Using systems models in farm management

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Introduction

"*We're getting a better understanding of the science behind (them) and it's giving us confidence to make decisions using the information. We're getting a handle on the situation rather than functioning on gut feeling.*" Farmer

"*Advantage is that you know where you are likely to be going in six months time, this gives 'hindsight in advance', and farming with hindsight is much easier*" Farmer

"*It influenced my advice: cropping and rotations, planting and nutrition*" Agribusiness consultant

"*There are not too many opportunities that come along that can deliver major outcomes to farmers and (this) is clearly one such*" Industry reviewer

"*The evaluation process provided strong evidence that (it) was having a positive impact: on learning within each participant group, attitudes, decision-making and practice.*" Researcher

These quotes explicitly address the topic of this paper - the application of simulation models in assisting the management of commercial farming enterprises. The need to begin this paper with such statements of support is because many readers, whether they be growers, consultants, extension officers or researchers, would have contrary or, at best, non-committal views on the usefulness of models in commercial agriculture.

Scepticism on the applicability of models is not due to their rarity nor lack of exposure. A recent survey of models targeted at farm production and catchment management (Hook, 1997) recorded over 90 models or computerised decision support systems (DSS) developed and/or supported in Australia. The compilation included models relevant to the cotton industry, the OZCOT and CERCOT cotton models and the now defunct SIRATAC DSS. It would be safe to assume that there are probably many more such products than those listed in this report. Yet, in Australia (Cooke, 1994) and world-wide (Plant, 1997), farmer acceptance of models and decision support systems has been disappointingly low.

In this paper, our objective is to relate our experiences of how some farmers and consultants have benefited from the application of systems models in their farming operations. We argue that this recent effort in applying models within industry has important distinguishing features from past efforts on decision support systems and that the current market pull for commercial access to systems models may be sustainable. We conclude with proposed plans to progress towards commercial delivery of systems simulation to farmers in the northern cropping region.

Why simulate?

A simulation model is simply a mathematical representation of an aspect of the real world. The case for simulation modelling as a scientific research tool needs not to be argued here. To be able to quantitatively explain biological and physical phenomenon and predict outcomes under different environmental stimuli is the goal of much of science. Nor would one argue with the widespread application of models in engineering and other real-life professions. One doesn't build bridges nor put people on the moon using trial and error when models can accurately predict consequences of different designs and actions. Likewise, in our everyday life, simulation is becoming ever more relevant –one can now assess mortgage loans at our banks via a loan repayment simulator. The awareness and acceptance of simulation as a legitimate form for generating information is undoubtedly increasing due to its wider exposure within the general public.

Simulation models are a means of easily and efficiently achieving understanding and gaining "experience". Maybe one doesn't have to live through 50 years of farming experience to gain some insight if one can simulate in minutes what would have happened in each of those 50 years. In this sense, a farming systems simulator could be used akin to a flight simulator – where one can learn from successes and mistakes of implementing actions without suffering the consequent pain and cost of real-life experience.

So, will farming systems simulation ever get to the point where real-life experience is no longer required for learning? Unfortunately, the answer is a definite no. Biological systems are not as predictable as physical systems, with no two organisms being nor behaving exactly the same - well, except perhaps for clones like Dolly the sheep. Where Newton's physical laws allow accurate prediction of mass and state in engineering, biological relationships are based on observed performances of populations of plants and animals. Nevertheless, we can say with some confidence, for instance, that a cotton plant will produce 1.5 g of matter for each megajoule of radiation it intercepts (Rosenthal and Gerik, 1991), or that a cotton crop will take close to 780 degree days to first flower appearance (Constable and Shaw, 1988). By combining such relationships into a simulation model such as the OZCOT cotton model (Hearn, 1994), the performance of cotton crops can be predicted under different environmental and management conditions.

The questions remain, however, as to how well simulation models perform in relation to commercial agriculture and how can industry make use of these tools?

What is FARMSCAPE?

FARMSCAPE (*Farmers, Advisers, Researchers, Monitoring, Simulation, Communication And Performance Evaluation*) is an acronym we have employed to represent a participatory R&D approach that explicitly addresses the question of relevance of systems models to commercial farming. It involves research to explore whether any farmer or adviser could gain benefit from tools such as soil characterisation and sampling, seasonal climate forecasts and, in particular, simulation modelling and, if so, how such tools could be delivered cost-effectively to industry.

