THE USE OF SEASONAL CLIMATE FORECASTS IN CROPPING SYSTEMS MANAGEMENT

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Abstract

Can the current long-range climate forecasting capability be used effectively in cropping systems management, *ie*. decisions that go beyond single crop issues? The following case study addresses this question and compares a standard, fixed dryland cropping rotation of long fallowing from sorghum to cotton with two alternative fixed rotations and with a flexible rotation influenced by an SOI forecast. The decision point is October of the second year where the manager can choose to proceed with the standard summer fallow, plant sorghum or plant cotton with the intention of definitely planting cotton in the following summer. The various scenarios were assessed using the cropping systems model APSIM. The simulation analysis showed that by changing between rotations based on the SOI phase in the August-September period preceding the decision point, average gross margins (GM) per year increased by 14%. At the same time, simulated soil loss from erosion was reduced by 24%. The SOI strategy did however increase the risk of an economic loss from 5% of years for the standard fallow-cotton rotation to 9%, but this risk was considerably less than for the two alternative fixed rotations. There is still considerable scope to increase our long-range forecasting capability as demonstrated by the possible gains achievable if we had 'perfect knowledge' of the season ahead.

Key words: Cropping systems, seasonal climate forecast, SOI, systems management, El Ni?o, APSIM, simulation model.

To date most agricultural applications of long-range climate forecasting have been for tactical crop management. However, agricultural decisions are made within the context of crop rotations and whole farm management. Many of these decisions could also benefit from such forecasts, but benefits are difficult to quantify. This paper presents a case study of such an application and provides a framework that allows for objective quantification of benefits.

Climate variability, climate forecast- ing and decision making in agriculture

Climate variability pervades agricultural decision-making in Australia. The common thread across a range of scale in decision-making is exposure to the chance of making a loss, or risk (financial risk, land degradation and other environmental risks). Climate variability generates these risks because outcomes of decisions cannot be predicted with certainty. However, while this creates risk, it also creates opportunity, as there is exposure to the chance of making financial and environmental gains. The introduction over the last decade of seasonal climate forecasts based on the El Ni?o - Southern Oscillation (ENSO) phenomenon, has provided a basis to go beyond adjusting to what we know with certainty (such as antecedent soil moisture) at the time when a decision has to be made (5). To date, most of these applications have been in the realm of tactical decisions for individual crops (6, 10). Most management decisions, however, have to fit within a whole farm strategic plan and into a rotational system such that many decisions are planned months ahead and their consequences seen months afterwards. Thus, knowledge of likely future seasonal conditions can also be used advantageously at the farm scale to adjust, for instance, enterprise mix or the proportion of crops grown (3). Using a case study for Northern Australia as an example, we investigate the feasibility of using seasonal climate forecasts in cropping systems management. For this purpose, we define an effective application of climate forecast information as an application that:

• leads to a change in a decision (*ie.* the decision is neither marginal nor obvious); and,

• results in either an economic improvement or a reduction in risk (4, 1).

Improving crop rotations

Cropping systems are defined by the sequence and type of crops grown in a rotation and by the way these crops are managed in response to environmental and socio-economic conditions. The cropping systems of the northern grain region of Australia are characterised by the opportunity to produce a wide range of cereal, pulse, oilseed, forage and fibre crops. Both summer and winter crops are grown, with yield largely determined by water supply from either in-season rainfall or storage in the soil prior to planting. Fallowing the soil between crops in order to build up soil moisture storage is a common and recommended management strategy to offset the risk of low in-season rainfall. However, a fallow length of up to 18 months results in low cropping frequency and, in some locations, might contribute to increased resource degradation such as soil erosion or salinisation (8). As an alternative to rotations of fixed fallow length, opportunity cropping represents the practice of planting a crop whenever a planting opportunity occurs, based usually on the accumulation of a minimum level of soil moisture storage and a planting rain.

Crop simulation modelling in conjunction with historical climate records is one avenue to assess economic and environmental consequences of adopting a more opportunistic management approach in response to current conditions and a seasonal outlook (6). The Agricultural Production Systems Simulator (APSIM) is a simulation environment designed to simulate the production and resource consequences of agricultural systems, including fallowing and cropping sequence (1, 9). In the following case study, APSIM is used to explore the potential for using a climate forecast in influencing management that has consequences beyond the yield of a single crop.

Material and methods

Dryland cotton production in northern Australia is a high return, high risk cropping option. Hence, the recommendation for dryland cotton is for planting after long fallowing from either sorghum or winter cereal to ensure the availability of adequate soil moisture, particularly in drier than average seasons. In many years long fallowing will improve yields and reduce risk of crop failure. In some years, however, the soil water profile may have been full long before planting time or in-crop rainfall may have been sufficient to discount the value of pre-plant moisture storage.

In this case study, conducted for a hypothetical cotton farm at Dalby, Queensland, several rotation strategies are compared. The recommended sorghum-long fallow-cotton rotation (SFC) is compared with planting either sorghum (SSC) or cotton (SCC) in the second year of the rotation and short fallowing through to cotton in the third year. These fixed strategies are contrasted with a variable strategy, whereby either of three management options (growing sorghum, growing cotton or fallowing) can be implemented in October of the second year, based on a seasonal climate outlook. Which option is implemented depends on the SOI phase at the end of September (12). The optimal decision rules were determined for each phase and were as follows:

- SOI = consistently negative, plant sorghum,
- SOI = consistently positive, plant cotton,
- SOI = rapidly falling, fallow,
- SOI = rapidly rising, plant cotton,
- SOI = near zero, fallow.

