In Search of Effective Simulation-Based Intervention in Farm Management

[1]McCown, R.L., Z. Hochman, and P.S. Carberry

[1]CSIRO Sustainable Ecosystems, APSRU, Toowoomba; E-Mail: bob.mccown@csiro.au

Keywords: *Intervention, Soft systems, FARMSCAPE, Participation.*

EXTENDED ABSTRACT

In the era of Operations Research/Management Science that preceded the DSS, models were used by experts primarily to identify optimum actions for manager clients - "to *substitute formal analysis for intuitive judgments"* (Hutton, 1965). In the 1970's, after thirty years of clients ignoring this normative approach, the DSS was heralded as a way to use models differently (Keen, 1987) - as a *tool in* decision process rather than *proxy for* decision process. In DSS, a model was to be used by managers themselves. It was a tool to enable the manager to generate and analyse more alternatives, but not alter the use of his/her judgement in selecting alternatives and assessing results. 'What if?' became the cliché of the field (Keen, 1987).

But the DSS intervention, in practice, has fallen into the same normative trap as its predecessor—not recognising the truth in the aphorism "in theory, there is no difference between theory and practice, but in practice there is." This paper concerns the nature of this trap, an exploration of theory that explores a path around it, and some evidence that this theory can be effectively implemented by using models differently.

Central to traditional systems thinking was the assumption that practice could be designed by using good 'theory' and because the result was objective in nature, it was intrinsically superior to intuitive customary practise. This was 'normative' practice, i.e., it was deemed to be what a rational farmer-manager *ought* to do.

The emergence of the DSS in management science was seen as something of a paradigm shift by a few who actually thought about the nature of practice. Central was the recognition that some decision makers can perform well using intuition/judgment. The model of management practice implicit in the DSS assumed that managers *are* rational, recognized that this rationality is 'bounded,' and proposed that computer models could alleviate the limits of human thinking and knowledge (Simon, 1996). Although Keen (1987) attributed what theoretical underpinning of decision support systems there was to cognitive scientist Herbert Simon and colleagues, he observed that most DSS developers were quite oblivious to theory. Generally DSS developers were attracted to this activity "as a way of extending the practical application of tools, methods, and objectives they believed in." In DSS software, models (or their derivatives) of the production system were embedded in *tools* for farmers to use in interpreting their situations and evaluating alternative actions. So why have cases of impressive use and usefulness of these tools been so rare and short-lived?

The answer is complex, but components include:

1. Under normal routine practice, farmers don't feel sufficient need for outside assistance to offset the cognitive cost and inconvenience of fitting a DSS into the management system
2. Farmers feel a need for assistance when normal practice is interrupted by a problem or a significant prospect of a novel beneficial change, but about which they are uncertain.
3. Some farmers welcome opportunities to engage scientists on relevant issues when useful learning seems a possibility.

Over the past 12 years our team has been using a systems simulator with farmers and their advisers to see what it takes for farmers to value what the DSS tries to deliver. We have found that the following are important:

1. Farmers access the simulator via a scientist-mediator.
2. Simulations are conducted in discussion sessions where farmers' 'what if?' questions are answered.
3. Simulations are customized using local weather, soil, and management data.
4. Scientists' aim not to convey messages but to facilitate experiences that are valued in planning and decision making practice.

As systems scientists, we are motivated to understand in systems terms our own experiences in this work, and this paper is an attempt to do this by exploring interpretation using concepts from the 'soft systems' paradigm.

1. INTRODUCTION

In the era of Operations Research/Management Science that preceded the DSS, models were used by experts primarily to identify optimum actions for manager clients - "to *substitute formal analysis for intuitive judgments"* (Hutton, 1965). In the 1970's, after thirty years of clients ignoring this normative approach, the DSS was heralded as a way to use models differently (Keen, 1987) - as a *tool in* decision process rather than *proxy for* decision process. In DSS a model was to be used by managers themselves. It was a tool that enabled the manager to generate and analyse more alternatives, but not alter the use of his/her judgement in selecting alternatives and assessing results. 'What if?' became the cliché of the field (Keen, 1987).

