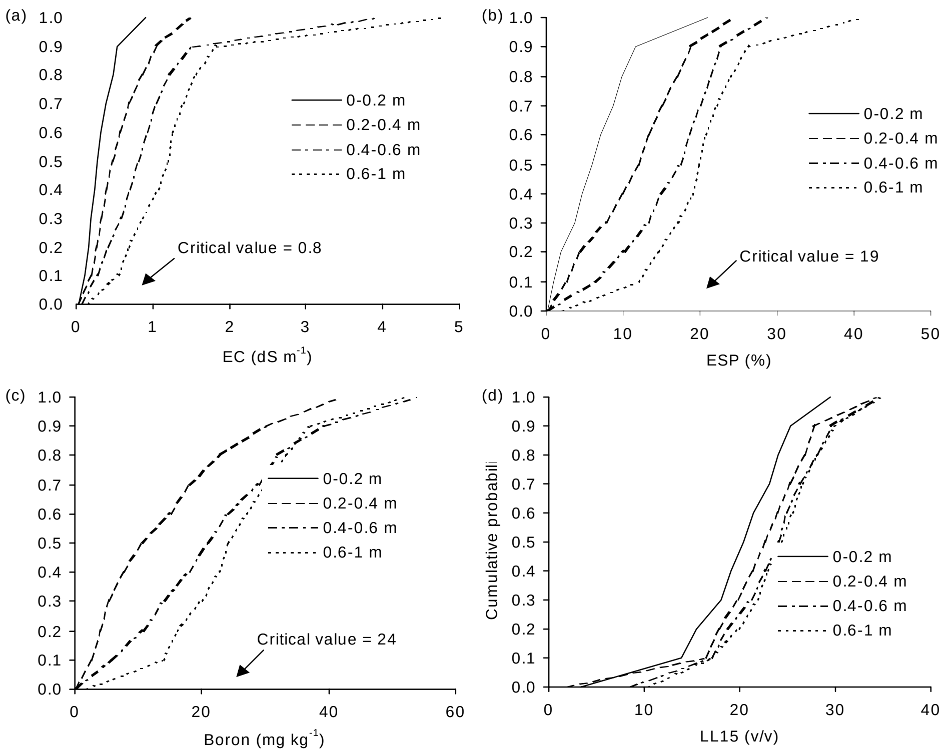

Figure 1. Cumulative probability distribution of (a) soil salinity as EC (dS m^{-1}), (b) sodicity as ESP, (c) soil boron and (d) volumetric soil water content at –15bars (LL15, wilting point), at 0-0.2, 0.2-0.4, 0.4-0.6 and 0.6-1m depths for 150 sites around Birchip. Vertical lines in figs. a, b and c indicate critical threshold values for Frame wheat grain yield after Nuttall et al., (2003).

Model testing and evaluation

The model was tested for (i) soil water balance and (ii) accuracy in its ability to estimate a wheat yield for two farms in the southern Mallee (located at Birchip and Brim).

<u>1. Soil water Balance</u>

The capacity of APSIM to simulate the soil water balance on soils from Birchip and Brim was tested by running the model during the seasons 1993/94. Soil water readings were available from regular measurements using a neutron probe, using data collected in a FM500 study. The Model run started at the sowing of a wheat crop in 1993 and ended after the fallow in April the next year (1994). Figure 2 shows a comparison of the results of the simulations with actual measurements of soil water taken at monthly intervals at different soil depths.

