The FARMSCAPE experience - Simulations aid participative learning in risky farming systems in Australia.

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Abstract.

The FARMSCAPE (Farmers', Advisers', and Researchers', Monitoring, Simulation, Communication, and Performance Evaluation) project commenced in 1992 in response to a perception that despite years of effort, computer-aided farm decision research and intervention was failing the tests of relevance and significance with farmers and advisers. Using "action research" principles FARMSCAPE researchers set out to learn whether successful family farmers could experience value in simulation as an aid to thinking about crop and cropland management where rainfall is highly uncertain. This became a research program on methodology for effective interactions among farmers, advisers, and researchers in which hard systems tools are used, not to optimise plans, but to structure uncertainty about external events and to explore consequences of possible actions through 'what if?' analyses and discussions. Learning occurred both as virtual experience and as 'discovery' of principles. Because decision making in their farming system is so dynamic, participating farmers recognised a need for such learning experiences in real time as an on-going decision support service, and this is being piloted.

Introduction

In 1992 a group of APSRU researchers faced the sobering realization that despite the lapse of 17 years, the lament by Spedding in 1975 that there were "few convincing examples of the use of complex models of agricultural systems being used as a basis for agricultural practice" still seemed valid. In the belief that simulation of important aspects of production was potentially valuable in farming, a team of researchers set out to see if any farmer could come to value simulation as an aid to thinking about crop and cropland management. The researchers initiated the engagement with a pilot group of farmers and advisors who were interested to learn more about managing change in an 'unpredictable' rainfed cropping system. An early result of this engagement was that the research focus shifted from questions of what simulators could do, to questions of what farmers might do with them (Winograd and Flores, 1986, p7).

Context/background

The Agricultural Production Systems Research Unit (APSRU) was formed in 1990 by merging three research groups to focus on decision support in dryland cropping. The core science-based technology for this has been the Agricultural Production Systems sIMulator, APSIM, that represents relationships in the production system among crops, soils, weather, management actions, etc. (McCown *et al.,* 1996).

The Australian north eastern cropping region is endowed with inherently productive soils but rainfall is highly variable. Dryland cropping industries are well established to service export markets and are not tightly regulated by government, but farmers' are exposed to high climatic and price risks. . Many farmers who were successfully introducing reduced tillage and stubble retention practices into their farming systems felt an added economic pressure to redesign their crop rotation systems either to include dryland cotton or to become more economically competitive without cotton. Compared to grain crops, producing a cotton crop has the prospect for much higher Gross Margins per hectare but also much higher risks because of high inputs in monitoring and controlling insects, and the crop's extended duration and consequent higher water requirements. In terms of the 'uncertainty' typology of Kahneman and Tversky (1982), in addition to 'external' uncertainties of weather, these farmers experienced 'internal' uncertainties concerning new, complex, husbandry.

A profound shift was also taking place in institutions servicing agriculture. Public sector extension services were being downsized while competitive private sector service industries were developing rapidly, especially around the fledgling industry of dryland cotton.

Theoretical Perspectives

This research drew initially from several perspectives. These are most simply related using the schema for developing methodology set out by Checkland (1985) in which an "intellectual framework" orders a dialectic concerning intervention in an area of application. In exploring a way for simulation to benefit management, the researchers' initial intellectual framework consisted of (a) the science-based, 'hard,' systems approach to analysis of problems and (b) the principles of participatory action research. Previous experience with crop simulation models had demonstrated that a black-box churning out information or recommended actions (experts' knowledge) to farmers facing complex farming situations have had limited appeal/impact on farmers and their decision making. To have value, this project recognised that a more effective role for, and use of, simulations would need to be developed through participative learning with all players involved in the knowledge system. The project sought to provide a context for learning by all participants rather than using simulation merely as a teaching aid by experts.

The role envisaged for the cropping systems simulator was informed by the metaphor of a 'flight simulator' for managers as described by Bakken *et al.* (1994).

