

Re-inventing model-based decision support with Australian dryland farmers. 1. Changing intervention concepts during 17 years of action research

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Abstract. The idea that simulation models of agricultural production can serve as tools for farmers remains a compelling idea even after 3 decades of mostly disappointing development efforts. This paper is the first in a series that reports on 17 years of systems research that used models differently from the Decision Support System idea that has dominated the field. The starting point of FARMSCAPE (Farmers', Advisers', Researchers', Monitoring, Simulation, Communication And Performance Evaluation) was finding whether farmers could value simulation when conditions for appreciation were improved by (a) specifying the simulator for individual paddocks in question and (b) delivering customised simulation to decision makers as a supporting service rather than software as a decision support product. The first aim of the program has been to learn how to effectively intervene in farm management practice using complex, abstract models of croplands, specified with local soil, climate, and management data. The second aim has been to learn how a resulting service that farmers value can be delivered cost effectively by a third party.

This first paper deals with an aspect of the first aim, i.e. valued decision support intervention. In the terms used by Checkland (1981), the activities that served this *systems practice* aim were guided by 'what we *thought* we were doing' in intervening in farmers' practice, i.e. our *systems thinking*. This first paper concerns FARMSCAPE *systems thinking* and how it evolved over 17 years as we learned successively through discovery of a new concept or representation in the literature to overcome limitations of the then-current conceptual framework. Subsequent papers deal with customising scientific monitoring and simulation for farmers, communication as engagement in situations of practice, understanding decision support intervention as facilitation of personal knowledge construction, and piloting commercial delivery of a simulation-based service to farmers and their advisers.

Additional keywords: simulation, soft systems, participatory research, implementation, APSIM, FARMSCAPE, Yield Prophet.

Introduction

This is the first paper in a series concerning an 'experiment' in providing scientific support for farmers' planning and decision making based on localised and customised simulation. This experiment began in 1992 and has continued to the present. The central questions of this 'experiment' have been, first, whether, and under what conditions, farmers can value simulation as an aid to their management and, second, how might services for a resulting market be provided. These questions stemmed from what seemed to us to be lack of a market among farmers for model-based Decision Support System (DSS) software. When we began, DSS development activity was at its zenith, and our research stance seemed to many colleagues to be altogether too pessimistic. But a decade later, in spite of extraordinary increase in the farming community of computer ownership and use, discussion of DSSs

for farmers was mainly in the past tense. Study of the rise and demise of the DSS and of the histories of significant precursors as a source of lessons became an important part of our research on a new approach (McCown 2001b, 2002a, 2002b, 2005; McCown *et al.* 2002, 2006; McCown and Parton 2006).

The FARMSCAPE research program began as an early initiative of the Agricultural Production Systems Research Unit (APSRU), formed in 1991 as a joint effort between the, then, Queensland Department of Primary Industries and CSIRO's, then, Division of Tropical Crops and Pastures. APSRU brought together 3 crop–soil management research teams whose main scientific tool was simulation modelling. The timing coincided with proliferation of powerful portable computers, a high level of funding for DSS development in Australia, and the early success of Wheatman, a local DSS

(Hamilton *et al.* 1991; Woodruff 1992; Hayman and Easdown 2002). There was high expectation in APSRU's parent organisations that this new group would become a leading producer of DSSs that were useful and used. This produced a high sense of 'mission' within the new research team.

This decision support mission of APSRU became complicated within the first year as the result of consultations with farmers. The initial disruption to researchers' unified thinking came in a 3-day workshop with leading farmers and advisers/consultants (Cox 1991). This provided unhurried discussion of practitioners' views of their decision making situations, procedures, and perceived needs. APSRU researchers presented their vision for cropping systems modelling and decision support for dryland farming. At the end, farmers were distinctly unenthusiastic about APSRU's proposed plans and strategies, and APSRU researchers were divided in their responses to this shock. This division led to 3 parallel lines of research: production of decision support systems that researchers judged to have potential usefulness (e.g. Dimes *et al.* 1996); study of farmer decision making processes (Cox *et al.* 1995); and on-farm research with farmers to ascertain under what circumstances, if any, farmers could find value in the simulations that researchers judged *should* be useful in decision making. This present series of papers concerns this third research program, summarised by Carberry *et al.* (2002).

Although we were greatly sobered by the scepticism of our potential clients, we noted that farmers and advisers did not disagree with our claim that their decision making was impaired by their uncertainty about crop water supply, mainly due to seasonal variability of rainfall, but also to difficulty of knowing stored soil water status. We believed that the information and insights provided by simulations using cropping systems models specified for local soil properties and measured conditions and using local historical weather records *should* profitably reduce this uncertainty. We had a rapidly growing capability for simulating cropping systems and a systems research culture focussed on better system performance in terms of benefits to farmers.

There was nothing novel about researchers with models engaging farmers and their advisers. Many of the better DSS development efforts have included extensive involvement of clients, in the interest of achieving software design that would eventually be used and useful (e.g. Landivar *et al.* 1989; Hayman and Easdown 2002). But the 'engagement' aim of FARMSCAPE was different in that there was no software product designed for farmers to use directly. Instead of a focus on a user-friendly software product, the focus was on creating conspicuous value to farmers through the use of tools that were clearly valuable in research and which seemed to the researchers to be of potential value to farmers in some yet-to-be-determined form. The farm management issue judged to be of central importance by the researchers has been the extreme uncertainty of production in dryland grain-growing regions of Australia due to variability and unpredictability of rainfall. The researchers believed that their cropping systems models could generate predictions of events

and action outcomes that *should be* useful in practical farming. But farmers, in general, were very sceptical about the relevance and significance of such technology for them. The tendency of farmers to dismiss computer models as 'toys for scientists' indicates the challenge we faced.

Our strategy was to engage farmers and advisers in their planning situations with the initial goal of finding *one* farmer who could become enthusiastic about the value of localised, paddock-specific simulation for thinking about management actions. However, after gaining a degree of confidence that this goal had been exceeded, a more ambitious goal was set. We sought (a) knowledge of the essential differences between scientists' understanding of farm decision making and farmers' practical knowledge and (b) the implications of differences for effective engagement and beneficial intervention in practice. Carberry *et al.* (2002) summarised what we actually *did* in the research program, which came to be known as FARMSCAPE (Farmers', Advisers', Researchers', Monitoring, Simulation, Communication, and Performance Evaluation). FARMSCAPE has been, first, about reinventing the concept of computerised support for farmers' management decisions *via* 3 innovations. These were (1) specifying the simulator for states of the paddock in question, (2) using the simulation model interactively in discussions aimed specifically at generating value to farmers and their advisers, and (3) design and development of simulation software that suits this mode of flexible and responsive use. Second, the program has been about ways to establish commercially viable mechanisms for delivery of a service based on this way of using this technology. In the terminology of Checkland (1981), the several succeeding papers in this series provide a comprehensive treatment of the research conduct—our 'systems practice'—and outcomes. The present paper focusses on concepts of *what we thought we were doing* and how these changed as we learned—our 'systems thinking'.