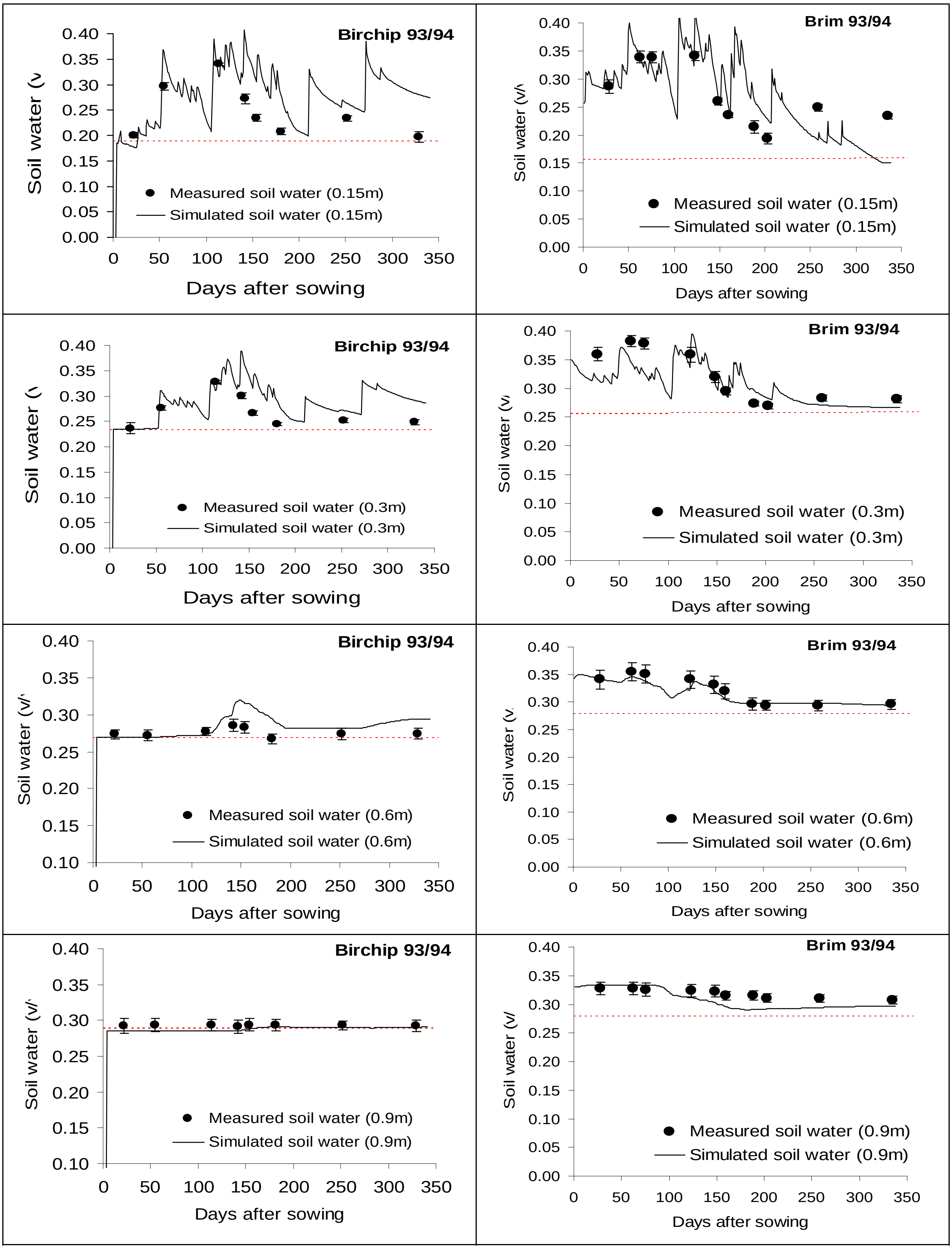

Figure 2. Measured (symbols) and simulated (continuous line) volumetric soil water content in different soil layers at Birchip and Brim. The horizontal dotted lines indicate the value of CLL (Crop Lower Limit or Wilting Point) for each soil layer, and vertical bars are measurements of the variation among the replicated measurements (standard errors).

At both sites the model simulated the measured soil water contents of the subsoil relatively well. This means we should be able to use the model for estimating soil water content across the region with some confidence. This will be particularly helpful at sowing when decisions on crop type selection and inputs have to be made.