> "If we view learning as a process where an action--> result--> reflection--> learning leads back to further action, flight simulators can facilitate learning by shortening the delay between action --> results. The simulator also demands structural explanations of the action --> result link that will force participants to search for a better understanding of the underlying forces that produce a given set of outcomes. (p250).

Following satisfactory cooperative testing of models (see next section), the interactions evolved into simulation-facilitated 'what if?' discussions. These discussions played two separate, but reinforcing roles in farmer learning: (1) a subjective testing by farmers of their management heuristics and (2) the construction of understanding of biophysical processes that aids management decision making.

Both roles are important to experiential learning (Einhorn, 1982, p275; Feldman, 1986, p270). Using the what-if framework encourages participants to ground scenarios in past experience and to test them against the experience of others. Discussion of simulation results stimulates further questioning and trials.

Learning in action

An evaluation framework to aid learning was built into the project from the outset (Coutts *et al.,* 1998). A central strategy was to engage in iterative interviews with representatives from different stakeholders involved in the project at key decision times during the year (for example when decisions were being made about planting). These included: researchers; farmers involved in discussion group activities; public extension officers; private advisors/consultants; and some people who were observers of the project without actually being part of it. These interviews provided a stimulus for reflection for those being interviewed, those doing the interviewing, and those exposed to the results. It also captured learning from these different groups within the context and period in which they were occurring. The information gained was also fed back to the wider group through a newsletter entitled FARMSCAPE Insights (all issues viewable on www.farmscape.tag.csiro.au)

Engagement with producers

Researchers negotiated collaboration with a number of farmer groups with an interest in conducting trials within their commercial crops (fig 1a, 1-3). The implicit strategy was to start by working with farmers thought to have a high potential to contribute as research collaborators. In some cases this was due to a high level of uncertainty within their farming situation due to scant experience with a new, high risk, crop. In other cases we worked with farmers who had already made those husbandry innovations that meant that their biggest production constraint was, as put by a participating consultant, that "they were up against the weather". The researchers offered to support farmers' experiments, both in aspects of monitoring soils and weather and in using simulation of the experiments to 'virtually' extend their duration. Few, if any, farmers expressed interest in simulation at the outset, but active collaboration ensued on the strength of enthusiasm of farmers for learning more about their own soil resource. This learning took the form of describing the characteristics of specific soils, especially their water storage characteristics as well as tactical sampling and analysis to get a measure of the current status of a paddock in terms of available water and mineral nitrogen. Research techniques and equipment were adapted for such on-farm practices (Dalgliesh, 1996; Dalgliesh *et al.,* 1998). Soil measurements often produced insights and information that farmers found provided better grounds for conceptualising and managing the soil resources of water and nitrogen. Evaluation data from the early years of the project clearly identify the participating farmers' experiences as 'discovery learning' (Rolings and Jiggings, 1998, p295).

Farmers' appreciation of the value to management of knowing the extent of "deep" water and nitrogen reserves in their soils led to a changed working concept of soil water storage and to changed monitoring practices. The new model, based on the metaphor of a leaky bucket of finite and measurable size, goes beyond the conventional indicator of storage — the depth a pointed steal rod can be pushed into the soil following rain. Farmers now communicate in a new language e.g. "How big is the bucket" and "the bucket is 70% full" that is commensurate with rainfall quantity. They expressed gratification with the advantages that this affords in monitoring, understanding and discussion of important issues such as how efficiently have they captured rainfall during a fallow and how efficiently have their crops converted rainfall into grain or dollars per hectare.

In a climate with very high rainfall variability, the opportunity for researchers to introduce simulation to aid interpretation of results of on-farm monitoring and experimentation came (repeatedly) when the inquirers reflected on such questions as "what would the results have been last season?" and "how often can I expect this?" (fig 1a, 7).