But the DSS intervention, in practice, has fallen into the same normative trap as its predecessor - not recognising the truth in the aphorism, "in theory, there is no difference between theory and practice, but in practice there is." This paper concerns the nature of this trap, an exploration of theory that explores a path around it, and some evidence that this theory can be effectively implemented by using models differently.

2. THE LOGIC OF 'SOFT' DECISION SUPPORT

In thinking about decision support for farming, it is useful to think of a farm as having a *production system* and a *management system*. Although the attention of DSS developers is generally focused on models of the production system, every decision support intervention has at least an *implicit* model of the management system. One model of the 'management system' is that of intuitive decision maker in need of a more rational basis for decisions, i.e., objective information and a valid logic for inferring action from states of the world. This model legitimises an intervention strategy of provision of a proxy for the manager's inadequate efforts, a legacy of "hard systems thinking" (see Checkland, 1981), e.g., operations research/management science.

> The assumption is that the manager, without any formal analysis, is forced to use intuitive judgments in all his problem-solving activity…Our analytical models may be very roughly classified on a scale representing the extent to which they attempt to *substitute formal analysis for intuitive judgments* (Hutton, 1965).

The critique of this 'normative' intervention, i.e., what farmers *should* do, was an important element of the arguments in favour of the DSS (Keen, 1987, which introduced a new model of the management system that featured the recognition that some decision makers can perform well using intuition/judgement. This model took managers to be rational, recognized that this rationality is 'bounded,' and proposed that computer models could alleviate the limits of human thinking and knowledge (Simon, 1996). Although Keen (1987) attributed what theoretical underpinning of decision support systems there was to cognitive scientist Herbert Simon and colleagues, he observed that most DSS developers were quite oblivious to theory. Generally DSS developers were attracted to this activity "as a way of extending the practical application of tools, methods, and objectives they believed in." In agriculture, the implicit model of the management system was of a manager in need of objective information that could be generated with sound models of the production system. Models of the production system (or derivatives of these models) were embedded in DSS software. The DSS provided *tools* for farmers' interpreting their situations and evaluating alternative actions. So why have cases of impressive use and usefulness of these tools been so rare and short-lived?

We have found multiple explanations with a considerable degree of plausibility (McCown, 2002b). But none is more plausible than the explanation provided by Arie de Geus (1994). Unlike most contributors in this field, de Geus came into the field of model-based aids to decision making after a long management career in Shell Oil. He then went on to make significant academic contributions to the field of systems dynamics. In explaining managers' natural indifference to scientists' models, de Geus said:

> I have not met a decision maker who is prepared to accept anybody else's model of his/her reality if he knows that the purpose of the exercise is to make him, the decision maker, make decisions and engage in action for which he/she will ultimately be responsible. People (and not only managers) trust only their own understanding of their world as the basis for their actions. "I'll make up my own mind" is a pretty universal principle for everyone embracing the responsibility of their life, whether private or business life (de Geus, 1994).

This candid stating of what might be seen by most non-scientists as "the obvious" provides a radically different model of the management system. It represents a paradigm shift from 'hard' management models to a 'soft' one – one in which the management system is interpreted as fundamentally subjective in nature. Accordingly strategies of intervention will be successful only if they are designed to work with that reality rather than as an attempt to treat it as an unfortunate, but hopefully, interim condition. But how, you say, can a systems research enterprise that values scientific rigour embrace as normal such an interpretation of real world *practice*? The remainder of this section attempts to provide an answer drawing on recent ideas from the field of 'philosophy of mind' and on a systems field not prone to use scientific models of the world.

The philosopher John Searle has recently contributed to rationalizing the age-old human dilemma of co-existing realities – our mental and physical worlds. Searle (1992, 1998) has made an effective case for the subjective mind to be seen as an emergent performance of the neuro-physiological brain, i.e., a *biological feature* of human existence. This means that:

> Not all of reality is objective; some of it is subjective. There is a persistent confusion between the claim that we should try as much as possible to eliminate personal subjective prejudices from the search for truth and the claim that the real world contains no elements that are irreducibly subjective (Searle, 1992).