2. Validation of model yield predictions

We tested the accuracy of the APSIM wheat model to predict crop yields over a twenty year period (1983 to 2002). Average yearly farm wheat yields for the same two farms mentioned above, were compared against the model predictions. A comprehensive data set including daily climate information and soil physical and chemical properties for the two farms was used to drive the model.

Other data needed to run the models included soil bulk densities, % organic carbon, soil water at sowing, sowing date, wheat cultivar and N fertilisation. For the simulations we have assumed that weeds, pests and diseases did not affect the crops. We estimated soil water content on the 1st of January of each cropping year based on rainfall during the preceding October to December period. The cultivar grown for the model simulations was Janz (to represent varieties with a medium length season). In the model, crops were sown in the third week of May and were supplied with sufficient N fertiliser to grow a better than average crop. Rooting depth of wheat at the two sites was determined to be 60cm and 70cm for the Birchip and Brim farm respectively.

Considering the assumptions made in the model for soil water content at sowing, wheat variety grown, sowing date and N fertiliser inputs average wheat yields from 1983 to 2002 were simulated well by APSIM at both the Birchip and Brim farms (Figure 3). In Figure 3 the closer the agreement between observed and simulated results, the closer the points will be to the 1:1 line. The model was able to explain 70% of the observed variability in grain yields across 16 years (wheat was not grown in every year, plus we did not include a frost year in the simulations).

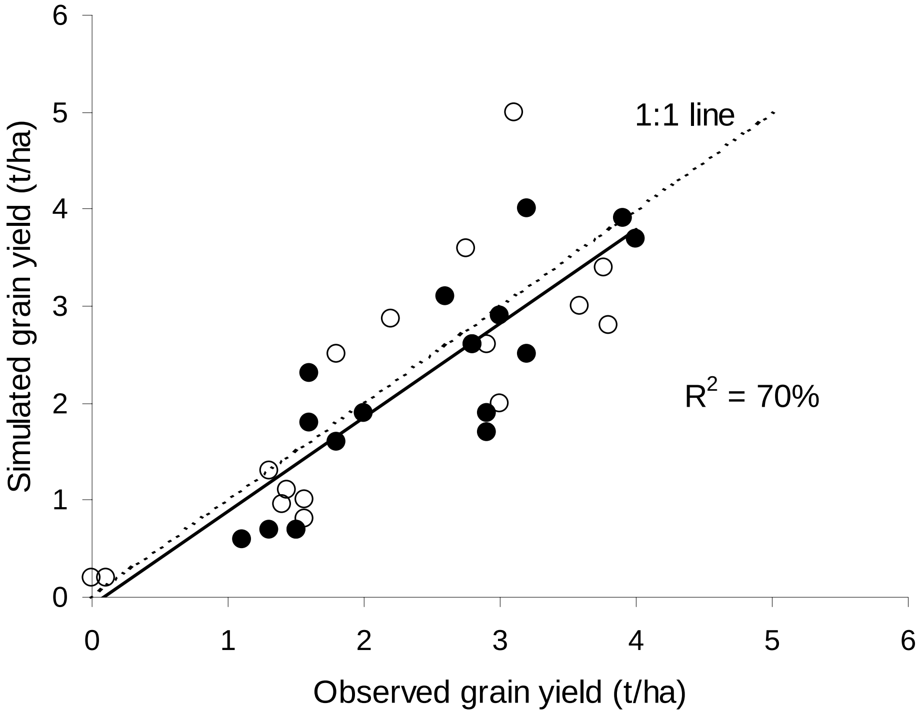

Figure 3. Observed and simulated grain yields for the Birchip (closed circles) and Brim (open circles) farms from 1983 to 2002.

Discussion
These results indicate that after the adjustment of the model for local conditions, APSIM can be used to forecast wheat yields in the southern Mallee with a good degree of certainty and reasonable error. The soil water balance is reasonably accurate and the ability of the model to account for different seasonal conditions and estimate a relatively accurate wheat yield is good news.