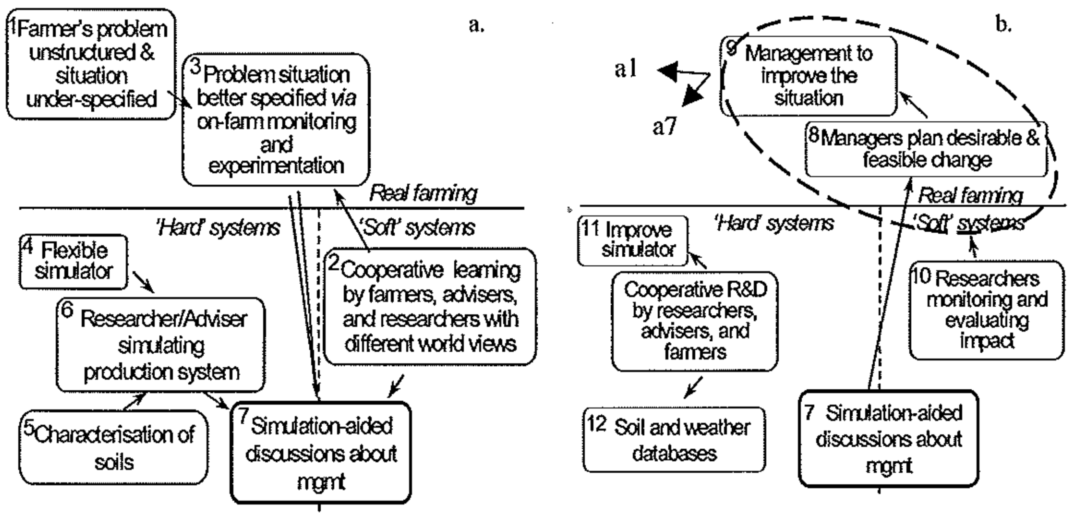

Figure 1: Framework for FARMSCAPE research

A complex interactive process is depicted metaphorically as divided among three domains. "Real farming" provides farmers' felt problems and the location for cooperative inquiry strategies of "looking closely" and "comparing" a3. "Hard systems" contains simulation tool maintenance as well as information for specification, initialisation, and inputs. "Soft systems" contains inter-subjective understanding seeking (a2->3, b10) and subjective and group learning (a2->7). There are no researcher "messages". "Discovery learning" in a7 may lead to planning and action in b8,9. Knowledge of such is gained by researchers in b10.

Comparison of simulated yield versus actual on-farm yield (Foale and Carberry, 1996; Robertson *et al.*, 2000) developed an appreciation by all participants of how well the simulator would perform "in the real world" of farm production. Initial tests (about 70 crops) engendered a high level of confidence among farmers, advisers and the researchers in the simulator's capability to simulate yields of commercial crops. Farmers' confidence from observing these results on their own farms led to imaginative proposals to use this tool to investigate important and problematic management issues on their farms.

Most frequently, interactions took place in group meetings hosted and guided by farmers or their advisers. Although discussions were wide ranging, the centerpiece became known as the WifAD (What if?, Analysis, and Discussion). Management scenarios proposed by farmers "on the spot" are simulated by APSIM, "driven" by a researcher and the results discussed—often giving rise to progressive rounds of simulated scenarios or to exploration of system structure.

The pilot project started with a small number of farmers and advisers. However, between 1995 and 1998 the FARMSCAPE approach was expanded so that some 230 farmers belonging to 28 groups supported by 15 advisers participated in learning activities. Participation involved characterization of about 50 soils, conduct of about 70 on-farm trials, collection of data from 13 weather recording stations and scores of WifAD meetings.

Management activity in which farmers found that simulation aided their learning and planning can be classed into four categories: (a) diagnosis of past experience using "theoretical benchmarking", (b) production decision making, (c) marketing decision making, and (d) evaluation of contemplated changes.

Benchmarking:

Farmers see analysis and discussion about whether a specific crop had performed to its potential as set by weather, soil, and management conditions, for example, as an important learning opportunity. Given actual seasonal climate, soil, and management inputs, simulation was used to calculate what a crop should have yielded in the absence of extraneous factors, thus providing a benchmark against which actual crop yield can be assessed. Figure 2 demonstrates a benchmark simulation of a sorghum crop at Kupunn, Queensland. In this case, the simulated and actual yields were very close and so the farmer could conclude that his crop yielded to its potential. Interesting questions still arise: how much less fertiliser nitrogen could have been used without decline in returns? Could higher returns have been achieved with the environmental potential of that season using both a higher plant density and fertiliser rate? How does this change risk as well as returns?

