Seasonal climate forecasting has economic value for farmers in south eastern Australia

Bettina Lythgoe[1], **Daniel Rodriguez[1]**, De Li Liu[2], John Brennan[2], Brendan Scott[2], Gordon Murray[2] and Peter Hayman[3]

[1]DPI - Horsham, PB 260 Horsham, VIC 3401, Australia, [2]NSW-DPI Wagga Wagga NSW, Australia; [3]SARDI Waite Institute Adelaide SA, Australia. **E-mail: daniel.rodriguez@dpi.vic.gov.au**

Abstract

We used the Agricultural Production Systems Simulator (APSIM) to quantify the economic value of the five SOI phases seasonal forecasting system. We used APSIM to estimate the profits and risks of cropping wheat under a "fixed" N management strategy *i.e.* ignoring seasonal forecasts, and a "flexible" N management strategy *i.e.* deriving the rate of N as a function of the June-July phase of the five SOI phases seasonal forecasting system. We showed that higher profits can be achieved without increasing the level of risk of economic loss by adopting a seasonal forecasting system to determine the rates of N to be applied in split N applications between pre-drill and tillering. This was particularly valid for the less marginal environments, and better initial conditions *i.e.* initial soil moisture. Improved profit–to-risk ratios could be achieved by applying a more flexible N management and adopting a seasonal forecasting system particularly at locations having more than 380mm of annual rainfall and on soils having potential plant available water higher than 115mm.

Media summary

Farmers in south eastern Australia can increase profit without increasing the risk of making a loss by adopting a seasonal climate forecast to tune crop nitrogen nutrition

Key words

Seasonal forecasting, nitrogen, modelling, APSIM

Introduction

In south eastern Australia crop yield depends heavily on the amount and distribution of rainfall during the growing season. High inter-seasonal climate variability and lack of tools to reliably incorporate seasonal forecasts into on-farm management are driving farmers to adopt fix crop rotations *eg.* cereal-fallow, and risk aversive management strategies based in low use of inputs such as nitrogen (N) fertilisers. In consequence, current-farming systems can still expose farmers to heavy losses during poor seasons, and more importantly, restrict their capacity to maximise returns during good seasons, when the risk of crop failure is low and returns could be maximised, for example, by applying higher levels of N. The objectives of this work were to, (i) quantify the economic value of the five SOI phases system (Stone and Auliciems, 1992) to design "flexible" N management strategies at mid tillering of wheat in south eastern Australia, (ii) provide guidelines to improve profits without increasing the level of risk exposure to climate uncertainty, and (iii) test whether by improving the N nutrition and crop production during wet seasons, it is possible to enhance water use and reduce deep drainage and prevent its environmental consequences.

Materials and Methods

The Agricultural Production Systems Simulator (APSIM) (McCown *et al.*, 1996) was used to simulate long-term yields, which were used to calculate farmers' income. APSIM allows the simulation of diverse crops and cropping systems targeting issues such as nitrogen management and climate variability (Hammer *et al.*, 1996), land degradation (Asseng *et al.*, 1998), crop rotations (Robertson *et al.*, 2000), and management alternatives (Carberry *et al.*, 2002). APSIM-Wheat (APSIM version 2.1 patch 2) has been tested against field studies in different regions of Australia and locally for this study (Rodriguez and Nuttall, 2003). To compare a "fixed" versus a "flexible" N management strategy we followed a similar approach as in Hammer *et al.*, (1996). Here we also evaluated the skill of the five SOI phase forecasting system by applying cross validation techniques (Robinson and Butler, 2002). We calculated the profits of "fixed" pre-drill and top dressing strategies using either the same amount of N each year or, a "flexible" top-dressing N management strategy deciding the rate of N each year based on the June-July SOI. This simulation study was conducted at four locations in Victoria (Longerenong, Birchip, Brim, Mildura) and four locations in New South Wales (Albury, Griffith, Temora and Wagga), which are representative of the south-eastern wheat growing area in Australia. Grain yields were simulated with APSIM for six pre-drill and top-dressed N rates. Top-dressed applications were made after the 1st of August if the crop had 6 or more leaves at the Victorian locations, and at Zadoks = 31 in the New South Wales locations, following common practice in each of the regions. We also simulated different starting conditions *i.e.* combinations of different levels of soil water, and soil nitrogen on the 1st of January reseated each year. Long-term climate data (1900-2002) was downloaded from the SILO website for each of the studied locations. The capacity of the five SOI phase forecasting system in June-July to discriminate median values of spring rainfall (September-November) was evaluated using a Kruskal-Wallis one-way ANOVA. Profit was calculated as the difference between the income and variable costs (180-220$/ha) plus the cost of N fertilisation. Income was calculated by multiplying the simulated yield by the price of grain, which varied depending on the simulated grain protein content. The risk associated with each N treatment, location, and starting condition was defined as the percentage of years in which a negative profit was recorded. At each location, for each starting condition, and for each of the six top-dressing N treatments, simulated grain yields and protein levels were grouped according to years having the same SOI phase in June-July. Then, for each location and for each starting condition the average profit was calculated for all possible combinations of top-dressing N fertilisation by SOI phase, in total 7776 combinations were formed. For each of those combinations their associated risk was derived. Deep drainage was estimated using APSIM for 103 years and each of the different management strategies and locations.