This indicates that acceptance of the management system of a family farm as inherently subjective is not corrupting of our systems methodology. But it does challenge us to think laterally about the means by which such objective models articulate with subjective systems in the world. One possibility is to look for a 'bridge' in a 'soft' systems field complementary to our 'hard' systems field (Jackson 2000). In the 1970's, Peter Checkland discovered that the inherently subjective nature of management processes were not amenable to hard systems methods and developed new theory and methods that made a formative contribution to the field of 'soft systems' (Checkland, 1981; Checkland and Scholes, 1990). What bridging role do we find here between our models and farmers' natural subjective management?

The nature of a 'soft' system can be discussed with the aid of Figure 1. The 'external world' is depicted as interfaced with an 'internal world' of management thinking.

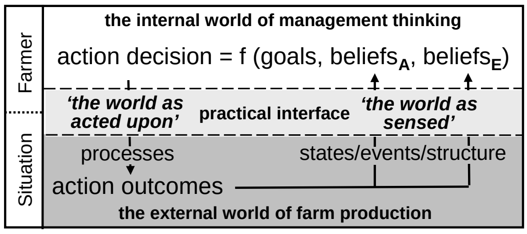

Figure 1. Farm management practice as a soft system

The farmer experiences the external world both as how it 'seems' (world as sensed) and, quite separately, as how it resists or accommodates attempts to change the situation (world as acted upon): "These two modes of apprehending structures are the warp and weft of our experience" (Simon, 1996). This *experience* forms the primary basis for de Geus's "own understanding" in management (quote above). *Scientific* understanding of just how this *subjective* understanding is formed, retained, and used is a central theme in psychology, but the specifics have proven to be extraordinarily elusive.

What is widely agreed upon is that as humans we represent our beliefs about the world and about ourselves in mental structures that have been variously termed schema, scripts, frames, mental models, concepts, and cognitive structures, to name but a few. But most significantly, there has been a recent swing from a traditional "objectivist" view of representations as "*mirroring*" the external world to a "new view" that recognizes that we represent the world to ourselves in ways that are *subjectively meaningful*, rather than merely or even primarily as objectively accurate. Meaning in such representations is structured by 'built-in' value-based interpretation in relation to purpose and action. The essence of 'soft systems' is that a manager's meaningful conceptual 'world' can be seen as having the properties that Checkland (1981) attributed to systems. It is holistic, has hierarchical features, and adapts through feedback and control. It is an "irreducibly subjective" system – a *soft* system, yet its legitimacy as 'real' is evidenced by its role in guiding *action* that *causes changes in the material world* (Figure 1).

The social science paradigm for this management behaviour is *interpretivism*. It explains human behaviour in social systems as resulting importantly from individuals interpreting situations in accordance with their beliefs and taking actions that are instrumental in achieving their desires, or goals. It is thus oriented to purposeful *action* of individuals (rather than to aggregate social behaviour that enables adaptive functioning of society, i.e. functionalist social science). Needless to say a manager's freedom of action is variously constrained by many aspects of both physical and social environments, but the representation in Figure 1 provides only sufficient structure to aid discussion of what decision support for such a soft system might entail.

Action decisions are a function of *goals* and *beliefs*. The latter are represented as beliefs about the environment relevant to action (b_E) and beliefs about the action (b_A) in relation to the efficiency and effectiveness in achieving the goal (g). Goals, b_E, and b_A serve as 'hooks' for production systems modelers. In this framework, decision support intervention can be viewed as participation by a scientist in farmers' planning practice with the aid of a flexible simulator of the production system. The aim is to assist farmers' deliberations about future actions and provide opportunity for them to alter their beliefs and goals by 'experimenting' in a virtual world.

3. APPLICATION IN FARMSCAPE

In our research with farmers, we have developed a mode of decision support that takes the form of discussion about real farming situations, aided by simulations of the situation in response to various actions proposed by farmer participants (Carberry et al., 2002). The aim is to enable 'experiences' for farmers by simulating a relevant situation that results in their reflecting on their goals and beliefs regarding the situation and the actions they are predisposed to take. Crucial to success is farmers' confidence in the simulation, and an inescapable investment is developing that confidence by comparing simulations with past events experienced by the farmers, by use of local weather records, and by specifying the simulator for present soil conditions. Most simulations are conducted to answer farmers' "what if?" questions in what became known in FARMSCAPE as WifADs ("what if" analysis and discussions). Discussions that follow the results of a simulation concern the believability of the output, the implications for action in the real world and what is revealed about how the production system 'works. ' Results of a simulation generally lead to yet another simulation in order to compare environmental states or events or alternative actions whose relevance often emerges in the discussion.