This allows the quantification of the value of the current forecasting system by demonstrating how much more profitable or less risky a flexible strategy is compared to fixed rotations. Meinke *et al.* (11) and Stone and Meinke (10) used the same principle for single crop decisions in peanuts and wheat, respectively. To quantify possible advances from an improved seasonal forecast, the performance of the four rotations is bench- marked against the hypothetical situation of 'perfect knowledge', where, with hindsight, the most profitable and least risky option is chosen each year, regardless of SOI phase. This procedure determines what could theoretically be achieved with a perfect forecasting scheme. For the purpose of this study, we defined the risk of making a financial loss as the chances of achieving a GM of less than $250/ha and annum.

Results and discussion

The simulation analysis shows that intensification of cropping (*ie*. the occasional or permanent elimination of the fallow) always increases average GM (Table 1). However, agricultural decision-makers constantly face a dilemma: alternative management options are rarely unambiguous in their outcome, whereby increases in GM are often associated with increased risk. The utility functions describing these trade-offs vary considerably depending on financial situation of the enterprise and personal preferences, ie. the manager's level of risk aversion. Here we used the utility function as determined from standard, sorghum-fallow-cotton rotation (SFC) to discriminate among various outcomes. Growing sorghum instead of having a fallow (SSC) increased GM by 8%, but also increased the risk from 5% to 15%. A second cotton crop in the rotation (SCC) increased GM by 14%, but also had a 19% risk of making a loss associated with it. An opportunity cropping strategy based on phases of the SOI by the end of September also increased GM by 14%, but had only a 9% risk of making a loss associated with it (Table 1). While opportunity cropping systems have been widely promoted as advantageous in terms of resource use efficiency (8), they are also riskier than fallowing; one may be sacrificing an assured crop from long fallowing for two mediocre crops. While the yields of any one crop may be lower, and risks higher in an opportunity cropping system compared to a fixed rotation based on long fallowing, this is offset by an increased number of crops over the same time period. Thus, opportunity cropping provides the flexibility to respond not only to current soil and climate conditions but also to the latest market and financial prospects.

The picture becomes even more complex when sustainability issues, such as soil loss due to erosion, are considered. For this case study we have not specified a utility function that quantifies erosion economically. Instead we simply present the simulated amounts for the various scenarios relative to the SFC (Table 1) as actual soil loss will vary greatly with soil type, slope, surface management and location. From a soil conservation perspective, SFC is clearly the least desirable option with twice the annual soil loss than SSC.

Table 1: Average performance of three fixed crop rotations (SFC, SSC and SCC) and an opportunistic system where decisions are based on the long-range climate outlook (SOI). The performance of these systems is benchmarked against a 'perfect knowledge' (PK) scenario.

	SFC	SSC	SCC	SOI	*PK*
Gross margin ($/ha/y)	741	803	846	844	*1113*
Gross margin (percent of SFC)	100	108	114	114	*150*
Risk (% yrs GM < $250)	5	15	19	9	*3*
Soil loss index (percent of SFC)	100	50	72	76	*66*

From a 'perfect knowledge' perspective there is still considerable scope for improving the current forecasting system. The 14% increase in GM achieved using the SOI phase system represents less than one third of what could be theoretically achieved with perfect knowledge (hind-sight). Likewise, production risks could be further reduced with improved forecasting skills. However, even with a perfect forecast a residual production risk of 3% remains in our example. A recent symposium on these issues has clearly shown that scientific advances over and above our current forecasting capabilities are likely in the near future (7).

The results show that the current fixed crop rotation with long fallow (SFC) has a low (5%) risk of making a loss, but appears inferior in terms of GM and soil loss. The generality of these findings needs to be carefully scrutinised for a range of locations, soil types and management strategies. For this case study, however, an SOI-based forecasting system suggested that changing the decision in many years would increase average GM returns by 14% and reduced the risk of soil loss by 24%. It also slightly increased production risk, but, based on the slope of the utility function derived from the SFC rotation, this increase in risk was adequately compen-sated for by the increase in average GM (data not presented).

Conclusions

In this paper we defined an effective application of climate forecast information as an application that (i) leads to a change in a decision and (ii) results in either an economic improvement or a reduction in risk. The case study clearly demonstrates that current long-range climate forecasting capabilities can be used effectively in cropping systems management and can contribute to decision making beyond single crop issues. The study further highlights the power of a systems simulation approach without which an objective, quantitative assessment of the economic and environmental value of the forecast would not be possible. The results show a 14% increase of average gross margin when using the forecast, but this needs to be traded off against a 4% increase in the risk of making a loss. Gross margin comparisons between the current practice using no forecast, the strategy employing an SOI-based forecast and a hypothetical strategy whereby the best option is chosen with hindsight (perfect knowledge) revealed considerable scope for future improvements of forecasting skills. It appears likely that at least some improvement in forecasting skills will be forthcoming in the near future.

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