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Agricultural Decision Analysis: The Causal Challenge

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Abstract

The paper sets out the agenda for reviewing models of decision making in the context of farmers' use of seasonal climate forecasting. Such forecasts have been framed in terms of shifts in cumulative distribution functions of yields or gross margins. Typically they have been applied to choices about crop variety, crop type, time of planting or level of fertiliser application. Fundamental questions are: how do farmers conceptualise and make use of the information contained in seasonal climate forecasts? Do our models of decision making represent well the way in which these decisions are made?

Keywords: decision making; farmers; seasonal climate forecasts; conceptualisation; review

1. Introduction

The research described in this paper had its inception in the development and application of an evaluation tool for Yield Prophet, the crop simulation model that links farmers to CSIRO's APSIM simulation modelling system. The impetus was two apparently conflicting observations. The first was that most farmers who used the Yield-Prophet simulation software were extremely committed to it, running many simulations, and apparently understanding and absorbing the probabilistic information contained therein. The second observation was that few farmers actually put into practice the cropping plans expected by scientists who were familiar with their farms and the simulation information.

A related issue is the value of the information contained in Seasonal Climate Forecasts (SCFs) and modelling approaches like Yield Prophet. When estimating this value the usual approach is to construct a normative model in which with-forecast and without-forecast

situations are considered. The forecast value is then measured as the difference between the returns obtained by the decision maker in these two modelled situations. A biased estimate of the value of a SCF would result if farmers' actions are not well represented by the normative model.

The conflict outlined in the first paragraph prompted a literature search to shed light on what influences other than those modelled in the Yield-Prophet simulations could be motivating cropping decisions. Armed with various suggestions from the literature, a pilot study was commenced. This consisted of one-on-one, in-depth interviews to examine the types of thought processes that were influencing farmers.

As the work proceeded, it tended to confirm results from the management and behavioural psychology literature explaining why decision analytic methods were having some difficulties in handling issues like timing of crop sowing decisions and decisions related to level of fertiliser applications. Also confirmed was my own (with hindsight) naïve and mistaken view that unstructured farmer interviews would lead to significant traction on the issue.

2. Yield Prophet

Yield Prophet is a web based tool for supporting farmer decisions about crop management in Australia's climatically variable environment. Yield Prophet provides information about individual uncertain situations using customised simulations based on local historical weather data, measured current soil water, and seasonal climate forecasting based on the El Nino Southern Oscillation (ENSO) system (Hochman and Broad 2006).

Yield Prophet enables farmers to interface with the APSIM crop simulation model (http://www.apsim.info/). It simulates crop growth based on paddock-specific inputs including soil type, pre-sowing soil water and nitrogen levels, in-season rainfall, irrigation and nitrogen fertiliser applications, and seasonal climate forecast information.

The model completes 100 simulations of the current season from the point in time specified (usually the current date). The output is a cumulative distribution function of crop yields. Various management options can be superimposed on the simulation to generate an alternative CDF for comparison. For example, Figure 1 shows simulation results for various alternative levels of nitrogen top dressing. Visual comparison by farmers of such yield distributions assists Yield-Prophet subscribers to decide on the appropriate level of topdressing for their farm.

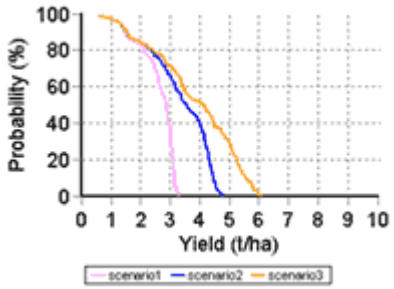

Figure 1. *Yield probability curves for three different nitrogen top-dressing scenarios generated for a dry land wheat crop on 1 August 2005. Scenario 1 (left line) is the yield probability adding no further nitrogen, Scenario 2 (centre line) is the yield probability with 35 kg/ha of nitrogen top-dressed on 15 August, Scenario 3 is the yield probability with 70 kg/ha of nitrogen top-dressed on 15 August 2005. There is an 80% chance of achieving a yield response with topdressing, and about a 50% chance of achieving a 1 t/ha yield response from 35 kg/ha of nitrogen.*

Source: Hochman and Broad 2006.

In a similar manner, the likely impact of different sowing dates, crop varieties, irrigation applications, or combination of these can be shown.

A key element of any conceptual framework for good decision making on dryland farms is the notion that some things are controllable and other things are uncontrollable and random, and expertise lies in recognising the controllable aspects of the situation. Yield Prophet is focused on helping to discern what is controllable and what is not. It supports expert control of what is controllable but also supports "playing the odds" in response to random climatic variation.