Contrary to the aim of traditional hard systems intervention, i.e., transferring knowledge regarding 'best practice', here the main aim is facilitating discussion to enable meaningful *experience* of a sort that is not readily achievable in real farming. Historical daily weather records enable realistic simulations of production over long periods. This allows exploration of the crop yield variation that constitutes statistically 'expected' climate for the future as well as comparison of yields from analogue years based on recently observed patterns in the Southern Oscillation Index (SOI). In addition, management actions and strategies whose evaluation in real world practice would be too risky or would take too long can readily be trialed using simulation.

One of the unavoidable overheads of this approach is the task of assessing the degree to which belief, goals, and actions have been altered (or deliberatively retained). In FARMSCAPE this has included entry-exit polls, written questionnaires or an open discussion of the questions following a meeting, and longitudinal in-depth interviews by an independent interviewer. Evaluations have provided a rich picture of change in beliefs, goals and actions of participating farmers (Carberry et al., 2002).

Human behaviour is sufficiently complex that it can be assumed that any theoretical treatment of it will be readily shown to have limitations. Historically, treatment of the management system (Fig. 1) in terms of transfer of objective knowledge generally missed the management reality highlighted in the quote from de Geus – "People (and not only managers) trust only their own understanding of their world as the basis for their actions." Although an *interpretive* orientation appears to be the key to effective decision support, the fact that managers sometimes see fit to adopt the objective models used by scientists must not be precluded. In FARMSCAPE, many farmers have found the researchers' soil water budget concept attractive, especially when represented as a leaky bucket metaphor. Farmers place great value on knowing the 'size of the bucket' as part of basic understanding about a specific soil, gained by ponding water in a confined area in the field (Dalgliesh and Foale, 1998). In their early enthusiasm for measuring the water content of the 'bucket' to guide planting decisions, farmers built or borrowed soil coring rigs and bought ovens and balances to measure soil water contents. In addition, after access to the simulator was discontinued at the end of the project, a number of farmers adopted/invented soil monitoring shortcuts as well as shortcuts to calculating the value of current soil water in sustaining a crop into the future and producing economic yield. In an interview ten years after the project, a farmer describing how his practice had evolved gave an example:

> "There's 30cm of moisture. The neighbours next door were out putting on fertiliser and

> ploughing fence to fence ready to go. We said forget it. We're not going to plant until we've got at least 60cm-70cm in it to go into sorghum and more for cotton. It's nice to be able to make a decision like that and walk away in confidence that you know that it's been calculated." (Farmer ten years after the FARMSCAPE experience).

In its entirety, this interview showed that new understanding - new beliefs/mental models - about soil water gained through site specific simulation of crops enabled a re-invention of the tools and technology used by the researchers, but still within the farmer's new conceptual framework of the soil water budget. It may exemplify what judge Oliver Wendell Holmes was thinking about when he said, "I don't give a fig for simplicity this side of complexity, but I would give my life for simplicity on the far side of complexity" (Hayman, 2004).

4. UNCERTAINTY – THE FLIP SIDE OF BELIEF

Figure 1 suggests that changes to a manager's action-guiding beliefs occur through experiential learning in what has been called an action learning cycle. A noteworthy feature central to commonsense understanding of successful work and life is the phenomenon that active learning takes place through 'surprises.' Conditions for changing current beliefs/understandings are created when states and/or events are sensed that deviate from what was expected on the basis of *current* beliefs/ understandings. But in stable situations associated with routine practice, observations and expectations tend to converge. In these conditions, action proceeds with minimal conscious thinking, and behaviour is described as 'habitual,' 'automatic,' 'intuitive,' etc. (Louis and Sutton, 1991). The capacity for this mode of behaviour is what novices acquire when they become experts (Dreyfus and Dreyfus, 1986).