Results and Discussion

The capacity of the five SOI phases system to discriminate patterns of spring rainfall was location and SOI phase dependent (Table 1). With the exception of Mildura, a consistently negative SOI phase in June-July significantly shifted median values of the probability distribution of spring-rainfall to the left, *i.e.* lower spring rainfall than the long term median. With exception of Temora, a consistently positive SOI phase in June-July significantly shifted median values of the probability distribution of spring-rainfall to the right *i.e.* higher spring rainfall than the long term median. During rapidly rising and consistently near zero SOI phases in June-July, spring rainfall tended to be higher, however significant shifts of median values were only observed at two of the eight locations: Albury and Wagga, and Mildura and Wagga, respectively. Under rapidly falling SOI in June-July spring rainfall tended to decrease but differences were not statistically significant.

Table 1. Kruskal-Wallis test results (p value) and sample size for spring rainfall at eight locations in south eastern Australia

	SOI phase in June-July				
	Consistently negative	Consistently positive	Rapidly falling	Rapidly rising	Consistently near zero
Birchip	**0.022**	**0.001**	0.296	0.336	0.142
Brim	**0.043**	**0.024**	0.179	0.190	0.380

Longerenong	**0.023**	**0.018**	0.603	0.057	0.075
Mildura	0.116	**0.038**	0.933	0.096	**0.037**
Albury	**0.001**	**0.007**	0.850	**0.041**	0.094
Griffith	**0.017**	**0.041**	0.912	0.051	0.093
Temora	**0.025**	0.096	0.629	0.114	0.144
Wagga	**0.002**	**0.028**	0.462	**0.022**	**0.035**
Sample size	17	27	9	24	37

Cross validation for above and below median values of seasonal rainfall and simulated wheat profits indicated an important spatial and temporal heterogeneity among phases. In general high skill levels (70-80% consistent) were detected for the June-July period.

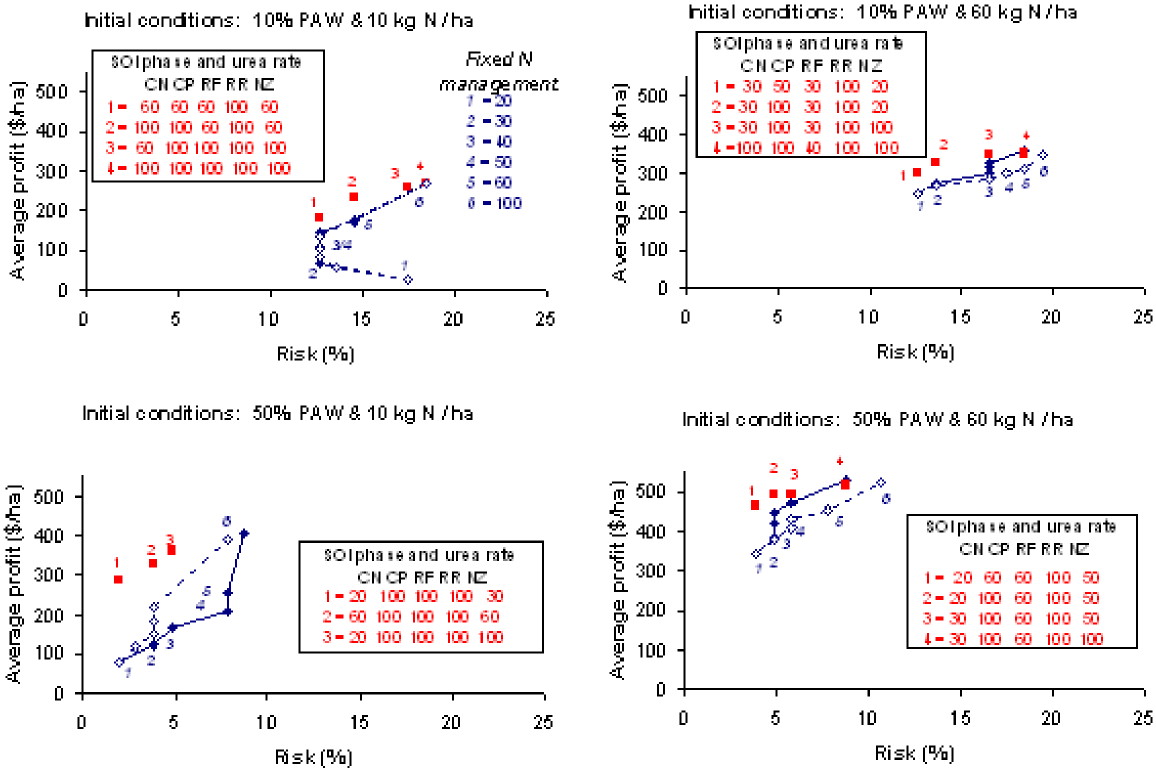

Figure 1. Average profit versus the risk of making a loss for a range of urea rates applied as fixed amounts each year at sowing (full line and filled diamonds), applied each year at top dressing (broken line and empty diamonds), and top-dressed adjusting the rate each year depending on the June-July SOI phase (squares). The numbers in italic associated with the continuous and broken lines indicate the total amount of urea applied at sowing or applied at topdressing (sowing +

topdressing) irrespective of the SOI. The numbers in the framed legend associated with each square indicate the total amount of urea (sowing + topdressing) applied when the June-July SOI was consistently negative (CN), consistently positive (CP), rapidly falling (RF), rapidly rising (RR), and near zero (NZ), respectively. The different figures represent different initial conditions reset every year on the 1st of January in the simulations. This is 10 or 50% of plant available water (PAW) and 10 or 60 kg N / ha in the soil profile.