Hochman *et al.* (2009) set out to investigate whether farmers and agronomic advisers understood the various representations of probabilistic information provided by the Yield Prophet program. They attempted to investigate how well Yield Prophet contributed to their decisions and whether farmers and their advisers were more inclined to trust their own judgement about the uncertain production future and to be sceptical about science-derived probabilities.

"In May of 2007 a series of workshops were held in five locations in Victoria and southern NSW to introduce new and potential subscribers to Yield Prophet and to update existing subscribers with information about new features that were recently introduced in preparation for the 2007 winter cropping season. An additional intention of the workshop was to provide training about probability and the different representations of probability in Yield Prophet. At the commencement of the workshop participants were asked to complete the questionnaire after a brief explanation of why we were asking these questions and that their answers would be used to inform future design of Yield Prophet's reports" (Hochman et al. 2009, p.4).

The results of the survey were somewhat surprising: “Given that the premise of this research was to investigate the nature of problems farmers and agronomic advisers have in understanding probabilistic information it was a surprise to find that Yield Prophet’s subscribers reported that they highly value the crop report, they find it clear to understand, and they use it frequently during the year. Similarly the Nitrogen Comparison Report, which displays only probabilistic information on the yield prospects of up to three nitrogen fertiliser use scenarios in a graphical format, was rated on average as *mostly clear*” (Hochman et al. 2009, p.5). These results were not expected given previous observations made on-farm that actual cropping decisions seemed to be largely uninfluenced by Yield-Prophet results.

The next step was to try to understand how farmers were using the Yield Prophet simulations in their decision making processes. This would eventually lead to a series of in-depth interviews, but in preparation for this the salient literature was consulted to provide some general insights to this type of problem and to provide a guide to the territory that might need to be covered in the interviews.

3. Selected Literature

The first step in defining the salient literature was to be clear about the characteristics of the model that was under consideration. While it was a systems simulation model and was *prima facie* a positive rather than a normative model, its mode of use was as a normative model. It was an analysis performed by a scientists’ model to provide prescriptive information to farmers. Moreover the information was essentially probabilistic information. In these essential characteristics, the analysis was similar to various other models of decision making under uncertainty. These include the models of decision analysis based on subjective expected utility, prospect theory, state contingent theory, stochastic programming and simulation. In all these approaches, the decision maker is viewed as selecting among a set of alternatives by assessing the value of each by reviewing probabilities of occurrence of various states of nature and the returns from each of these states of nature. There are five aspects: choices, events, probabilities of these events, outcome values, and some means of aggregation across these outcomes (ie an objective or utility function).

When viewed in this manner, the relevant literature becomes the literature related to the use of probabilities in decision making. Rottenstreich and Kivetz (2006) define decision situations as eliciting either a probabilistic of non-probabilistic mindset. Also some decision makers are more likely to bring a probabilistic mindset to a given situation than others would (MBA students rather than history majors), but to a limited extent though prompting some individuals can develop probabilistic mindsets.

With a probabilistic mindset, decision makers use judgement of likelihoods, and methods of analysis include decision analytic methods generally (Anderson, Dillon and Hardaker 1977),

prospect theory (Kahneman and Tversky 1979) and state contingency theory (Chambers and Quiggin 2000). With a non-probabilistic mindset, decision makers use expertise (Gilboa and Schneidler 2001), affect (Windschitl and Wells 1998), or causal intuitive rules (Hastie 2001; Kahneman 2003; Shapira 1995). In the non-probabilistic area, methods of analysis are not well developed.

In a set of experiments designed to show the importance of context, Kusev *et al.* (2008) showed that both context and probabilities influence decision making, and that risk preferences and decisions under risk are not task independent. Moreover, they postulated that the behaviour they observed in their experiments involving insurance was like that observed by Gilboa and Schneidler (2001) because is was related to decisions under uncertainty being made by analogy to similar situations previously encountered. While Kusev *et al.* (2008) described the memories of such previously encountered situation in frequency terms, Gilboa and Schneidler (2001) did not.

In the literature that examines actual business decision making, as opposed to experiments using hypothetical questioning, the use of causal intuitive rules has received the most attention, and this area was examined as a basis for developing an understanding of the use of Yield Prophet in farm management decisions. Rottenstreich and Kivetz (2006) divide intuitive rules into scenario construction, role-based considerations and appeals to social norms. Each of these is considered below.

Scenario construction

In a study of decision making by business executives, Shapira (1995) observed that probabilistic information was rarely used, but instead managers constructed scenarios surrounding decision issues. Attributes of these scenarios often included the ability to "make a decision work" by means of post-decision actions, and overconfidence as a result of an over-exaggerated estimate of their own degree of control. In other situations, there was so much complexity that they were disinclined to make probability judgements.