'Automatic' behaviour is much maligned by business consultants and other interventionists because managers experiencing stable situations feel little need for outside intervention. To observers they appear 'conservative,' or worse. But the view from 'the inside' is quite different. One of our farmer colleagues when asked why more farmers don't make greater use of decision support systems replied, "You need a doctor when you are sick, not when you are travelling well enough." Being on 'autopilot' when you are travelling well enough tends to be interpreted by behavioural scientists as use of an adaptive capacity to economise the scarce resource of *attention*. In our own study of the DSS phenomenon in agriculture, we tend to attribute much of the non-use of DSS offerings to farmers' perception that they were 'travelling well enough' (McCown 2002b). Such reasoning should not overlook the fact that a DSS pertains to a very restricted element of a manager's activity system. It seems not unreasonable to conjecture that a farmer may be coping with one or another disruptive, uncertainty-creating phenomenon much of the time. But because the area of activity is ever changing, utility of a particular DSS is only intermittent. This intermittency of need for any given DSS militates against use of any at all.

Farmer-managers are receptive to decision support intervention when they face sufficient felt uncertainty. This can be created by disruption due to system failure or to awareness of system novelty that affords significant opportunity (Louis and Sutton, 1991). In its early years, the FARMSCAPE project coincided with the major novelty of dryland cotton as well as uncommonly dry seasons. We attribute much of the receptivity to what we had to offer to farmers' significant felt uncertainties. But Louis and Sutton (1991), in addition to nominating 'discrepancy' (between observations and expectancies) and 'novelty' as disruptions to "automatic cognitive activity," nominate a third stimulus to managers' new learning, i.e., contracted facilitative intervention to "focus attention" strategically. In the case of FARMSCAPE, we judge that we capitalised on all three of Louis and Sutton's factors and mostly in combination.

McCown (2005) discussed Karl Weick's insightful and practical ideas about 'sensemaking' processes in response to system disruption"

> …sense making begins with the basic question, is it still possible to take things for granted? And if the answer is no, if it has become impossible to continue with automatic information processing, then the question becomes, why is this so? And, what next? (Weick, 1995).

Weick (1995) argues that sensemaking that leads to adaptive change in the direction of system improvement can begin at either end of the learning cycle of Figure 1 -- with either belief or with action. It can be either because, as depicted in Fig. 1, there exists a mutual causality in "those situations where beliefs can affect themselves through the mediation of action, and situations where actions can affect themselves through the mediations of beliefs" (Weick, 1995). As we found in FARMSCAPE WifADs, meaningful discussions and enabling simulations can begin either with a farmer's hypothesis/speculation about weather or soils, or with a contemplated action (whose consequences could be regrettable).

Sensemaking is an evolutionary process, in which progression takes place as good-performing options are retained and disappointing ones are abandoned. Simulation-enabled WifADs are a means of substantially reducing uncertainty by enabling *virtual* experience for farmers in a 'bootstrapping' phase of change. However, a sober reality for those concerned with a sustainable means of delivery of such decision support is that subsequent *authentic* experience tends to eliminate the felt need for the *virtual* type—until the next significant disruption of practice.

In addition to a distinction between beliefs about the environment as expectations and beliefs about actions as 'theories,' a soft approach to decision support is aided by a recognition of a further dimension of belief, i.e., that of strength with which it is held, or inversely, the degree of *uncertainty*. Kahneman and Tversky (1982) distinguish between uncertainty that a decision maker can attribute to either (a) the vagaries of the external world or (b) inadequacies in their own internal knowledge. External uncertainty may be viewed in two fundamentally different ways: as *distributional* or *singular*. The former relates to history and relative frequency. The latter concerns causal systems that produce variability. This is instructive to 'modellers' supporting decision making of dryland farmers. The 'compression of time' through simulation using models of the external world and histories of weather records provides a farmer with a unique opportunity for strengthening "distributional" expectancies. For reasons explained by Einhorn (1982), *authentic* experience such as real farming does not generate good distributional expectancies. For many farmers this *virtual* experience is the first step to meaningful objective probabilities of relevant events and outcomes. In places like Australia where the SOI has forecasting skill, interventionists also capitalise on the *singular* mode of attribution by assisting farmers in assessing the value of this forecasting instrument and in interpreting the signal for particular situations (Carberry et al., 2002).