Getting started

Carberry *et al.* (2002) refer to our initial phase of work, 1992–95, as 'pilot on-farm research'. In this period of activity we were guided by our understandings of two 'systems' concepts: 'operational/operations research' (OR) and 'farming systems research' (FSR). OR, the application of formal scientific and economic models to planning of operations, had been a significant phenomenon in the management of large organisations following WWII (McCown 2002a). We were students of the OR-stimulated application of dynamic simulation models to issues of Farm Management, led by agricultural economists (Dent and Anderson 1971; McCown and Parton 2006)¹. In the dryland farming environments in which we were working, simulation of performance in all years of weather records provided a unique means of evaluating the risky prospects of a new cropping practice (Carberry *et al.* 1991, 1996; Carberry and Muchow 1992).

We had been students of FSR as a systems methodology that addressed the challenging issue of the 'relevance gap' between

¹We later learned that agricultural economists had applied OR's economic optimising models to farming well before 1950 (Case and Williams 1957; McCown *et al.* 2006) and that even the idea of the dynamic simulation model was imported from OR in the 1950s by agricultural scientists working on time-dependent processes of environment and production (interview with C. T. deWit; McCown 2002a, p. 13).

research about farming and the practice of farming by conducting research in farmers' fields in close conjunction with farmers and construing inquiry in terms of system needs and opportunities from the *practice* perspective (McCown 1989). Although we were actively combining this approach with an OR-style of model use, we were unaware of any abstract representation that integrated OR and FSR. It was apparent from the literature that these systems approaches were practiced in very different settings and scientific communities with rare reference in FSR literature to OR, an exception being Shaner *et al.* (1982). We later learned that FSR had blossomed at a time when many agricultural economists had become disenchanted with the OR idea of models for management (McCown *et al.* 2006) and joined the fledgling FSR movement as an alternative 'systems' idea (Norman 2000; McCown and Parton 2006). However, discovery of a paper by Anderson *et al.* (1985) eventually provided the conceptual 'leg up' we needed. They adapted a much re-used figure of Collinson (1982) depicting the FSR research process (Fig. 1). Their contribution to our thinking was their introduction of OR activity in the so-called 'Planning' stage of FSR (Tripp and Woolley 1989) as the link between on-farm and on-station research.

This became the basis of our first conceptual framework for reflecting on and communicating our systems methodology (e.g. McCown *et al.* 1994) and was customised to depict the strategic structure of APSRU (Fig. 2). This re-depiction of FSR as providing model-base decision support was the centrepiece of APSRU's Board-approved initial Strategic Plan.

We began by negotiating arrangements with individual farmers in 3 farmer groups for collaborative research on ways to improve production efficiency and to reduce production risk in relation to soil water and nitrogen. On a sample of fields, chosen partly for the learning potential their history contributed, the researchers would facilitate 'looking closely' at soil water and nitrogen dynamics in relation to weather, soil type, and past cropping activity. In some cases, this amounted simply to monitoring soil water and nitrogen under commercial crops and intervening fallows; in others, an additional dimension of inquiry was added by superimposing field strips of management

treatments the width of a single pass of the farmer's machinery for comparison with the overall 'treatment'. In these negotiations, in addition to offering our specialised capability for soil sampling and analysis, we offered our capability for augmenting these studies with simulation modelling, which, we argued, enabled 'expanding' field studies from a single season or year to periods as long as the record of local daily rainfall and to additional management actions. Farmers welcomed the soil-related offer and declined the simulation offer. A typical response to the latter was, 'If you blokes are interested in that, that's o.k., but it's not something that I can spare time for'. This was a serious threat to the ultimate aim in our 3-pronged research strategy, of demonstrating relevance of simulation (Carberry *et al.* 2002), i.e.

- (1) collaborative experiments with farmers and their advisers in commercial paddocks on issues they identified as important;
- (2) monitoring the state of the major production variables of climate, soil water, and nitrogen; and
- (3) using simulation models to go beyond the experiments in generating yield expectations and exploring the issues and options of interest to managers.

In line with farmers' preferences, work began on aims '1' and '2', but with the data collected both to elucidate the management situation in ways directly valuable to the farmers and to enable relevant simulations if and when opportunities with farmers arose ('3' above).

One early achievement of the pilot on-farm study was providing farmers with the opportunity to examine soil to the full depth of rooting of their crops. Researchers were impressed with farmers' confessions that they knew so little about the resource they appreciated as the key to their enterprise. There was also surprise at the amount of time and attention farmers committed to the activities of sampling soil to depth in study paddocks and in characterising soil water storage properties (Dalglish *et al.* 2009, this issue, Paper 2). While farmers were familiar with the easily accessible near-surface properties of their soils, it was a new experience to examine and handle soil from

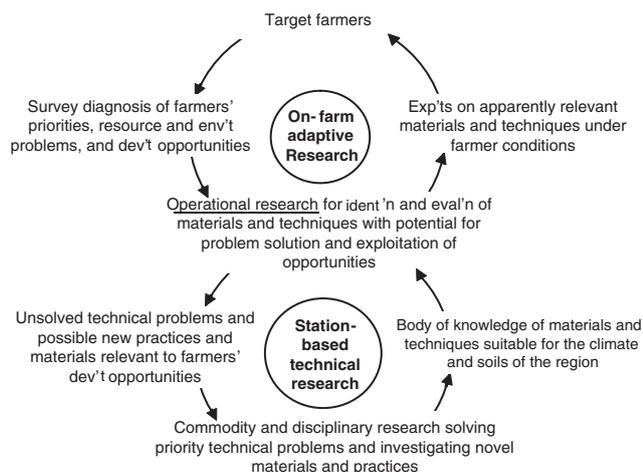


Fig. 1. A model of farming systems research (from Anderson *et al.* 1985, adapted from Collinson 1982).

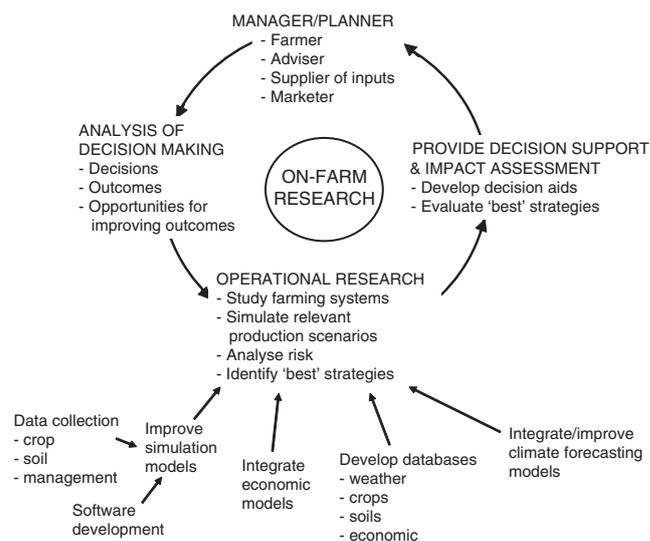


Fig. 2. A framework for using models in farming systems research.

cores taken to 1.8-m depth. Crop roots were apparent in soil over 1 m deeper than depths expected by many farmers.

Such *discovery learning* (Kolb 1984; Roling and Jiggins 1998, p. 295) was augmented by meetings where scientists shared their representations of soil data and interpretations and implications were discussed. Importantly, the scientists graphically represented and explained their conceptual models of cycles and budgets of water and N. At the end of the season, interest focussed on accounting for differences in crop yields between treatments or sites and between what was measured and what farmers had experienced in other years. This was the context that provided the opportunity for re-introducing *simulation* to the discussion as a tool for relieving the quandary about the results from a single season in a highly variable climate. Carberry *et al.* (2002) described a notable 'breakthrough' event that warrants repeating here.