For most locations and starting conditions the average profit for the “fixed”, pre-drill and top-dressed urea application strategies, increased with the amount of urea applied (Figure 1 shows Brim as an example). This increase in average profit was also associated with an increase in the chance of making a loss. However, using a “flexible” N management strategy, *i.e.* using the five SOI phase system to determine the rates of urea to be applied around tillering, the average profit of wheat cropping was generally increased considerably without increasing the risk of making a loss. Exceptions were observed particularly in the driest locations. At Birchip, Mildura and Griffith, a “flexible” strategy did not produce higher profits when initial plant available water (PAW) on the 1st of January was low, *i.e.* 10% of maximum PAW, and at Mildura, when the starting conditions where 50% of maximum PAW and 10 kg N/ha, and Griffith, when the model was initialised at 30% of maximum PAW and 60 kg N/ha.

At Brim, with a 10% of maximum PAW and 60 kg N/ha on the 1st of January, at the same level of risk assumed with a “fixed” management, *i.e.* 13.6% risk, the flexible strategy produced an additional $52.5/ha and $59.5/ha profit, compared to the “fixed” pre-drill and top-dressed strategies, respectively. This was achieved by applying a total of 30 kg urea/ha (20 kg pre-drill and 10 kg top-dressed), 50 kg urea/ha (20 kg pre-drill and 30 kg top-dressed), 30 kg urea/ha (20 kg pre-drill and 10 kg top-dressed), 100 kg urea/ha (20 kg pre-drill and 80 kg top-dressed), and 20 kg urea/ha (20 kg pre-drill and 0 kg top-dressed), at mid tillering in years when the June-July SOI was consistently negative, consistently positive, rapidly falling, rapidly rising and consistently near zero, respectively. The benefit of a more “flexible” N management was not observed in every season. In general during the driest seasons the “flexible” and “fixed” systems produced similar profit to risk ratios, while during the wet seasons the “flexible” strategy proved highly effective at even doubling profits without increasing the levels of risk of making a loss. In Brim, in about 60 to 70% of the years the “flexible” approach had greater or similar yields than the “fixed” strategy. While in the rest of the years the “fixed” strategy had greater yields than the “flexible” strategy. Similarly, in Temora the profit of the “flexible” compared to the “fixed” strategy was greater or similar in 70 to 90% of the years. Differences in simulated drainage between the “flexible” and “fixed” strategies were small.

Conclusions

We showed that higher profits can be achieved without increasing the level of risk of economic loss by adopting a seasonal forecasting system to determine the rates of N to be applied in split N applications between pre-drill and tillering. This was particularly valid for the less marginal environments, and better initial conditions *i.e.* soil moisture.

References

Asseng S, Fillery IRP, Anderson GC, Dolling PJ, Duning FX, Keating BA (1998). Use of APSIM wheat model to predict yield, drainage, and NO_3^- leaching for a deep sand. Aust. J. Agric. Res., 49, 363-377.

Carberry PS, Meinke H, Poulton PL, Hargreaves JNG, Snell AJ, Sudmeyer RA (2002) Modelling crop growth and yield under the environmental changes induced by windbreaks. 2. Simulation of potential benefits at selected sites in Australia. Aust. J. Exp. Agric. 42, 887-900.

Hammer GL, Holzworth DP, Stone R (1996) The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. Aust. J. Agric. Res. 47, 717-731.

McCown RL, Hammer GL, Hargreaves JNG, Holzworth DP, Freebairn DM (1996) APSIM: A novel software system for model development, model testing, and simulation in agricultural systems research. Agricultural Systems 50, 255-271.

Robertson MJ, Carberry PS, Lucy M (2000) Evaluation of a new cropping option using a participatory approach with on-farm monitoring and simulation: a case study of spring-sown mungbeans. Aust. J. Agric. Res. 51, 1-12.

Robinson JB and Butler D (2002) An alternative method for assessing the value of the Southern Oscillation Index (SOI), including case studies of its value for crop management in the northern grain belt of Australia. Aust. J. Agric. Res. 53, 423-428.

Rodriguez D and Nuttall J (2003) Adaptation of the APSIM-Wheat module to simulate the growth and production of wheat on hostile soils. Proceedings of the 11th Australian Agronomy Conference, Geelong, Victoria.

Stone R and Auliciems A (1992) SOI phase relationships with rainfall in eastern Australia. Int. J. Climatol. 12, 625-636.