How can we use this information to simulate what might happen this year?

We simulated 103 years of climate records from Birchip to evaluate the long-term prediction of grain yields assuming different levels of soil water content on January 1st. For the simulations we used plant available soil water contents of 0 mm (dry soil at Wilting Point) and 32 mm (only slightly moist soil) on January 1st, similar to conditions we are experiencing this year.

To explore the impact of climate variability on grain yield we also simulated wheat yields for:
(i) all years from 1900 to 2002, i.e. 103 years,
(ii) all El Niño years from 1900
(iii) all the years following an El Niño year from 1900

The results are presented as pie charts in Figure 4.

(i) Simulations from 1900 to 2002
In this scenario we simulated wheat yields by running the model for all years - APSIM uses the rainfall for each year since 1900 and simulated a yield (ie. we get 103 simulated yields). Using this scenario we did not take into account that we were coming out of El Nino drought year. We ran the model using the two levels of soil water on the first of January of each year as specified above.

We present the information as a series of pie charts divided into terciles. For example take the first pie chart - in this case we started the model with zero plant available soil moisture on the 1st of January. The first tercile indicates the model is predicting that in 33% of years, the grain yields was less than 0.7 t/ha, in another 33% of years the yield was between 0.7 and 1.6 t/ha, whilst in the third 33% of years the grain yield was above 1.6 t/ha.

The second pie chart indicates that when we started the season with some soil moisture (32mm of plant available moisture) in 33% of years the yield was less than 1.1 t/ha, in the next 33% of years the yield was between 1.1 and 2.0 t/ha whilst in the third 33% of years the yields were above 2.0 t/ha.

Comparing the yields achieved in each tercile for soils starting with zero moisture and some soil moisture it is easy to see how critical conserving soil moisture is over the summer period.

(ii) El Nino year yield simulations
In the second row of pie charts the simulations only used those 24 out of 103 years when an El Niño event occurred. These charts indicate that in an El Niño year, farmers in the southern Mallee have about a 60% chance of having a “poor season” with grain yields ranging from 0.7 to 1.1 t/ha, depending on the amount of soil water left in our soil profiles from the previous year.

In El Nino years there is 26% chance of having an “average season” i.e. grain yields between 0.7 t/ha to 2.0 t/ha depending on the amount of soil water left in our soil profiles by January 1st from the previous season. The chance of a “good season” during an El Niño year is very small (about 14%).

(iii) Years following an El Nino event simulations
In the third row of pie charts we simulated what would happen during those years following an El Niño year, we find that the chance of having a "good season" increased up to about 50% (this is higher than the 33% that would be expected from the long term average). In contrast, the chance of having a "poor season" is reduced to 20% (this value is lower than the 33% that would be expected from the long term average).

These results were produced from the analysis of historical climate records and should not be considered as a forecast. This is mainly because the El Nino years were assigned after the event, i.e. after we knew it was an El Niño year. At the time of sowing we will not know if next season will turn out to be an El Nino year or not for sure. Furthermore every El Niño event is unique and different from previous events. Nevertheless the results are very interesting and it will be of great value to see how accurate this kind of information turns out to be. Furthermore, the discussion does not apply to the whole of the Mallee or Wimmera but to those areas with similar subsoil constraints.

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References

Nuttall, J.G., Armstrong, R.D., and Connor, D.J. 2002 (submitted).

Daniel Rodriguez, and James Nuttall Adaptation of the APSIM-Wheat module to simulate the growth and production of wheat on hostile soils. XI Australian Agronomy Conference, Geelong February 2003.