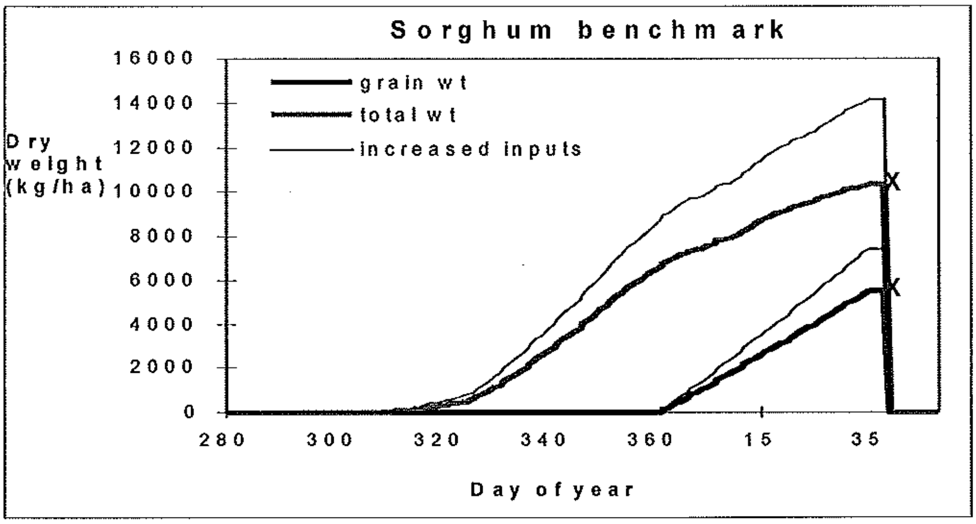

Fig. 2: Simulated daily increases in sorghum grain and total dry weight – X signifies actual weights at crop maturity. The thick lines are for actual management, the thin lines for increased inputs.

In benchmarking WifADs the simulator often aided discussions. Matters discussed ranged from when did a crop ran out of soil moisture or nitrogen; or did a cold period reduced production at a sensitive growth stage; or did roots "manage to tap into" stored moisture allowing a crop to keep growing through a dry period. Such discussion-simulation cycles enhanced participants' understanding of the impact of physical influences on their immediate farming experiences.

Production decision support:

Analysis of how a particular management action influenced yield in a previous season triggered farmers' interest in whether such hindsight could be turned into foresight. Could simulation be used in planning for the current or upcoming crop? Based on knowledge of pre-plant soil water, soil nutrient status, and seasonal climate outlook, can simulation be used to forecast the likely outcomes of decisions on crop choice, variety selection, fertilizer rate, sowing date, plant population, or row configuration? Based on pre-plant soil monitoring data, simulation enabled assessment of expected crop performance in the upcoming season by calculating what would have happened with the same "starting conditions" in past years for which rainfall records exist. Additional skill was added to such forecasts by using the Southern Oscillation Index (SOI) phase system (Stone *et al.,* 1996) as an indicator of climatic outlook.

This type of WifAD tended to stimulate farmers to develop new heuristics for action. An example describing how a new rule for sowing time of sorghum in a negative SOI phase emerged from a farmer's intuitive hunch that was confirmed by simulation at such a WifAD session (and subsequently by experience) is provided by Hochman *et al.* (1998).

Marketing decision support:

A grain-grower with a considerable history of involvement in FARMSCAPE kept reminding researchers that while it is important to grow a good crop, it is just as important to sell it well. In the case of sorghum for example, between July 1998 and January 1999, the price at the farm gate fell from AUD150/t to AUD100/t. Growers who were confident of a good season could have taken out a contract early on to capture the high prices. Reducing uncertainty about yield adds to the producer's ability to hedge against fluctuation of income. The farmer who initiated this activity thought APSIM could be a useful tool to help give an indication of potential yield. So, using his data on soil nitrogen and moisture for July, and keeping in mind the phase of the SOI, APSRU researchers ran the APSIM model using climatic data for the last 50 years.

