Crop and whole-farm tools for analysis of profit, risk and environmental impact

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Abstract

The software programs, WhopperCropper and APSFarm, could both be considered 'discussion' support tools. However they are at opposite ends of the spectrum of complexity of programs used for climate risk management. WhopperCropper (WC) enables the decision maker to view the full range of potential production and financial outcomes from varying levels of inputs relevant to practical farming. WC has the flexibility to be used by researchers, advisors, farmers and teachers and has entered all of these markets. Training has transitioned from workshops run by the development team to commercial delivery by a private company. Approximately 470 advisors have been trained during the six years of the project. Conversely, APSFarm has been developed aiming to support the discussion required to design more profitable and resilient farm businesses. Therefore, APSFarm is particularly suited to analyse both strategic and tactical decisions. In this respect, APSFarm can be used to evaluate trade-off analyses between competing farm business objectives e.g. profit, sustainability, economic risk, environment and social factors, by considering the influence of external drivers such as markets, labour availability, climate variability and change and policy.

Key Words

Risk management, APSIM, WhopperCropper, APSFarm

Introduction

Farmers make critical management decisions on various time scales from a single day's activity to decisions regarding whole farm enterprise structures. There are a range of tools available with the potential to provide valuable information on the likely impact of alternative management decisions with respect to single enterprises or the whole farm business. This paper describes the application of two complementary discussion support tools, one at the enterprise level i.e. WhopperCropper, and a more complicated one, a recently developed whole farm systems simulation model, APSFarm. WC can be used to support crop level decisions by easily navigating a database of a factorial of pre-run simulations using APSIM (Cox et al 2003, Nelson et al 2002). APSFarm is an extended configuration of the APSIM (Agricultural Production Simulator) cropping systems model (Keating et al 2003). It incorporates the capacity to simulate every economic activity that occurs in the farm business (Rodriguez et al 2007, Power et al 2008). APSFarm was originally developed in collaboration with growers and consultants from Central Queensland due to the need for more holistic approaches in the analysis of farm businesses. The aim is to help farmers more quickly generate relevant information that translates into knowledge and generate farm business scenarios that include the potential impacts of new technologies, changes in climate and markets.

Methods

WhopperCropper

WhopperCropper operates at the single paddock level and produces yield, gross margin and many other outputs. The aim is to provide insights into the full range of potential outcomes for 'what-if' scenarios. Long-term weather data were used to create the database of simulations for every combination of the crop input (Table 1). The scenario options are tick-selected from easy to use menus and no other data entry is required. Annual yields for every factorial combination of the inputs in Table 1 are generated using the full range of available weather data. A range of probability distribution graphs can also be generated e.g. boxplots.

Table 1. Main input factors and numbers of factor included in WhopperCropper

Input parameters	Number of factors
Crop type	the common summer and winter crops
Soil water-holding capacity	up to five levels
Soil water at planting	1/3, 2/3 and full
Planting date	up to five dates
Maturity length	three categories
Plant population	typically three levels
Row configuration	wide rows in sorghum and cotton
Effect of soil nitrogen content	typically three levels
Nitrogen fertiliser rate (planting and in-crop)	typically six nitrogen rates
Southern Oscillation Index phase system	five-level phase system

APSFarm

Unlike the tactical focus of WhopperCropper, APSFarm has been designed to support the design of whole farm businesses. In APSFarm, simulations i.e. crop management and business strategy rules, are built during interviews and discussion sessions with growers and consultants. Crop management rules are similar to those in WC, but in APSFarm, business level rules (e.g. levels of diversification – cropping intensity – enterprise mix) including a comprehensive economic, and resource (i.e. land, machinery, labour) menu are added. The rules are described as ‘states’ and ‘fluxes or transitions’ following concepts of finite state machines. The model is then used to develop scenarios of possible alternative business trajectories using historical weather series or climate scenarios. Model results are then used to drive better informed discussions with participating farmers and/or consultants. In the example below we show how we have used artificial intelligence techniques, i.e. a differential evolution (DE) algorithm (Figure 1), to explore the full landscape of possible business trajectories in terms of trade-offs between profit, economic risk and environmental outcomes (i.e. soil loss) for a 2000ha farm business at Capella, Central Queensland.