This initial meeting was held in farmer Ross Skerman's kitchen and also involved John Marshall, a local extension agronomist. The agreed purpose of the meeting was to review the on-farm trial results from the previous year's (1992–93) dryland cotton crop. Two issues were of interest from this trial. The first was to review the risky decision to plant cotton very late (1 December 1992) on low starting soil water (52% of available soil water capacity). The second concerned the impact of a large 'bulge' of mineral nitrogen discovered at depth below this crop through soil monitoring. Neither Ross, John, nor we researchers had expected 330 kg ha⁻¹ of nitrate-N to be present under a crop on which we had imposed a nitrogen application trial!

While Ross and John were initially sceptical about how much added value might come from running a computer model 'on the kitchen table', they patiently accommodated the idea. The session started with benchmarking the performance of the dryland cotton crop which yielded 1.9 bales ha⁻¹ – the yield simulated at that time was 2.2 bales ha⁻¹. Pre-run simulations (done in preparation for the meeting) were presented to demonstrate no benefit from applying fertilizer to this crop with its large mineral N bulge at depth. Then, it happened. Ross asked that first important question: '*I wonder what would have happened if I could have planted my cotton at a more preferred time (early October)?*' We did the run – the simulation showed a higher yield for earlier planting in that season. Ross then followed on by inquiring '*I wonder how often a late cotton planting would succeed?*'. The WifAD [What if? Analysis and Discussion] was born with the response of '*Hey, let's use the model to explore that question – we can take the last 10 years of your rainfall record and run the model to see what would have happened with late planting over the past 10 years*'. From then the questions flowed: '*How would sorghum compare for December planting dates?*'; '*At what date should I switch from cotton to sorghum?*'; '*How would the result change if I had higher starting soil water?*'; '*What if I had fallowed that paddock through to a winter crop?*' and so on for the next three hours. That first session only stopped due to the mental fatigue of the computer operator who had

been cajoling his 'unfriendly' models to be responsive to increasingly complex questions.

That first 'kitchen table' session was followed quickly by others, which stimulated similar reactions from farmer and adviser participants.

This was a turning point in our systems *practice* and the start of a paradigm shift in our systems *thinking*. As can be seen in Fig. 2, even though we had radically changed the setting in which we used our models, we continued to construe what we were doing with them as 'designing best practice'. Such design is based on what Checkland (1981) called 'the logic of the situation', a characteristic of the 'hard' systems thinking of OR. But it is clear from the above narrative that what was happening in the interaction with the farmer and consultant was not this at all, but rather the enabling of these practitioners to conduct relevant 'experiments' to answer their very situated management questions. The dialogical nature of the interaction meant that the participants were progressing in their understanding through successive cycles of knowledge construction, each starting where the last one left them. The knowledge being created was not primarily the 'public knowledge' characteristic of science that might then be applied to practice. It was instead, primarily *personal* knowledge of a participant that was meaningful to his/her future practice. But it wasn't simply 'subjective' knowledge, because what was happening was shared and 'negotiated' through discussion. Carberry *et al.* (2002) commented that this was the birth of the WifAD (discussed in the following section), but it also marked our entry to a new paradigm of 'soft' systems thinking.

Soft systems thinking is a form of systemic thinking that understands [perceived] reality as the creative construction of human beings. It sees...reality as the construction of people's interpretation of their experiences. [] Soft systems thinking is concerned with situations as they are defined through action... (Flood 2001, p. 137).

In the period (of years) when this event took place we were being exposed to the 'new' ideas of Soft Systems Methodology and Action Research. The effect of this on our thinking was influenced by it taking place in an environment of contention and conflict stimulated by local post-modern critique of traditional 'hard' science, a widespread phenomenon in the early 1990s. Although we resisted the admonition from critics to leave our computers in our offices when we engaged farmers (Carberry *et al.* 2002), we were stimulated to read literature being championed by our critics. Our thinking was especially influenced by Peter Checkland's arguments and his story of the use of action research in the development of Soft Systems Methodology (Checkland 1981; Checkland and Scholes 1990). We elaborate this influence on our work in the next section.

While the experience related above was a turning point in our systems *thinking*, it was also a significant milestone in our pragmatic pursuit of better systems practice: 'what works' in using models with farmers. Formal evaluations based on interviews with participants provided abundant evidence of change in the attitudes of farmers and their advisers towards soil monitoring and simulation (Carberry *et al.* 2002). Comparison of the objectives of the pilot on-farm research

with those of the succeeding FARMSCAPE Phase 1 (1995–98) (Carberry *et al.* 2002) provides further interesting evidence when it is recalled that our dual objectives were to first find out ‘what works’, and if something did, to then find a way for it to be delivered as a product/service to farmers and consultants. Whereas expectations implied in the initial objectives were not much higher than the establishment of a new respect for models, what followed was an optimism that delivery of a service could be provided by consultants trained in model use and soil monitoring.

Action research

The first research that was called action research (AR) was conducted by the psychologist Kurt Lewin in the 1940s. In Lewin’s action research the researcher negotiated his/her inclusion in the activities of a group of practitioners and utilised the accessibility to the situation and ‘insider’ perspective to study the group’s behaviour and processes. However, without qualification, today, the term *action research* applies to a diverse group of methods of participatory social inquiry held together by a more or less common humanistic philosophy (Reason and Bradbury 2001). Whereas scientific research aims to generate publicly testable propositions about the material and social worlds, action research is a disciplined approach to intentional ‘learning from experience’ in activities generally shared with others. Knowledge produced, e.g. about a new technology, is not accessible for rigorous testing by non-participants, but for participants, the shared experience is not just subjectively meaningful, but it gains from discussion a degree of epistemic rigour². For scientists engaged in decision support research, action research provides a methodology for learning about phenomena that are peculiarly ‘human’, to which formal experimentation and ‘hard’ systems analysis are inapplicable. The need for this alternative methodology arises when important functional elements of the system of concern are inherently subjective, a state of *awareness in the world* that scientists have traditionally confused with ill-disciplined description of the world.

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, p. 19).

It seems to be an objective reality that much of our behaviour, as human beings, conforms to our personal *subjective* understandings. For FARMSCAPE research on decision support intervention, a new objective reality was that managers make decisions in keeping with their own subjective understanding of their situations; not because they do not know any better, but because such behaviour is indicative of the competent and responsible self-efficacy expected of successful managers.

This soft systems stance contrasts with that of hard systems in which a DSS is designed to serve as a rationalistic replacement

for farmers’ intuitive decision procedures. While the DSS field was dominated by this *hard* notion of ‘knowledge transfer’ or ‘technology transfer’, a profound transformation in thinking and practice was taking place in the psychological and educational professions and, to a lesser, but significant, extent in management science. In the alternative *constructivist* view (Boudourides 1998), knowledge is actively constructed by the participant, *facilitated*, rather than *transmitted*, by the interventionist. The practical implications of this change of paradigm for those concerned with decision support for farmers are reinforced by observations from ‘inside’ practice, e.g. from Arie de Geus, a notable oil industry manager and sometime academic.

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, p. xiv).