FARMSCAPE has been based on the key elements identified in its name:

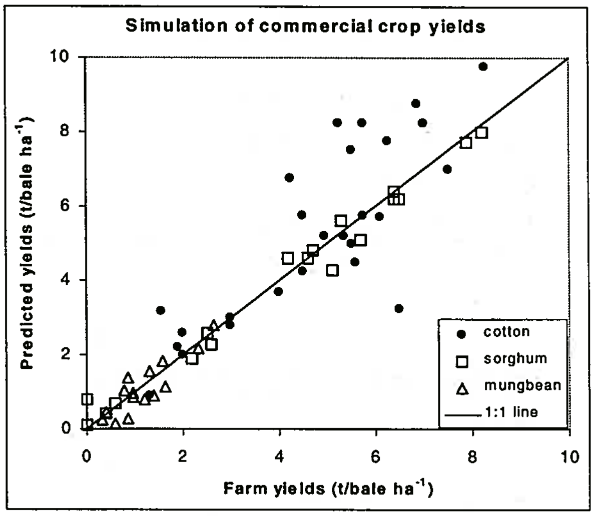
(i) the close collaboration of farmers, their advisers and researchers in discovering together how best to explore management options;
(ii) the implementation of research on commercial farms, especially incorporating improved soil monitoring to gain better knowledge of actual soil water and nitrogen in individual paddocks;
(iii) the application of a well-developed capacity to simulate systems using the APSIM systems model (McCown et al 1996) linked with the OZCOT cotton model (Hearn, 1994) with a requirement that simulations be credible against real-world experience;
(iv) the broader communication of project outcomes not only through public extension activities but particularly through agribusiness client services, and
(v) the continual assessment of project activities and impacts via formal evaluation processes.

Since 1992, FARMSCAPE has encompassed on-farm research and farmer group activities conducted from Capella in Central Queensland to Breeza in northern NSW, with most emphasis having been on the Darling Downs. The focus of FARMSCAPE has almost exclusively been on dryland farming systems. We have established direct working relationships with over 200 farmers and 15 advisers who have influenced research direction and provided strong support for continued evolution of the FARMSCAPE tools and techniques.

Are simulation models relevant to the real world?

Over the past 6 years, a number of commercial dryland crops have been monitored and used to test APSIM and OZCOT simulations. Figure 1 presents results for cotton, sorghum and mungbean, while other crops such as wheat and chickpea have also been tested. In most cases, these tests have confirmed that the models are able to simulate commercial crop production – in Fig 1 they accounted for 87% of observed variation over 59 crops (70% for the 30 cotton crops). For most of those crops where predictions were significantly different, we have been able to determine the reasons for the discrepancies – most are due to impacts of factors not accounted for in the models (eg. severe pest damage). For many farmers and consultants, APSIM and OZCOT have proved credible enough to be relevant to commercial cropping practices and now want to use them in benchmarking the performance of their own crops and in exploring alternative management strategies.

Fig. 1: Predicted yields versus commercial crop yields



How can systems models be used?

(i) Scenario exploration

A common and useful application of simulation is to explore new options or environments as general scenarios that are broadly relevant to a region or group of farmers. In this light, we were asked recently to investigate the returns and risks of dryland cotton by a group of farmers located near Spring Ridge on the Breeza Plain, NSW. The farmers in this group have been primarily growing wheat and sorghum in rotation after long fallows, with the occasional sunflower crop. While the farmers were comfortable with their present cropping systems, they did raise the question of whether alternative crops should be considered.

The OZCOT cotton model was run with inputs generated by the farmers and a local consultant in order to generate risk analyses and gross margins for dryland cotton assuming a full profile of soil water (300 mm available water) at sowing time (Table 1). The resultant predictions were mostly consistent with the expectations of the both a neighbouring cotton farmer and the consultant. The average gross margin was calculated as $1100/ha for cotton (yield 3.7 bales/ha; $560/bale) compared with $630/ha for sorghum (yield 6.2 t/ha; $120/t). While there was a risk of not breaking even, the farmers considered the risk in crop failure was not much greater than that for other crops. The group discussed offsetting this risk by limiting the area of cotton in relation to their other summer crops. Their farmers also confirmed that there were better chances of making higher gross margins than for either sorghum and sunflower.