In the use of decision rules to construct scenarios, Lopez (1981) observed that decision makers are often security minded, with a desire to avoid bad outcomes. They often express a form of decumulative reasoning like "I'll get at least something…", and they often think in terms of a chance of reaching a specific target.

In Shapira's (1995) study, business decision makers dealt with risk by collecting more information, checking more closely different aspect of the problem, delaying the decision, avoiding taking the decision or delegating it to another individual in the organisation. The process of integration in the mind.

Together these types of studies suggest that many decision makers are constructing in their minds alternative future scenarios. In such scenario planning, decision makers explore the business environment, improve anticipation by widening perception, improve diagnosis by

seeing more possibilities, increase the scope for action by better understanding and develop plans for the future that are more robust (Shapira 1995). Ingvar (1985) coined the metaphor "memories of the future" for the integrating process that the mind goes through to develop theories about the environment in the form of scenarios. A question for our field study became whether farmers whether farmers were constructing scenarios in this manner in the Yield-Prophet context.

Role-based considerations

With role-based considerations the decision maker recognises the situation as one where the best action is known (Weber, Ames and Blais 2005). In a farming context, in a particular location you might never consider sowing wheat before the end of April, because frost damage to the crop at flowering time would be the consequence. This is a kind of "if-then" rule which is clearly non-probabilistic.

There could be various motivations behind role-based actions. Not least in a farming context is a moral imperative to act like a good farmer. For example, for most farmers, only in extreme business circumstances would the resource base of the farm be degraded.

Social norms

The issue of social norms may seem far removed from the issues surrounding the use of Yield Prophet. However, as the following example reveals, there could be a number of social (or moral) issues related to farming decisions.

> "Suppose that one particular Friday evening, a person chooses between going to an entertainment movie of a documentary film about famine in Africa (the proceeds of which will be donated to charity). It is the last showing for both movies. The person chooses the entertainment film, thus revealing his preference.
>
> Now, to change the problem slightly, suppose that Friday after lunch, the person has the opportunity to take off early and see one of the two films (again, the last opportunity to see either one). He refuses the entertainment film, but might in fact go see the documentary. On narrow preference grounds, this choice is irrational….." (Prelec and Herrnstein 1991, pp. 334-335).

However, as Prelec and Herrnstein (1991) go on to show, it is easy to show that there are other rule-based social norms (possibly conditioning) that explain these choices. The decision to leave work early may contravene a rule internal to the person about leaving work early. To counteract this the documentary film and charity donation could be viewed as "work", so justifying the decision to take off early. The conclusion of these authors is that such rule based issues cannot easily be incorporated into the probabilistic structure of a decision analytic arrangement of the problem. Are there such rule-base issues related to the farming context that forms the basis of this paper?

4. Farm Visits

During 2007 wheat sowing periods (April-June) in-depth interviews were conducted on-farm with four farm decision makers in southern Queensland. The objective was to discover whether any information could be gathered about the way in which these farmers were rationalising their decisions with respect to Yield Prophet. In addition six more farmers were contacted in the period between July 2007 and August 2008. These farmers were at the point of considering top dressing their wheat crop with additional nitrogen.

All ten farmers were familiar with Yield Prophet as subscribers or potential subscribers. Space limitations in this brief paper prevent description of the response of all ten farmers, and more detailed comments below are restricted to three of the farm visits. They are purposely selected to provide an impression of the range of decision making issues.

Generally the following issues were used to guide the discussion.

- Is the farmer scenario planning or risk managing?
- Is the farmer "sense making" or "decision making"?
- Is desire to avoid bad outcomes a prime driver? ("I'll get at least something")
- Is there an aspiration focus? (eg income sufficient to guarantee minimal living level)
- Is there a survival focus? (is the farm at risk?)
- Is there a difference between business risk taking and gambling?
- Is there a "comfortable" level of risk?
- Does the amount of risk that is "comfortable" depend on recent risk experiences?
- Is this heuristic decision making?

Most of the farmers seemed to be talking about scenario planning rather than risk management. The discussion went to issues like: "if we plant that paddock now then we need to follow that up with considering how much nitrogen to apply, restricting use of the area next season and then skip a crop in that paddock at this time next year and even consider a long fallow." Some of these scenario discussions went into alternative futures up to five years ahead. When risk was mentioned it was generally in the context of a large loss (a quantity) rather than a chance (a probability). Only one farmer regarded farming as similar to rolling a dice, and this was only in the period after a significant decision had been made. The other nine considered that they had good control over their operations, and that this would enable them to get something out of their cropping decisions. Some of the farmers had a poor understanding of and appreciation for SOI forecasting despite subscribing to Yield Prophet.

Table 1: The Position of Each of the Farmers (1=Farmer 1, etc..)