During this period, traditional Australian agricultural science was being challenged by the claim that technical intervention in farming should be *person-oriented*, based on action research and soft systems thinking (e.g. Bawden 1991; Bawden and Ison 1992; Ison and Ampt 1992). Extension staff, newly equipped with post-graduate training in soft systems methodology, were exerting a reforming influence in our local research community in Queensland (Blackett 1996; Hamilton 1998). It was a time of fierce contesting of ideas and values even within our own team (Ridge and Cox 2000). In reflection, our awareness and appreciation of action research and soft systems were enhanced by this debate, in spite of its antagonistic nature. The antagonism concerned the critique of our approach on the grounds that engagement with farmers aided by hard scientific models was philosophically incompatible with a soft intervention approach.

Our new understanding was that opportunities for more effective support for management decisions lay in new ways of using our scientific knowledge and tools to influence (a) managers’ subjective understanding of their situations and (b) their practices. We adopted action research, as espoused by Checkland, as a basis for research on *whether* and *how* simulation could be valued by farmer decision makers.

The concept of action research arises in the behavioural sciences and is obviously applicable to an examination of human activity systems carried out through the process of attempting to solve problems. This core is the idea that the researcher does not remain an observer outside the subject of investigation but becomes a participant in the relevant human group. *The researcher becomes a participant in the action, and the process of change itself becomes the subject of research.* In action research the roles of researcher and subject are obviously not fixed: the roles of the subject and the practitioner are sometimes switched: the subjects

²When a statement of belief, not fully substantiated as a true fact, survives critical discussion, (philosophically) it achieves some of the (epistemic) status of a *fact*.

become researchers... and researchers become men of action (Checkland 1981, p.152, emphasis added).

It was illuminating for us to learn that AR and participatory principles were having a profound effect on the on-going evolution of FSR. The increasing centrality in FSR of the human side of practice—its ‘situatedness’—was reflected in a series of name changes: from Farming Systems Research to On-Farm Client-Oriented Research (OFCOR) (Merrill-Sands and McAllister 1988), Participatory Action Research (PAR) (Whyte 1991, 1997), and Farmer Participatory Research (FPR) (Okali et al. 1994). Van Eijk saw this as ‘a gradual shift in paradigms’ as farming systems researchers came to recognise that

... only farmers can bring realistic ‘holism’ to a research project... ‘Technology’ is only part of the story. Important political, social, and the religious concerns affect farmers, who must weigh technologies within a broader framework of ‘life’ (van Eijk 2000, p. 324, quoting Rhoades 1994).

Whereas Figs 1 and 2 represent the notion of simulation modelling and OR within FSR, Fig. 3 marries this with action research. Models of cropping systems and methods for specifying are developed in *Conventional research*. In *Farming Systems Research*, these are taken on-farm to simulate performance of individual paddocks in response to environmental and management perturbations. A gain in relevance is accompanied by reduced rigour due to reduced control of conditions (Fig. 3). This provides grounds for complementing attempts to implement conventional research methods with an action research strategy. However, the aim is still design of ‘best practice’ based on evidence that is as objective as possible. Whereas this ‘localisation’ remains a *hard* systems methodology, when it is used as a tool for facilitating experiential learning rather than for design of best practice, it qualifies as *Participatory Action Research* (Fig. 3), a *soft* systems methodology.

In summary, two variants of AR have been important in FARMSCAPE intervention. Participatory Action Research features the facilitation by interventionists of novel experiences for *farmers* that lead to relevant knowledge construction in

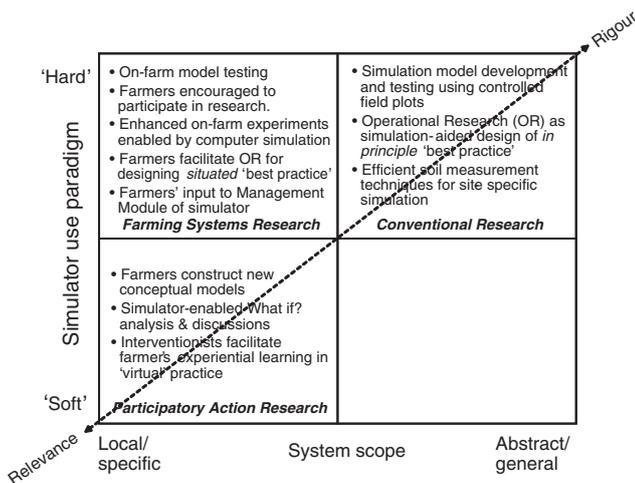


Fig. 3. A framework for complementary types of research culminating in local, relevant decision support (adapted from McCown 2001a).

practice (or virtual practice), and is discussed in later sections of this paper. The other AR role has a focus on the knowledge construction by *researchers* through ‘what works?’ in the ongoing experiment in using simulation modelling with farmers in their decision situations. The outstanding example in the literature of this latter role for action research is in Peter Checkland’s development of Soft Systems Methodology (SSM) (Checkland 1981; Checkland and Howell 1998).

Checkland’s version of action research has special appeal to members of a science research culture. Checkland, himself, was trained in natural science, and was concerned about the loss of investigative rigour implicit in opting for action research on ‘soft’ systems. He argued that loss of rigour was too great without the declaration of an intellectual framework for the activity, a framework that can be discussed and publicly criticised. In Fig. 4, ‘M’ is the methodology of intervention to influence ‘A’, an area of practice, while ‘F’ is a framework of ideas that serves as a surrogate for a scientific theory or hypothesis concerning the problem area and the intervention.

Action Research and its many variants are increasingly being treated as serious and appropriate alternatives to the hypothesis testing which is at the core of research methodology in natural science. But proponents of Action Research need to recognise the limits to the claims they can make for the validity of their approach. Unable to match the complete replicability of experimental happenings which characterise natural science, researchers investigating social phenomena via Action Research must at least achieve the situation in which their research process is *recoverable* by interested outsiders. In order to do this it is essential to state the epistemology (the set of ideas [F] and the process in which they are used methodologically [M]) by means of which they will make sense of their research, and so define what counts for them as acquired knowledge. This gives well organised Action Research a ‘truth claim’ less strong than that of laboratory experimentation, but one much stronger than that of mere ‘plausibility’, which is all that much putative Action Research in the literature can claim (Checkland and Howell 1998, p. 20).

In FARMSCAPE, our core M featured researchers using innovative soil characterisation, local soil monitoring

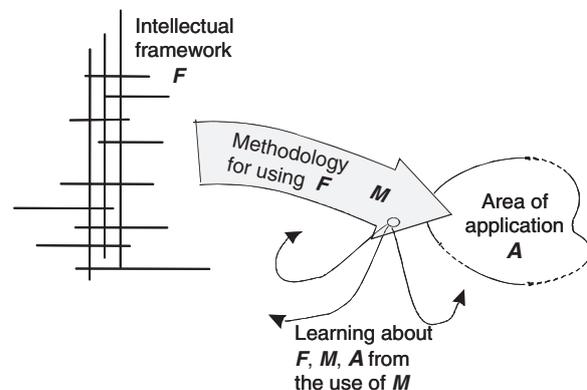


Fig. 4. A methodology based on Action Research for developing intervention methods (from Checkland 1981).