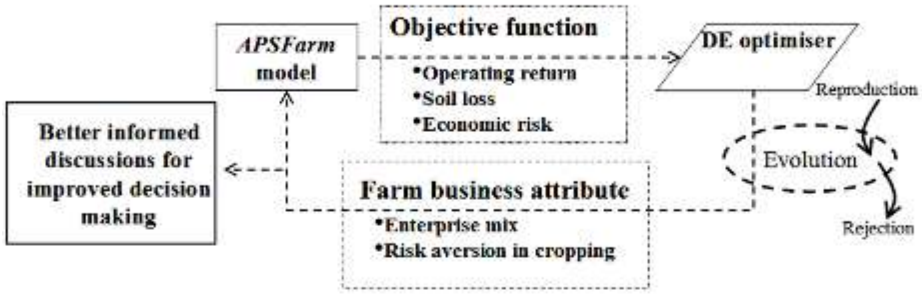

Figure 1. Schematic representation of the use of APSFarm integrated with a multi-objective DE optimisation routine.

Discussion

Using WhopperCropper

The effect of different input levels can be analysed as single, two way or multiple interactions. For example a user may commence with a simple analysis of the effect of soil water at sowing (SSW) (one third, two thirds) with all other inputs constant. A second level analysis could be the SSW * a nitrogen fertiliser rate effect. A three-way analysis could involve the previous two factors * southern oscillation index phase (SOI) (e.g. positive or negative). The building of scenarios, in gross margin terms, is shown in Figure 2.

Uptake and impact of WhopperCropper

There has been considerable debate regarding the effectiveness and suitability of decision support systems marketed to farmers (Hayman and Easdown 2002, M^{c}Cown 2002). However, WhopperCropper (Nelson et al 2002) engaged professional advisors rather than farmers both in the program design and as its target market (for 'discussion support') and this has appeared to be successful. Three major evaluations have been conducted during the six years of the project; 55, 40 and 45 users in 2003, 2005 and 2007 respectively from a total of 470 trainees. A small sub-set of evaluation results indicates a moderate level of satisfaction and usage (Table 2).

In 2005, 65% and 50% of advisors reported increase in knowledge and skills respectively. In addition, the advisors also indicated a 37.5% and 37% increase in knowledge and skills of their clients. Thirty per cent of respondents indicated the decision change had a positive outcome. Specific decision and frequency of the decision changes were also determined (number of decision changes in brackets): change sow date (11), fertiliser rates (7), crop type (7), plant populations (7), SOI phase considerations (6), area planted (1).

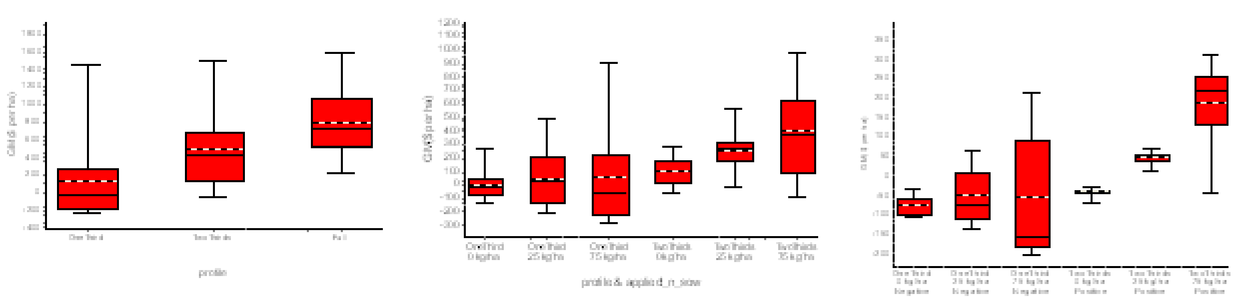

Figure 2. Boxplots of the range of gross margins of a one, two or three factor interaction including soil water at sowing, N fertiliser rate and SOI phase with other input factors set at a single level.

The whiskers and edges of the 'boxes' represent 0, 25, 75 and 100 percentiles respectively. Within the boxes are the median (solid) and mean (dashed) lines.

Table 2. A sub sample of data from user surveys conducted in 2005 and 2007

	Usefulness				Times used					Effect		Purpose of use		
	Extremely useful	Very useful	Useful	Some use	>50	20 – 50	10 -20	<10	0	Increase own knowledge	Increase client knowledge	Consultation	Public meetings	Other (teaching, media, etc)
2005 Version 3	12.5	32.5	35	5	12.5	12.5	15	30	20	65	37.5	55	17.5	32.5
2007 Version 4	6	28	16	50#	3	7	4	42#	43#	28	45	45	14	16

 # lower usage values in 2007 reflect the effects of the drought and the short time from receiving the new version until the evaluation study