5. CONCLUSIONS

Effective simulation-based decision support using models requires adequate representations of the world. But it also requires a 'model' of management that recognises that farming action is based on farmers' own understandings. Successful intervention is about facilitating meaningful experiences for farmers that challenge/change beliefs, goals, and actions. This 'participatory approach' involves researchers joining farmers' planning practices and is a paradigm apart from the suggestion often made that the key to more effective DSSs is through involvement of farmers in the production of these products of science. The latter strategy demonstrates insufficient appreciation that "in theory, there is no difference between theory and practice, but in practice there is."

There is ample evidence that the DSS goal, so often unfulfilled, of making a difference to better farm management can be achieved by scientists with their models engaging farmers and their advisers in the practice situation. The pressing question now concerns feasible business systems for providing such interactions, and this is the focus of our current efforts.

6. REFERENCES

Carberry P., Z. Hochman, R. McCown, N. Dalgliesh, M. Foale, P. Poulton, J. Hargreaves, D. Hargreaves, S. Cawthray, N. Hillcoat, and M. Robertson (2002), The FARMSCAPE approach to decision support: Farmers', advisers', researchers' monitoring, simulation, communication, and performance evaluation, *Agricultural Systems* 74(1):141-178.

Checkland, P.B. and J. Scholes (1990), *Soft Systems Methodology in Action: Account of the Last Decades Development of SSM*, Wiley, Chichester.

Checkland, P.B. (1981), *Systems Thinking, Systems Practice*, John Wiley & Sons, Chichester.

Dalgliesh, N.P. and M.A. Foale (1998), *Soil Matters: Monitoring soil water and nutrients in dryland farming*, Agricultural Production Systems Research Unit/CSIRO, 122pp, Toowoomba, Australia.

Einhorn, H.J. (1982), Learning from experience and suboptimal rules in decision making, In: Kahneman, D; Slovic, P; Tversky, A (eds), *Judgment Under Uncertainty: Heuristics and Biases*, 268-283, Cambridge University Press, Cambridge.

de Geus, A.P. (1994), Modeling to predict or to learn? In: Morecroft, J.D.W. and J.D. Sterman (eds), *Modeling for Learning Organizations*, pp. xiii-xvi, Productivity Press: Portland, OR.

Dreyfus, H.L. and S.E. Dreyfus (1986), *Mind Over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*, Free Press, New York.

Hayman, P.T. (2004), Decision support systems in Australian dryland farming: A promising past, a disappointing present and uncertain future, *Proceedings for the 4th International Crop Science Congress*, Brisbane, Australia, 26 September – 1 October 2004.

Hutton, R.F. (1965), Operations research techniques in farm management: survey and appraisal, *Journal of Farm Economics* 47:1400-1414.

Jackson, M.C. (2000) Systems Approaches to Management, Kluwer: Boston.

Keen, P. (1987), Decision support systems: The next decade, *Decision Support Systems* 3:253-265.

Kahneman, D. and A. Tversky (1982), Variants of uncertainty, In: Kahneman, D., P. Slovic, and A. Tversky (eds), *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge University Press, 509-520, Cambridge.

Louis, M.R. and R.I. Sutton (1991), Switching cognitive gears: From habits of mind to active thinking, *Human Relations* 44:55-76.

McCown, R.L. (2002), Changing systems for supporting farmers' decisions: Problems, paradigms, and prospects. *Agricultural Systems* 74(1):179-220.

McCown, R.L. (2005), New Thinking about Farmer Decision Makers. *In: The Farmer's Decision: Balancing Economic Successful Agriculture Production with Environmental Quality*. J.L. Hatfield (ed.) Soil and Water Conservation Society, 11-44, Ankeny, Iowa, USA.

Searle, J.R. (1992), *The Rediscovery of the Mind*, MIT Press, Cambridge, MA.

Searle, J.R. (1998), *Mind, Language, and Society*, Basic Books: New York.

Simon, H.A. (1996), *The Sciences of the Artificial*, 2nd Ed., MIT Press, Cambridge, Mass.

Weick, K. (1995), *Sensemaking in Organizations*, Sage, Thousand Oaks, USA.