Simulations were conducted on four occasions (times were negotiated to fit in with the farmer's potential key decision points and both the farmer's and researchers' busy work schedules). The first simulation was done in July 1998 when soil water and nitrogen data were available, the second was in December 1998 just after planting when most management parameters (planting date, variety, sowing rate) were known and on two other occasions during the growing season. In each of these simulations the weather data of the past fifty years was used to simulate past outcomes for the remaining portion of the season up to harvest. Results were presented and discussed in terms of probability of outcomes. For example the July simulation indicated a median yield of 5.5 t/ha while a yield of 2.75 t/ha was exceeded four years in five. .

In July, when prices were high, the farmer forward sold an amount that was equal to the lowest yield outcome in his farming experience. The farmer's actions regarding the marketing of the 1998-89 sorghum crop did not appear to be influenced by the study until he developed the conceptual framework that would enable him to adjust his worst case yield scenario for such factors as his antecedent stored soil moisture. In the lead up to the 1999 winter cropping season the farmer's learning from this research became apparent when he forward sold a portion of his wheat crop based on the yield probability indicated by the worst fifth of the 50-year simulation. The farmer's explanation of this policy change was that his marketing approach was still conservative but he now has a new way of understanding his risk.

System Design (Analysis of management change):

The interests of farmer groups with experience in WifADs concerning benchmarking and production decisions have inevitably moved to more challenging issues of long-term strategies. They expressed interest in using APSIM to compare their crop rotations and to include in the analysis some other rotations that they had been considering. It is worth noting that this was not a request to find "the optimal" rotation. It was a request to compare a limited number of rotations that were already considered by the farmers and their advisers to be desirable on a number of grounds, including reduced dependence on chemicals for the management of soil-borne diseases and weed control—phenomena not dealt with by APSIM.

Cooperative learning took place through a number of iterations. At the initial meeting the contending rotations were selected and the farmers' management rules for each rotation were agreed upon. Researchers then set up and ran the simulations and prepared spreadsheets for presenting results. In the next meeting costs and prices for gross margin analysis were agreed on and results presented and discussed. With some groups this led to another round in which refined variations of one or more rotations were simulated and reported. While the main focus of the groups was on average income per hectare per year other issues, such as organic matter rundown and soil loss were also of interest, opening the door for future exploration of resource conservation issues.

Engagement with private and public extension/consultancy providers

The fifteen consultants and extension providers who participated in FARMSCAPE were initially skeptical about the value of simulation models. Their learning was in part similar to that described for farmers but had the additional dimension of learning about how monitoring and simulation could be incorporated into their professional practice. An early indicator was an upsurge in both farm-built and commercial rigs for deep soil sampling to meet farmers' increased demand for pre-season analysis of nitrogen and water status in the root zone

As adviser's appreciation of the value of simulation grew, they became interested in learning how to use APSIM. At first the advisers found that they could not dedicate sufficient time to overcome the steepness of the learning curve to become competent APSIM users.. Two developments significantly impacted on this situation. The first was the development of a more "user friendly" interface for APSIM that allows for construction of simulations without the need for high level computing skills. The second was a realization that emerged through discussions with a senior consultant in an agribusiness/consulting company that they needed to learn more about the potential for simulation in their business before they would commit the staff resources that are required to attain competency in the use of APSIM. This led to the temporary secondment of a member of the FARMSCAPE research team in the company's offices. The secondment facilitated an action research project to discover whether there were sufficient benefits to their consulting business once the barrier of having a trained APSIM user within the company was removed. The company subsequently committed staff and resources to establish an in-house capacity to run and deliver APSIM simulations to their farmer groups, and a second company in the region has also moved in this direction.