(Dalglish *et al.* 2009, this issue), and customised simulations (Carberry *et al.* 2009, this issue) in farming practice situations (A) with farmers and their advisers. Our M was continually being adjusted as we learned from the response of participants to our offerings in real problem situations in A. This cycle of adjustment of M from research experience in A was action research of the conventional type of which Checkland was critical. Our first F (hereafter referred to as a 'Framework') was 'OR in FSR' (Figs 1, 2). This is 'what we thought we were doing' in our intervention. This was 'theory' that was useful in framing plans and evaluations and for communication with others in the systems research community. But 'OR in FSR' was followed by a succession of Frameworks that trace our learning. A change event could be a modification of an existing Framework or it could be addition of a new one. This evolution was the result of a combination of our experience and discovery of relevant concepts and others' experiences in the literature. The remainder of this paper concerns concept changes together with data from the farmer-adviser-researcher interaction experiences, interpreted either as supporting the validity of a current Framework or revealing a limitation.

A succession from Frameworks in FARMSCAPE

From 'OR in FSR' to Participatory Action Research

The first major change in our Framework followed from the experience of Carberry *et al.* (2002), reiterated in p. 1020 above, in which the simulator enabled farmer discovery learning rather than enabling researchers' design of best practice for farmers. This was a shift from the upper left quadrant to the lower left quadrant in Fig. 3, capitalising on the previous step of situating the systems analysis and simulation at a specific physical location and soil conditions. While this was a big step in making simulation relevant to the farmer, Participatory Action Research (PAR) went further by situating it in the farmer's personal planning activity as an opportunity for relevant learning.

In Fig. 3, the notion of 'participation' takes two forms. One is solicitation of *farmers' involvement in research* to design best practice. The aim is to use farmers to ensure relevance of the research and to develop a sense of their ownership of the research, in the *research* domain. The second form is when researchers *effectively* join farmers' practice (as per above quote from Checkland 1981), and they enter the *farming* domain, and to some extent, the *lifeworld*³ of the farmer (McCown 2005). This is the experienced, subjective, world of a farmer. Understanding and learning in the lifeworld is subjective. Intervention that facilitates such learning is 'soft' (Fig. 3, Participatory Action Research). Although the semantic difference in these two forms of 'participation' is subtle, they are paradigms apart. One is about research to design objectively superior practice; the other is about facilitating subjective experience of novel processes and outcomes that are subjectively evaluated *in practice*.

The primary aim of FARMSCAPE was to learn how to intervene in practice situations to facilitate farmer decision and

learning, and evaluation was primarily in terms of changes in farmers' thinking, intended actions, and actual actions. The learning cycle of the *researchers* that underlies evaluation and evolution of their action research Frameworks consists of: plan, act, observe, reflect. Although this is unavoidably the subjective 'trial and error' procedure through which we all learn in deliberative action/practice, when used by professional scientists it is fundamental that the process be made as objective as possible. Checkland's Framework contributes to this by providing something like a scientific hypothesis subject to criticism, revision, and falsification. A second practice that contributes to this in action research conducted by a team is the *discussion* by which plans, observations, meanings, and learning become 'public', are subjected to criticism and, thereby, become more objective (Popper 1994, p. 13).

Figure 5 (from McCown *et al.* 2003) depicts the iterative nature of FARMSCAPE action research in the first few years, in which on-farm experimentation was central.

FARMSCAPE as multi-paradigmatic multi-methodology

Prior to the 1990s, the idea of paradigm change meant contention, displacement, and substitution, e.g. Burrell and Morgan (1979). But during the 1990s, it became permissible, at least among management interventionists, to think of paradigms as *complementary*, able to be combined in ways that provide the most complete functionality of available theory (Flood and Jackson 1991; Mingers 1997). In FARMSCAPE, the methodology appropriate for analysis and simulation of production systems was that of hard systems (Checkland 1978, 1981). The methodology appropriate for engaging farmers in their management situations was a soft systems methodology. The combination of these in FARMSCAPE (McCown *et al.* 1998) is depicted in Fig. 6.

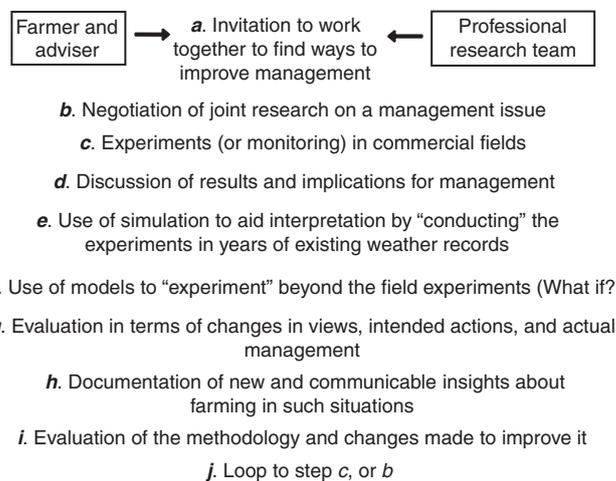


Fig. 5. The action research cycle of FARMSCAPE during an early stage of FARMSCAPE.

³As people develop ways of conceptualizing and acting toward the world, they begin organizing their lives around those particular themes and practices. These 'life-worlds', 'ways of life', 'social worlds', and the like, are important since they entail the stocks of knowledge, frames of reference, and senses of direction that the people constituting this and that community take into account in developing their lines of action (Prus 1996, p. 248).

Three activity domains are distinguished: farm management, hard systems, and soft systems. The numerical ordering of activities to aid presentation here over-stylises what is in practice a flexible, responsive system. Parts 'a' and 'b' are linked by box 6. Intervention begins with a real farm problem that is often unstructured and under-specified (box 1). The problem's nature and significance warranting attention are negotiated by farmers, their advisers, and researchers (box 2). This often leads to joint on-farm activities (box 3) in fallows, commercial crops, or in trial 'strips' imposed on commercial crops that involve 'looking closely', augmented by deep soil coring and measurement of water and nitrogen profiles, the results of which are discussed in group meetings. Preparatory to simulations (box 5), soils are characterised with respect to water storage capacity, organic matter content, and subsoil constraints (box 4) (Dalglish *et al.* 2009, this issue, Paper 2).

Simulations are conducted with farmers, who specify prices and nominate the management settings and rules, lending a *soft* (personal, situated) aspect to simulation which uses *hard* systems models. This technology enables 'what if' analysis and discussions (box 6) focussed on pertinent problems or issues in the local physical and human context. Farmers and advisers go back to the real world of farm management action where they plan (box 7) and act (box 8). The degree that this can be attributed to FARMSCAPE interactions is monitored in the evaluation component of the research (box 9). A secondary outcome of WifADs (box 6) is feedback that leads to improvement of the simulator and/or the data for specifying the simulator (box 10).

An important implication of the pragmatic philosophy that condones multi-paradigmatic multi-methodology is that a useful Framework is eventually and inevitably recognised to be too *limited*, and a less limiting representation is sought. Advances are made by complementing a limited Framework with a new one rather than replacing the old one. A suite of complementary conceptual frameworks is accrued, and there is a degree of

redundancy among frameworks. For example, in Fig. 6, the legacy of 'OR in FSR' is apparent in 'hard systems', and an action learning cycle is implicit in the 'loop' from activity 9 back to activities 1 and 2.