The farmer group also asked for simulations to investigate the risks of dryland cotton starting with half a profile of soil moisture (average 3.23 bales/ha; Table 1), the effects of sowing time and different rates of nitrogen. Subsequent to undertaking these analyses, three of the farmers have decided to grow cotton for the first time in the 1998/99 season as part of their summer crop program. It is important to note that this simulation exercise did not make the decision for the farmers, but merely provided them with another source of information to assess the returns and risk of a new farming option.

Table 1: Risk analyses generated for dryland cotton production at Spring Ridge (Breeza Plain).

Outcome	Probability of Achieving Outcome (%)	
	Full Profile Soil Moisture	Half Profile Soil Moisture
≥ 1.70 bales/ha (0.7 bale/ac breakeven)	84	78
≥ 2.47 bales/ha (1.0 bale/ac)	63	53
≥ 3.71 bales/ha (1.5 bales/ac)	43	34
≥ 4.94 bales/ha (2.0 bales/ac)	32	22

≥ Greater than or equal to

(ii) Benchmarking past crop performance

Whether a crop has performed to its potential is often of great interest to farmers. Given actual seasonal climate and management inputs, models can predict what a crop should have yielded in the absence of extraneous factors, thus providing a benchmark against which actual crop yield can be assessed. Fig 2 demonstrates a benchmark simulation of a sorghum crop at Kupun, Qld. In this case, the simulated and actual yields were very close and so the farmer could conclude that his crop yielded close to its potential. However, by re-running this benchmark simulation, but using a higher plant density and fertiliser rate, the model also suggested that the farmer could have produced even higher yields than that achieved - the crop did not reach its environmental potential in that season

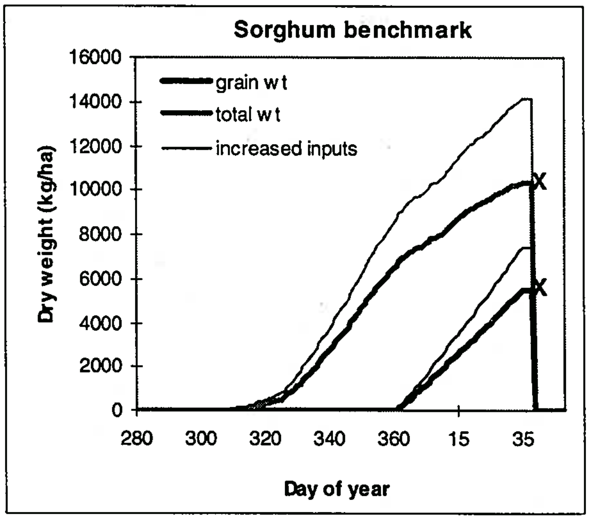
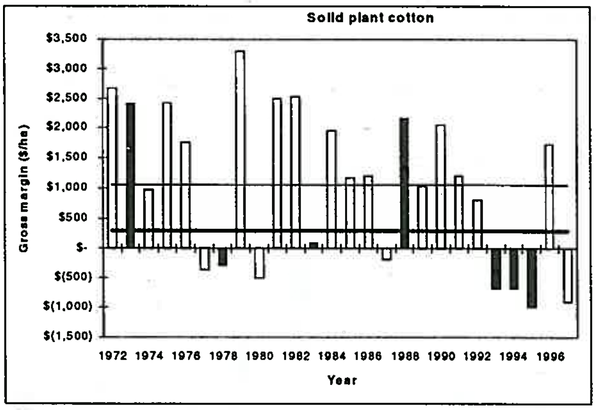


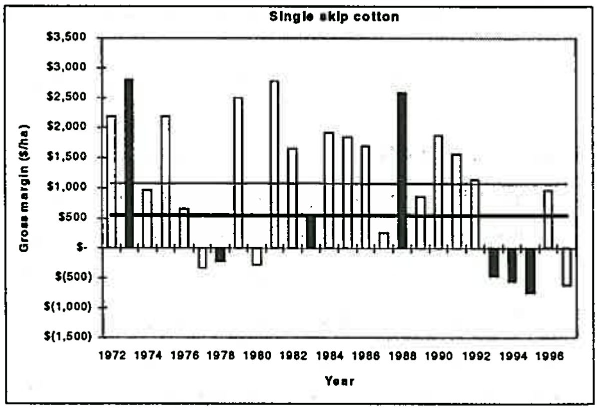
Fig. 2: Simulated daily increase in sorghum grain and total dry weight – X signifies actual weights at crop maturity