Learnings/reflections

Producer learnings and benefits

Field activities

A group of 10 farmers monitoring soil nitrogen below the "plough zone" for the first time provide an example of producers learning from undertaking soil monitoring activities. They found that their normal assumptions guiding fertiliser application praxis were risky in that mineral nitrogen measured in the top 90cm varied from very little to 150 kg N/ha. In one farmer's words, "Understanding the crop's nitrogen requirement and how to measure the amount of nitrogen being used has made a difference to our fertilizer program because we can now calculate what nitrogen levels we have in the soil and what we need to grow a target crop." (FARMSCAPE Insights May 1999, p.6). Another common insight for farmers was that they tended to under-estimate the depth from which crops withdraw soil moisture in dry seasons. The value that farmers place on this type of information is captured by one farmer's reflection that "Before we had never heard of deep soil moisture, now we are making our own soil corer so we can measure it ourselves." (FARMSCAPE Insights April 1997, p. 8).

Simulation aided Discussions

In response to monitoring and benchmarking experiences, farmers who initially doubted that simulated potentials were achievable in practice on their own farms, subsequently believed that: "many farmers are selling themselves short by not expecting enough from their country and not maximizing water use efficiency". This statement demonstrates an acceptance of simulations using APSIM as a benchmark of potential yield that can be achieved in a particular season at a particular location.

Having such a benchmark provides a diagnostic tool for understanding why potential yields were not achieved. Farmers see simulation as a surrogate for experience:

- "What is this good for? Mate, you can get experience fast!"

In addition to gaining "experience", analytical insights are facilitated:

- "This is better than actual farming experience because it shows you *why* a particular result happened."

Researcher learnings and benefits

Participating researchers initiated this action research program to learn if there was a role for simulation as an aid to farm management. Their learning has framed subsequent research and "intervention" in facilitating "communities of inquiry" within "communities of practice" (Argyris *et al.* 1985). At one level they learned with farmers much about the nature of the climate and implications for investment and husbandry. At another level they learned about how "hard systems" tools can contribute to participatory action research and various systems interventions, including facilitation of learning. More specifically, dialectic with farmers and advisers shaped the tools and techniques that facilitated the four classes of simulation aided deliberations (interventions) that have changed, in various ways and degrees, farmer's practices. Researchers' tools were modified and improved through practical application.

A particularly valuable learning by researchers was that the most important contribution of the FARMSCAPE project to farm management was in the structuring or reduction of uncertainty by facilitating farmers' "experience" through simulated scenarios constructed by farmers as meaningful. In contrast with DSS tools, a WIfAD has no pre-conceived message. Participants in the interactions construct any take-away "messages". Researchers are intensely interested in what farmers take back into practice, and accounts of change in attitude and action are sought through subsequent interpretive evaluation. (fig. 1, b10)

Private and public extension/consultancy learnings and benefits

The impact of soil monitoring on consulting practice is evident. Since the commencement of FARMSCAPE more than twenty commercial rigs for sampling soil to depth in the root zone have been built in SE Queensland. The number of deep soils samples analyzed for nitrogen increased tenfold in the period between 1992 and 1996 (Foale and Good, 1998).

Both private and public advisers contributed to these developments. Interestingly, however, private consultants and public extensionists tend to emphasize different learnings from their involvement with simulation in FARMSCAPE. Private consultants' statements show that they value the learning that they and their clients experience:

- *"Got a lot of questions in mind to test on APSIM."*
- *"We now do a lot more measuring, so we can manage better."*
- *"A [simulation] run looking at rotations with and without cotton got me thinking."*
- *"Evaluation [using simulation] of planting dates, linked with varieties brought out a lot of good stuff."*

Public extensionists were more focused on impacts and how specific messages could be extended to a wider audience:

- *"Farmers have been 'touched, opened up' will never be the same."*

- *"It has changed some of my own [mental] models: I revisited and strengthened some parts."*
- *"Can extend experiments to 100 years, we no longer use only a couple of years of data to make general recommendations."*