	Yes	No
Scenario planning	1,2,4,5,6,7,9,10	3,8
Sense making	1,2,3,5,7,9	4,6,8,10
Avoid bad outcomes	1,2,3,5,6,7,9,10	4,8
Aspiration focus	1,2,3,5,6,7,8,9,10	4
Survival focus	2,3,5,6	1,4,7,8,9,10
Farm business risk like rolling a dice	3	1,2,4,5,6,7,8,9,10
Farm business risk like professional punter (skill and knowledge of risk present; element of control)	1,2,3,4,5,6,7,8,9,10	
Acceptable risk depends on recent experience	1,2,4,5,6,7,9,10	4
Heuristic decision making	1,2,3,4,5,6,7,8,9,10	

Farmer 1

Farmer 1 was probably the most typical of all the farmers interviewed. He said (as a Queenslander), “Yield-Prophet can work better for southern farmers because of winter rainfall down there.” “In-crop fertiliser application is less relevant to us.” He clearly understood the SOI and SOI forecasting, probably has moderate wealth, and has been farming for many years. He had a rotational scheme, and would only vary it slightly in response to a seasonal forecast. Of all the farmers interviewed, he was the one for whom the decision analytic approach would prove most beneficial.

Farmer 3

This farmer (Victoria) at first claimed to be less experienced (though perhaps he isn’t), and is focusing on single, up-coming decisions rather than scenario planning. He considers Yield Prophet extremely useful. Unprompted, he expressed the idea of two targets: “good average” and “poor average” outcomes. He considered that he was more risk averse following bad outcomes. He considered that there was a difference between farm planning and action. In the planning phase, the risk was like professional punting (skill present), at the action stage, it was like rolling a dice. This farmer clearly had a survival focus in mind.

Farmer 4

This farmer (Queensland) seemed very confident, close to risk neutral. He described an if-then heuristic that he applied to major farm activities. For example, he viewed activities like spraying for weeds as a simple necessity. If weeds were likely to develop then spray, irrespective of cost. He applied this if-then description to a number of situations that other farmers would have regarded as risky. He described planning in scenario planning terms, but this was real deterministic planning. He was not "sense making", but gave the impression that he had already done the sense making, and given his extensive experience (and wealth?) was simply resigned to moving the plan forward as a contingency to meet unfolding circumstances. If there was any gamble it was a calculated gamble. He approach was: "Always spray and sow a crop, some years you get nothing, but over a sequence of years you do alright." He considers SOI forecasting useless because he was going to follow his plan regardless of expected seasonal rainfall conditions. While he used heuristics, his whole approach was close to deterministic. He would sow the same proportion of his property to wheat (the main crop on the property) each year.

5. Discussion

Overall the farm interviews conducted to date confirmed two important concerns. The first was that the farmers interviewed seem to have characteristics close to the business executives of Shapira's (1995) study when it comes to making farm management decisions. That is for the most part they were scenario planning and were using causal heuristics. In terms of the Rottenstreich and Kivetz (2006) definition of decision situations as eliciting either a probabilistic of non-probabilistic mindset, the farm decisions about time of sowing and nitrogen topdressing seemed to be largely thought of in non-probabilistic terms. However, such a conclusion is so tenuous at this stage, that it could hardly be considered a conclusion, but merely a suggestion that more research is needed. This introduces the second concern.

The second concern was that much more rigour was needed in the questioning process to achieve success in a worthwhile full-scale study. Rottenstreich and Kivetz (2006) suggest an unbiased way to assess whether a decision maker is using probabilistic information is to present than with a significant problem and allow them to ask two questions about it, firstly unprompted, then prompted by listing the type of questions other people have asked in these circumstances. In the unprompted situation, there is a tendency to ask questions about non-probabilistic information. In the prompted circumstance, the decision makers acknowledge the importance of probabilistic information, and are more likely to include probability-based questions in their preferred list of two.

In a Yield-Prophet context, you would expect the provision of the type of CDF information shown in Figure 1 to prompt a probabilistic cue in memory. However, this may not be the

case. Taken together, the work of Gilboa and Schneidler (2001), Kusev *et al.* (2008) and Shapira (1995) give credence to the idea that new probabilistic information can be moulded together with experience in the mind of the decision maker in a causal heuristic interpretation of similar previously encountered situations. Whether this is the case for farm decision makers encountering Yield Prophet is worthy of further research.

6. Conclusions

As made clear in the introduction, this is a description of work in progress, and as such only tentative conclusions are possible. The empirical evidence from ten farmer interviews suggests that their mindset, in the two farm decision making contexts examined, largely involves non-probabilistic, scenario construction. This suggests that it would be worthwhile to extend the research to consider how scenario construction proceeds. This would include an investigation of: the influence of context, the types of memory cues involved, the farmer's level of expertise, understanding of probabilities, and causal heuristic rules used.

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