The farm as a system containing a 'soft' Management System

In our early efforts to find a better way to support farmers' decisions, we had two themes which we were trying to bring together: on-farm action research to achieve relevance to farming practice and models that demonstrably aided farm management. It was some time until we discovered a similar effort. Sorensen and Kristensen (1990) described their group's approach to achieving more realistic simulation of animal production systems in Denmark. They construed the problem they faced as one due to the progression of agriculture in the 1990s beyond the need for models to optimise efficient management choices to a need for realistically capturing in models how good managers were adapting to the new regulatory environment driven by new environmental and food safety concerns. Importantly, they saw farm management knowledge as mainly acquired/validated *in practice* and, hence, fundamentally subjective. Modellers could tap into this only through on-farm engagement in discussion and description. As in FARMSCAPE, they were concerned with scientific models being relevant to specific farming situations by being realistically specified using on-farm measurements, an investment rarely made by those who have applied simulation models to agricultural production systems⁴. However, the Australian researchers targeted participating farmers and their advisers; the Danes targeted advisory and policy professionals. In spite of this difference in perceived clientele, the key representation of Sorensen and Kristensen filled an important gap in our conceptual thinking and led to a new FARMSCAPE Framework.

What appealed to us was the *cybernetic* structure that showed subjective management as control-and-feedback

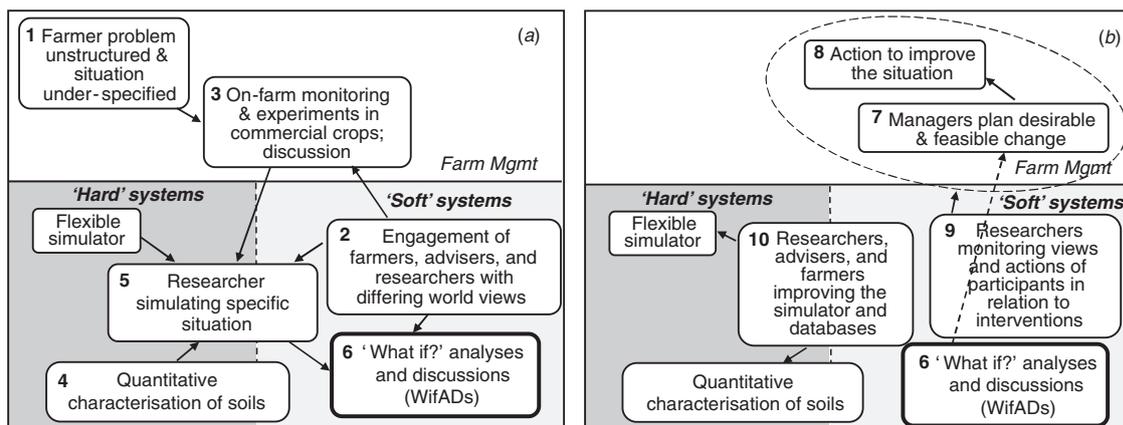


Fig. 6. A map of FARMSCAPE multi-methodology inspired by Fig. 6 in Checkland (1981). Stages 1 and 2 are linked by activity 6 (from McCown *et al.* 1998).

⁴Notable exceptions in Australia were the efforts of HowWet developers to link water balance to field infiltration measurements (Hamilton 1998) and the use of grain yield and protein as a bioassay for N status in WHEATMAN (Woodruff 1992).

communication. This structure was congruent with FARMSCAPE participatory action research, both in recognition of practice being subjective, and also in the teleological dialectic between action and learning through system feedback. We could simulate the relevant Production System, and our challenge was to relate this usefully to the Management System (Fig. 7). As students of the earlier Farm Management enterprise (McCown and Parton 2006; McCown *et al.* 2006), we were acutely conscious that those economists who had used abstract models of the *Management System* to optimise farmer action in a situation had ultimately failed the test of relevance to real managers in applying their models in management interventions. We were committed to *engagement with* those in the Management System rather than to simulating their behaviour. This engagement took mainly two forms: enhanced soil monitoring techniques (Dalglish *et al.* 2009, this issue, Paper 2) and meetings of farmers, advisers, and researchers. The meetings featured virtual experiments using the production system simulator for ‘what if?’ analyses and discussions (WifADs).

Sorensen and Kristensen also made no attempt to model the Management System. According to Noe and Alroe (2003), ‘...the controlling system remained an unexplicated black box...’. However, the clients of these authors were advisory and policy professionals rather than the managers of the farms represented. Because our primary clients are farmers, we have been highly motivated to understand the ‘black box’ in ways that might enable more effective decision support intervention.

Facilitation of ‘virtual experience’

For some time we were inclined to interpret the effects on the management system using ‘what if’ analyses and discussions (WifADs) as providing a sort of ‘virtual’ *experience* to participants. We observed that those who most valued WifADs were those farmers who had developed significant trust in the simulator’s ability to approximate reality of their farming world. The necessary ‘truth test’ could be either impressive approximations of a farmer’s historical yields or of a local FARMSCAPE field trial or monitored crop (Carberry *et al.* 2009, this issue). Such tests provided the confidence for farmers to do virtual experiments in WifADs and take the outputs seriously. Realism for a particular situation was enhanced by having the measured soil water and nitrogen values as model inputs.

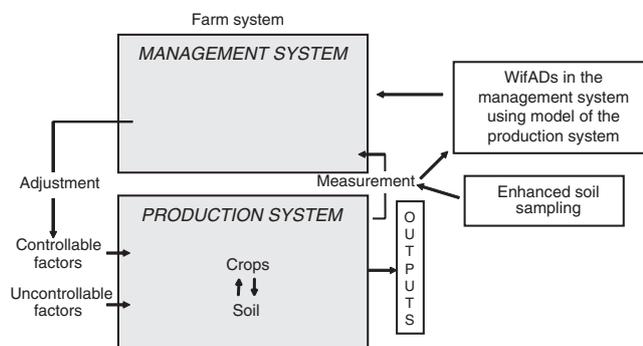


Fig. 7. FARMSCAPE interventions in the farm represented as a cybernetic system (adapted from Sorensen and Kristensen 1990).

Evaluations following WifADs provided ample evidence of changes in farmers’ yield expectations, intentions, and plans (Carberry *et al.* 2002, Carberry *et al.* 2009, this issue, Paper 3). Our ‘virtual experience’ interpretation was later reinforced by our discovery of simulation literature concerning ‘microworlds’, ‘management games’, ‘management flight simulators’, ‘Computer-Based Learning Environments (CBLEs)’, ‘business simulators’, and ‘learning laboratories’ (McCown 2005).

Figure 8 depicts an intervention in the Management System in which the Production System is replaced by a simulator of production. In the resulting cybernetic system, the manager experiences both control of the virtual production system and learning from feedback. The theory is that simulation enables participants to learn by ‘virtual’ experience; experience that, while less authentic than first-hand experience, has peculiar advantages over many real life situations, e.g. any mistakes and losses are only virtual. Senge (1990) explains that ‘learning by doing’ only works so long as the feedback from our actions is rapid and unambiguous, and this is often not the case in the real world. When we act in a complex system the consequences are often neither immediate nor unambiguous, but are removed from us in time or space. This leads to what he calls the dilemma of learning from experience: ‘we learn best from experience, but we never experience the consequences of our most important decisions’. The rationale for management simulators is that ‘virtual worlds’ are created, that serve as

... learning environments where time can be slowed down or speeded up, complexity can be simplified, irreversible actions made reversible, and the risks of experimentation eliminated (Isaacs and Senge 1992).