(iii) Tactical crop management

The APSIM or OZCOT models can be used in planning for the current or upcoming crop. Decisions on crop choice, varietal selection, fertiliser rate, sowing date, plant population, row configuration and so on can be assessed based on knowledge of pre-plant soil water, soil chemical analysis and seasonal climate outlook. Based on this information, the models can provide an assessment of expected crop performance in the upcoming season by simulating what would have happened under these same conditions in past years for which rainfall records exist - Fig 3 presents an example for cotton planted as either solid or single skip under low starting soil water conditions. The grower for whom these simulations were undertaken, changed to single skip cotton in the 1997/98 (*El Nino*) season rather than his normal solid plant configuration.

Fig. 3: Predicted gross margins for solid and single skip cotton crops grown at Brookstead when sown on 40% soil water profile. Solid bars represent *El Nino* seasons, the average for which is represented by the horizontal thick line, whereas the thin line is the average over all seasons.





(iv) Planning strategic crop rotations

A significant advantage of APSIM is that it is a model of a cropping system, able to simulate the production and environmental consequences of different crop rotations. This capability has been used by farmer collaborators in FARMSCAPE to explore cropping rotations suited to their own farming operations. It has also been used as a research tool to explore the prospects for innovative design of cropping systems. For example, the degree to which the efficiency of dryland cotton systems could be improved if they became more flexible through an opportunity cropping strategy has been recently explored by Carberry et al (1998). In a simulation case study, a standard dryland rotation of long fallowing from sorghum to cotton was compared to alternative fixed rotations and to a rotation influenced by a seasonal climate forecast based on the Southern Oscillation Index (SOI). The decision point is the October after sorghum harvest where the manager can choose to proceed with the standard summer fallow or plant sorghum or cotton in that season with the intention in all cases of planting cotton in the following summer. These three fixed rotations (fallow-cotton, sorghum-cotton, cotton-cotton) are compared to a SOI-influenced strategy – where the rotation chosen each year was determined by the phase of the SOI in October – using APSIM and OZCOT to simulate system performance over the 100 yr climate record for Dalby Qld.

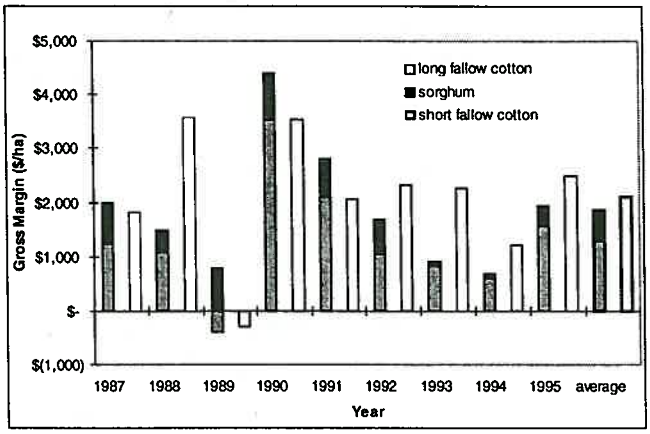
This simulation case study demonstrated that SOI could contribute some skill in improving management decisions over a two year rotation. By changing between fallow-cotton, sorghum-cotton or cotton-cotton rotations based on the SOI phase in the August-September period preceding the next two summers, average gross margins for the two year period increased by 14% over a standard fallow-cotton rotation (Table 2). At the same time, soil loss from erosion was reduced by 23% and cash flow was improved in many years because an extra crop was sown. The SOI strategy did however increase the risk of economic loss from 5% of years for the standard fallow-cotton rotation to 9%, but this risk was considerably less than the 15% for sorghum-cotton and 19% for cotton-cotton rotations.

Table 2: Average performance of three fixed rotations and a flexible rotation based on an SOI seasonal climate forecast (from Carberry et al., 1998).

	Fallow-Cotton	Sorghum-Cotton	Cotton-Cotton	SOI
Gross margin ($/ha/2 yr)	1482	1605	1691	1683
Risk (% yrs GM < $500)	5	15	19	9
Cash flow (year 2)	-56	380	820	405
Soil loss (relative to fallow)	1	0.49	0.72	0.77

The scenario described above is similar to that of a farmer collaborator at Bongeen, Qld, in late Nov. 1995 when his doubled cropped wheat after sorghum failed. He was faced with a decision on whether to continue with essentially a bare fallow through to cotton 10 months hence or plant sorghum at that time and follow with a short fallow through to the intended cotton crop. The simulation of the two rotations showed only a slight gross margin advantage to long fallowed cotton (Fig. 4). The farmer planted sorghum to gain stubble cover for soil protection and was still able to follow with a cotton crop in 1996/97.