APSFarm

Based on a number of interviews with farm managers and consultants, we set up APSFarm to simulate a 2000ha cropping farm business near to Emerald, Central Queensland, Australia (23.53?S, 148.16?E). The business operates a no-till cropping system comprising three major soil types. The cropping enterprises included sorghum, wheat, chickpea and maize. About one third of the cropping area is dedicated to winter crops. Depending on soil water at planting, double cropping is considered, though summer cropping is predominant. Available farm machinery determines work rates e.g. a planting rate of 13 ha/hr, and a spraying rate of 23 ha/hr, and incurs an operating cost for every activity. Farm scale economics are monitored, thus the current cash status can be used as an input to management decisions. Each paddock (management unit) has a current 'state' e.g. fallow, wheat, sorghum, etc., and 'rules' that allow 'transition' to adjacent 'states'. These rules represent both the capacity e.g. availability of machinery, land, labour, and capability e.g. cropping skills, farm business strategies, risk attitude. These rules are usually expressed as a Boolean value (true for feasible, false otherwise), but can also have numerical values; higher values representing the desirability of a particular action. Each day, the model examines all paths leading away from the current state to adjacent states, and if the product of all rules associated with a path is non-zero, it becomes a candidate for action. The highest ranking path is taken, and the process repeats until nothing more can be done for that day.

In this study we used APSFarm to investigate optimum farm business strategies under contrasting climate series i.e. dry, average or wet decades, in terms of trade offs between profit, economic risk (i.e. down side risk), and environment (i.e. soil loss). In Figure 3a, b and c, we show the performance of the farm business assuming present management (red dots), and identify a better position in the landscape of possible outcomes having a higher profit, lower economic risk, and environmental impact (i.e. arrows and circled areas). Once the model is validated with the participating farmers, the pathway towards the improved performance is discussed to identify blockages, additional constraints, and "ground-truthing" the feasibility of the required changes.

a) b) c)

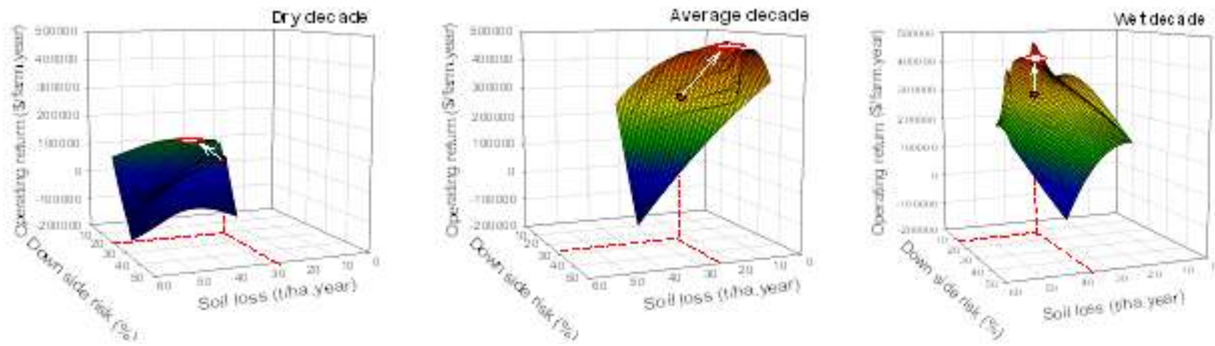

Figure 3. Present farm business position (red dots) and landscape of possible outcomes in terms of profit, economic risk and soil loss, for a 2000ha farm at Capella, Qld. during dry (a), average (b), and wet (c) decades.

So far benefits of developing APSFarm have been threefold: (1) in the process of model design and development APSFarm became the framework that 'packaged' the knowledge and discussion whilst allowing the group to identify opportunities for change and improvement; (2) modelled results provided realistic measures of trade-offs between profit – risk – environmental impact across a number of possible alternative futures; (3) our farmers benefited from the test benching and fine tuning of cropping rules by reducing and accounting for the dimensionality of their complicated production systems.

Conclusion

Both tools have the potential to assist researchers, growers and advisors make better informed discussions on management decisions at a number of scales i.e. enterprise to the whole business. WhopperCropper is readily available, easy to use and gives broad insights into the effects of input factors in terms of yield or gross margins at a paddock level. In many cases the insight gained will be sufficiently 'roughly right' to lead to a management change. Evaluations to date have revealed satisfaction with the product and indications of continued use. In APSFarm either the physical, natural, social, or economic assets (resources) of the farm business can become key input 'rules' or constraints. When used in conjunction with multi-objective optimisation it has the capacity to explore a full landscape of possible management and strategic scenarios in terms of trade offs between competing farm business outcomes.

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