Professional and Institutional Implications

The novel marriage of what science is 'good at' and what farmers are 'good at' has attracted strong interest from research-funding institutions. The major institutional support for the FARMSCAPE approach has come from CSIRO[1] and the grains industry through the GRDC[2] has contributed very significant funding since 1992 and has made an on-going commitment up to 2002. Four additional Rural Industry Research Foundations have funded FARMSCAPE projects and Queensland Rail has also provided sponsorship funding for this work. Collaborators from Queensland and NSW State Departments[3], the CSIRO Cotton Research Unit, the Conservation Farmers Organisation, The University of Queensland, The University of Southern Queensland, The Brigalow-Jimbour Floodplains Group, and a number of private companies[4] have contributed to FARMSCAPE.

Participants who wanted to see the FARMSCAPE approach extend beyond the research and development phase raised the issue of access to the model to assist with on-going learning for individual farmers. A few farmers wanted APSIM on their computers and this was tried (with limited success) with one farmer. However, most farmers have come to conclusions such as..."*I would pay a good independent consultant to do it with me. I don't have enough time to learn to drive it*...and... *I hope that the program will be taken up commercially to enable growers to use it to its full extent.*"

Public extensionists have focused on equity issues as exemplified by the following statements:

- *"Farmers in general see FARMSCAPE as good but are concerned about the small number of farmers involved..."*
- *"It is critical to make the links between small group work and outcomes very clear, for example, through industry newsletters. Then everybody should be happy."*

The interest of private consultants was stimulated by their clients' demand for soil sampling and simulation:

- "*Farmers are asking us to model crop rotational systems and look at different scenarios.*"
- Most farmers are not interested in doing this themselves..."*I prefer to pay to get the analysis done*".
- Many consultants see the user-friendly interface for APSIM as "*... the biggest breakthrough in all this*".

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[1] Commonwealth Scientific and Industrial Research Organisation
[2] Grains Research and Development Corporation
[3] Qld Departments of Primary Industries and of Natural Resources, NSW Department of Agriculture
[4] primarily IAMA Limited, Michael Castor & Associates

Perhaps the most profound implication of FARMSCAPE for institutional research practice concerns the move *beyond* good science practice (whilst not deserting it) to using scientific expertise and tools for committed reflecting-in-action in human affairs (Schon, 1982). Historically, there has been a marginalising of such practice in scientific research institutions. But, in the new research climate, with increased linking of research funding to outcomes, evidence of desirable impacts on farmer and adviser practice may well result in accommodation and even institutionalisation of this *additional* paradigm.

Scaling-up

In response to the publicly expressed demands and commitments of farmers and consultants, a FARMSCAPE training and accreditation program is being piloted, beginning with 8 private consultants and two public extensionists. The Farming Systems Institute of DPI Queensland and the Australian Cotton Cooperative Research Center nominated the public extensionists for training so that they may be qualified to train other public extensionists. Private-sector trainees will be accomplished professionals in their businesses, and will adapt the product to suit their business requirements. Trainers will be students of this process of adaptation. Although some formal training will be required, much of the learning will be resource based and will take place within workplace activities.

The challenge in scaling-up goes beyond training for technical competency in field and simulation activities that support consulting. Performance will also be evaluated in terms of candidates' provision to farmers of a discovery-learning environment that will stimulate learning about the physical farming environment and relevant action-outcomes correlation.

Final words

FARMSCAPE represents a shift in discourse in hard systems research. Instead of formal knowledge and tools being used to inform farmers of what best practice would be — and what they should do — the aim is to use the science indirectly to facilitate discovery learning about situated farming practice. It is clear that where decisions are strongly affected by high climatic uncertainty or where there is high uncertainty about future long term consequences of an action or strategy, farmers and advisers can come to value simulation, adequately situated, as an aid to practice. The consensus view among farmers is that the most feasible way to provide this management tool in this region is by an enhanced farm consulting practice. While much remains to be learned about professional practice that utilises "virtual experience" around WifADs, development of a viable commercial service raises a host of new learning challenges. Some of these are procedural, but others concern reflection on such matters as the feasibility of commercial consultants fostering an environment for farmer learning and development.

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