Fig. 4: Gross margins for either sorghum-cotton or fallow-cotton rotations simulated at Bongeen Qld.

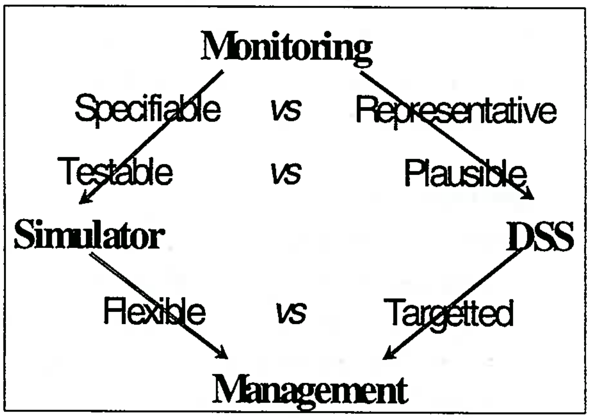


What have we learnt?

FARMSCAPE is a research activity that recognised early on that, if we wanted to explore ways in which farmers could better manage their farms, then these farmers needed not just to be consulted on the design of what should be done, but they also needed to participate in the implementation of the research and the interpretation of its outcomes. In other words, instead of using our scientific models to build derivative tools which we scientists believed could help farm managers, for instance a computerised Decision Support System (DSS), we took these base models out onto farms and asked farmer and adviser collaborators to design and test applications for their own situations. What emerged has been confirmation of the benefits of farmers gaining better knowledge of their water and nitrogen resources through increased intensity of soil monitoring and the discovery of a role for systems models in assisting the management of cropping systems.

FARMSCAPE has helped demonstrate that the key to farm managers valuing simulation is the positioning of these simulations in the context of their own farming situation. A simulator enables information to be specified to an individual paddock, its results can be tested against one's own crop performance and a simulator such as APSIM can be used to explore a whole range of issues. In contrast (Fig. 5), many DSS packages, (eg. WHEATMAN; Woodruff, 1992), provide generic or representative information for a district, they depend on plausible answers (as many of their assumptions cannot be tested using one's own data), and many DSS are generally targeted at single or few issues.

Fig. 5: Schematic comparison of a simulator versus a decision support system (from McCown et al, 1997).



An important distinguishing feature in our use of a simulator with farmers is that, while the simulator provides information that may be useful in making a decision, in the end, the farmers have to decide what would be best for their own situation. In contrast, many DSS packages have been designed to provide recommendations on what decisions should be taken. In leaving the interpretation up to the farmers, a simulator provides a means of learning about the farming system.

Where to next?

Developing the FARMSCAPE approach and tools to the point of commercial delivery is a logical next step for this R&D activity. A market now exists for timely and high quality interactions based on soil monitoring and simulation amongst a significant sector of the farming community. Formal evaluation of the current FARMSCAPE project has demonstrated impacts on participating farmers and advisers. The demand for simulations has increased rapidly to the point where we can not meet that demand, nor justify providing a "commercial" delivery service. Our intention is to do all we can to transfer to agribusiness the capability to deliver FARMSCAPE-based interactions.

Our preferred delivery mechanism is to establish an Accredited Adviser Network for delivering simulation and related products such as soil monitoring, seasonal climate forecasts, analysis of relevant management scenarios and "what-ifs, analysis and discussion" to farmer clients in the northern cropping region. Our proposal is that a number of agribusiness and private consultants be accredited and supported in implementing the FARMSCAPE approach within their business practices. Due to the high demands of training and support required, accreditation training and support initially could only be provided to a limited number of collaborating companies.

Finally, on the research front, we intend to continue exploring the role for simulation, expanding our interests to include irrigated cotton production systems and the agribusiness service sector. In the latter case, bank lending policy and agribusiness advice were definitely affected by recent *El Nino* events. Whether better information on seasonal climate forecasting and cropping prospects can improve institutional decision making (eg. bank leading policy, crop insurance policy, product inventory, marketing advice, etc.) is an emerging area worthy of further exploration.

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