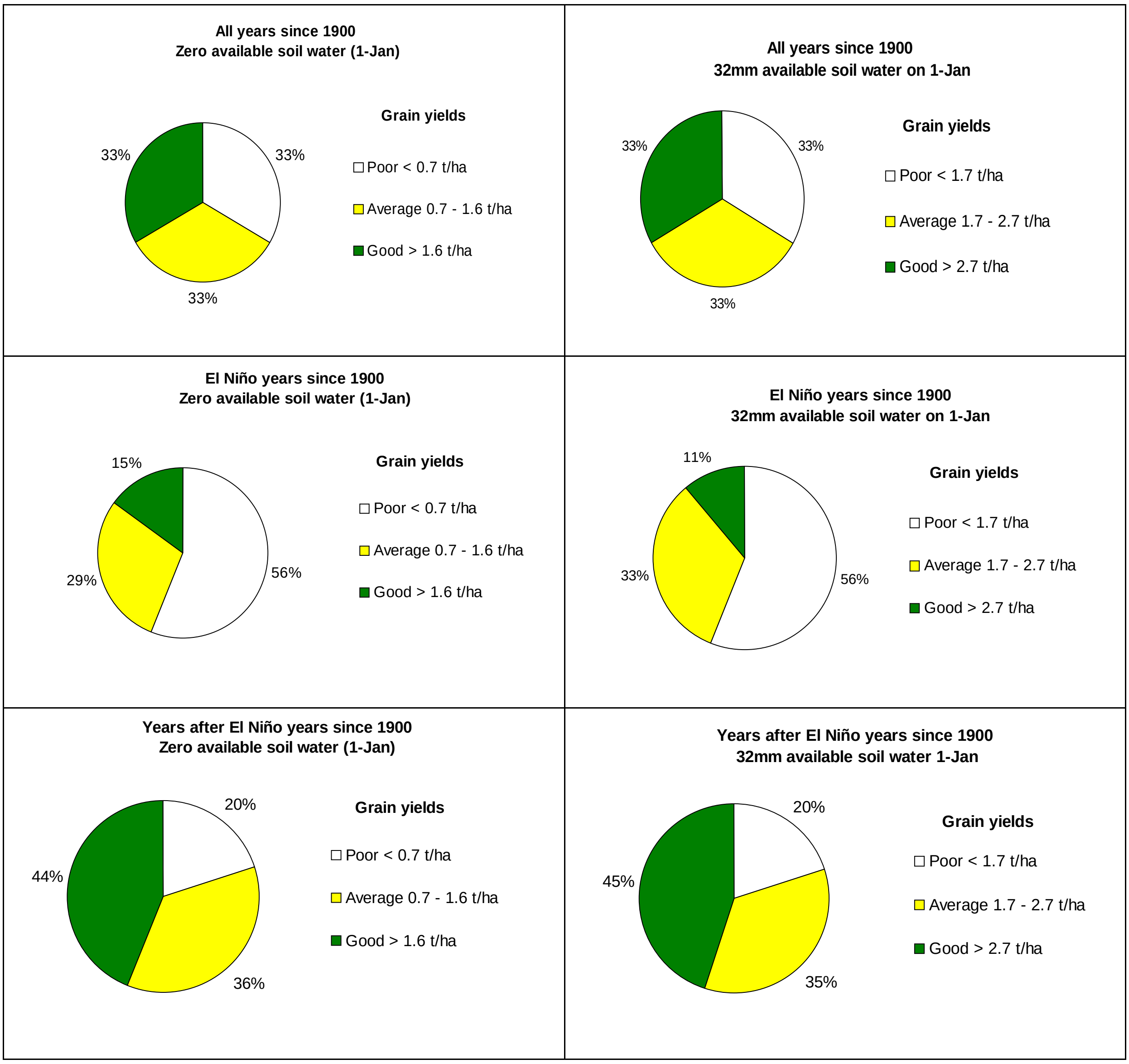

Figure 4. Pie charts indicating chances of a poor, average and good season in Birchip for all the years since 1900 (first row of charts), all El Niño years since 1900 (second row of charts) and those years following an El Niño year (third row of charts). The left column of charts are simulations assuming zero mm of available soil water on 1-January and the second column of charts are simulations assuming 32mm of available soil water on January 1st.