In a review of the second coming of management simulation and games, Lane (1995) concluded that the key feature of a simulator designed to aid management learning is its verisimilitude: correspondence of model behaviour to behaviour of the real world. For meaningful virtual experience to take place there is generally a need for a briefing session before the simulation

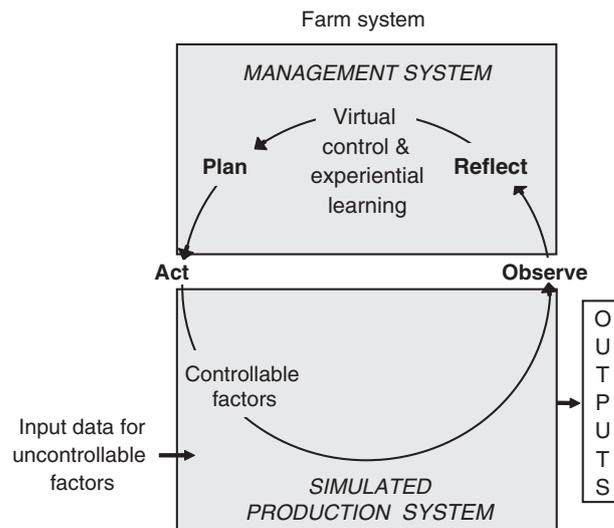


Fig. 8. A framework for intervention that substitutes a production systems model for the actual system in facilitated action learning.

and a debriefing session afterwards 'which helps participants to reflect on their actions during the experience so as to derive the most learning from it' (Lane 1995). One of the explanations for the demise of the first coming of business simulations, 25 years earlier, was poor facilitation, with the result that simulations were often run carelessly, sometimes merely for entertainment (Lane 1995).

FARMSCAPE's WifADs evolved to provide an experience that farmers found meaningful. But farmers, themselves, tended not to describe their experience in WifADs as 'experience-getting', and recent interpretation of virtual reality experiences offers more complex descriptions.

Virtual reality is not 'real', but it has a relationship to the real. By being betwixt and between, it becomes a play space for thinking about the real world. It is an exemplary evocative object. When a technology becomes an evocative object, old questions are raised in new contexts and there is an opportunity for fresh resolutions (Turkle 1997).

A salient event in our progression beyond this Framework based on the notion of virtual experience took place in a WifAD during a computer 'run' emanating from preceding discussion. The farmer host was asked by a researcher, what specifically was the value that he was getting from these sessions about which he was conspicuously enthusiastic. 'Was it something like *experience*?' Without hesitation, he replied, 'Hell, no. It's much *better* than experience. I know what yield of cotton I got on this paddock in, say, 1994, but I have little idea *why*. With *this* [simulation in WifAD process] we know how much water and N is in the soil at planting, and with the weather data, we can do things like go back and test the effects of hot or cold spells by replacing them with data of more normal weather. This is *far* better than experience.' This was a milestone in our progression towards an intervention Framework consisting of a *cognitive* model of farmer management and learning.

A model of the cognitive structure of learning and decision making

So far, this paper has tracked the changes in systems thinking of FARMSCAPE scientists as they pursued their first objective, i.e. creation of value for farmers of more intensive soil monitoring and customised simulation. The really big learning was appreciation of the degree that successful intervention with this technology depends on inherently *human* aspects of the farm system, i.e. the Management System, as opposed to technical aspects of the Production System. This 'people' dimension was addressed by adopting the methodology of Action Research in the tradition of Peter Checkland and the Lancaster group, which led to the development of Soft Systems Methodology (Checkland 1981, p. 146). This enabled scientists with no formal social science qualifications to bridge the gap between knowledge (and derived tools) in a community of science practice and knowledge in communities of farming practice.

Progressive inclusion of 'the social' in our systems *thinking* is reflected in the succession of concepts discussed in this paper. Significant steps included (1) commitment to a participative social process of interaction, leading to personal knowledge construction by participants and (2) the idea of facilitation of farmer learning *via* experience, often virtual experience, rather

than the traditional transfer of propositional knowledge. These ideas, profound as they are with respect to behavioural aspects of decision support intervention, do not require explicit use of behavioural or social science theory. They are accommodated comfortably within models of the farm where a human Management System is distinguished from a technical Production System (Figs 8, 9).

Over time, however, the need for theory has grown. One factor contributing to this has been the shift of our focus from showing that farmers can value simulation-based interactions, to our second major objective, i.e. developing a system for delivery of a commercial service based on the FARMSCAPE approach. The new task requires using what we have learned to design an intervention that has similar value to farmers but that has much lower transaction costs than FARMSCAPE. The design challenge is made greater by opportunities in geographic regions outside the region where FARMSCAPE developed. Such design needs and conditions put a premium on understanding 'what is happening' in FARMSCAPE interactions with regard to farmers' changes in thinking and decision making. This has led to the development of a Framework that contains explicit elements of theory from behavioural and cognitive sciences, yet is a natural development from the farm model of Sorensen and Kristensen (1990), adapted in Fig. 7.

Reflecting on what they saw as theoretical deficiencies of this figure, Noe and Alroe (2003) lamented that in this model the Management System 'remained an un-explicated black box'. These authors proceeded to identify theory that they judged to be missing. From their standpoint, the need is for theory that informs transdisciplinary farming systems research, and they proceeded to assemble diverse elements of available and appropriate theory. However, from the perspective of FARMSCAPE intervention, the theoretical content that is missing from the black box of the Management System is quite different. What is in need of explication in our case is the ways in which FARMSCAPE interventions influence farmers' *thinking* that leads to changed management action.

A start was made in developing a cognitive Framework by McCown (2005). In interpreting an historical paradigm change in decision support intervention in farmers' practice, treatment was constructed around the difference between seeing farming as 'behaviour' determined by personal and environmental factors, and 'action' motivated, rather than determined, and guided by personal knowledge. Using the most fundamental starting point for social science's understanding of human action, 'folk psychology' (Rosenberg 1995), a simple framework was devised

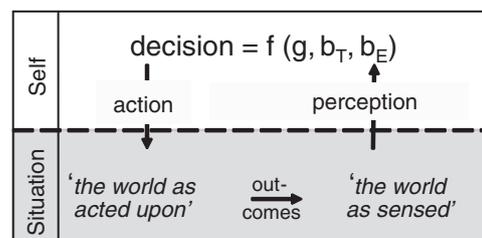


Fig. 9. A cognitive model of farmer decision making (McCown 2005). Decision is a function of a goal (g), beliefs about the task (b_T), and beliefs about the environment (b_E).

that linked a person's actions to change the world to their desires and beliefs. In Fig. 9, *decision* leading to *action* is shown as a function of goals (g), beliefs about the environment (b_E), and beliefs about the task (b_T). The *situation* is the relevant world requiring management action and whose state can be perceived (Fig. 9).

Beliefs about the environment (b_E) are formulated from experience of 'the world as sensed', and beliefs about the task (b_T) formulated from experience of 'the world as acted upon'.

Our investment in a cognitive Framework has continued, spurred by our need to get maximum insight from our experience to aid design of service delivery. A later paper in the series is dedicated to this learning from theory and its grounding in our intervention experience, especially from participatory evaluations featuring interviews of farmers and advisers about *their* experience with us.

Discussion

The DSS idea was imported into agriculture and provided to farmers under the prevailing RD&E philosophy that combined (a) generation of valid objective knowledge and information tools with (b) techniques for transfer of information/technology (McCown 2002a, 2005). Implicit in this philosophy was the expectation that rational practitioners are receptive to systems of objectively relevant and sound information. With this frame of reference, when these products were largely ignored by farmers, it was logical to blame deficiencies in the use environment, e.g. lack of computers, insufficient computing skills, low education levels, lack of progressive attitudes, etc. This perspective was blind to the main challenge with *discontinuous* technology such as a DSS (Trauffer *et al.* 2005; Trauffer 2007). Unlike a *continuous* technology, e.g. a new wheat cultivar for a wheat farmer, use of such a discontinuous technology necessitates significant change in practice. At the outset, a discontinuous technology is seen by a farmer as simply not relevant to his/her practice. This interpretation changes only if the farmer comes to *think differently* about the system and his/her practice. Although we did not conceptualise it clearly at the outset, the activity in which we exposed farmers to new soil water concepts and measurements and crop simulation in the FARMSCAPE program facilitated their creation of *meaning* of these for their practice. This included discovering through situated learning a relevance that was not initially apparent, together with a vision of significant benefit to goal attainment. This *relevance* and *significance* created (or not) in practice is generally missing from traditional information technology RD&E philosophy and strategy, because it was lost in the abstraction process needed for theory formulation. And in applications, 'theory cannot give back meaning' (Dreyfus 1991, p. 116). FARMSCAPE's action research facilitated farmers' construction of meanings of models and simulations for their situated practice.

A major limitation to learning from the DSS experience has been the difficulty, following distribution of DSS software to farmers, in finding out how or how much the product affected management thinking or practice. In FARMSCAPE, action research methodology enabled new research/intervention to be guided by feedback from completed events. Through both

informal and formal evaluation we could observe individuals' behaviour as they experienced new concepts, types of measurements/ information, perceptions of risk, etc. Real-time formative evaluation using entry-exit poll questionnaires was complemented by summative evaluation using interviews. Questions were designed in accordance with the conceptual Framework to achieve structured, coherent enquiry. Although moving to less limited Frameworks is necessary in the interest of learning and improvement of intervention practice, the downside is some loss of coherence between the current Framework and earlier data. Recurring wishes that we had asked somewhat different questions are an inescapable negative consequence of ongoing learning in the form of new Frameworks.

Even before we were thinking reflectively about our 'systems thinking' and our 'systems practice' (Checkland 1981), our engagement with farmers and advisers was benefiting from the invisible hand of action research keeping us heading in the direction of what farmers valued. And we always had a 'theory' about what we were doing, later seen as a Checkland 'Framework'. A new Framework for our intervention was prompted by a combination of a sense of inadequacy of the present one and the discovery in the literature of new Frameworks that fitted our situation and experience better. This paper has provided an overview of these Frameworks and some account of their dynamics.

The major discontinuities in the progression of intervention Frameworks described in this paper have been between:

- (1) on-farm research to design 'best management practice' for farmers and advisers;
- (2) facilitation of management action (or virtual action) leading to farmers' experiential learning and personal knowledge construction;
- (3) depiction of management as a cognitive system enabling researchers to think about and discuss '2' in terms of disaggregated sociocognitive processes.

The change from Framework 1 to Framework 2 corresponded with a profound change in our practice, as described earlier in the quote from Carberry *et al.* (2002). The rationale for the change concerns the effect of our intervention on clients' experience of *relevance to practice* and *significance to goal achievement*. The effect on the scientists' practice of the change from Framework 2 to Framework 3 has so far been mainly in the logical structure of our evaluation interviews and what we look for in transcripts of old interviews. The rationale for this change in Framework concerns the growing sense of need to disaggregate clients' sociocognitive experience, assessed previously as degree of enthusiasm, in the interest of better explanation and prediction. This added articulation stands to benefit (a) distinguishing the effects of the different components of intervention, (b) understanding of variation in adoption among individuals, (c) planning appropriate new activity in a new geographic region, and (d) managing the risks of cost-pruning 'short-cuts' in designing delivery of an affordable service. All these are issues to be addressed in later papers in the series.

A central issue in this series concerns the tradeoffs between (a) intervention that is experienced as relevant and significant

to management and (b) intervention that can be commercially successful. The FARMSCAPE approach has often been criticised for its high transaction costs, costs that make commercialisation unlikely. But the aim of FARMSCAPE has been to find out if there is anything with commercial potential. The task of inventing a commercial product was seen from the beginning as a secondary objective. A succession of attempts to achieve this second objective is reported by Hochman *et al.* (2007), and the story of the current and most successful, Yield Prophet, is reported later in the series (Hochman *et al.* 2009, this issue, Paper 4).

Our overall strategy of using an effective, but expensive, intervention as a test-bed for designing a cost-effective intervention can be seen as the inverse of the DSS strategy (if the DSS enterprise had a strategy and was not simply a bandwagon pulled by charismatic technology). It could be argued that the DSS strategy was to test the acceptance of a product whose potential value was unknown but whose delivery, once computers became standard equipment in farm businesses, was inherently cost-effective and was never going to be an issue. Both strategies carry a significant risk.

Papers 2, 3, and 4 of this series feature our 'hard' systems practices, implemented in a 'soft' systems framework. Papers 2 and 3 deal, respectively, with the practical implementation of the technologies at the centre of FARMSCAPE interventions: soil concepts and measurements novel to farmers' practice and yield simulation customised to individual paddocks in question. Paper 4 concerns *Yield Prophet* as a trial commercial service delivery system.

The aim of the pilot study was to establish a firm case for a full-scale research project on the benefits to farmers of researcher-mediated, customised, simulation of their cropping situations. However, what happened in the 3 years of piloting resulted in the industry-funding organisation shifting its priority from 'can this be valuable?' to 'how can this be delivered?' In hindsight, this was a mixed blessing. Although the enthusiasm of farmers and advisors provided accelerated *development* funding opportunity, the price of this acceleration was reduction of opportunity for our research understanding to progress beyond the mundane level of consumer response to a trial of a novel product. For the industry-funded research organisation, this 'fast tracking' was normal and is above criticism. But for researchers committed to 'research for understanding', as well as 'research that makes a difference' in practice, this result had limiting consequences which we later realised and attempted to remedy by altering our research methodology to increase our understanding of what was happening in our action research.

In conclusion, a referee called to our attention a quote attributed to Disraeli: 'read no history, only read autobiography'. Our aim in this series is to describe and interpret a particular sustained learning experience (*autobiography*) about how to create value in farming practice for scientific systems models. Such an aim ensures the omission of other meritorious research efforts of the same period and, therefore, a gravely deficient *history*. Our approach also ensures a degree of stereotyping of other varied approaches to decision support. This results from our efforts to simplify and clarify differences by abstracting concepts and methods and creating contrasting categories. This,

unfortunately, risks offending those who feel misrepresented by the oversimplification. However, an alternative that attempted to deal with subtle intermediates soon becomes unwieldy. We are hopeful that these limitations of the series will be overshadowed by insights that reduce the enduring problem of implementing model-based support in farm planning and decision making.

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