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Linking Simulation Modelling to Participatory Research in Smallholder Farming Systems

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Abstract

Simulation models have proven beneficial to commercial farmers in Australia when applied within a participatory action research approach. This paper reports on an attempt to combine a participatory research approach and computer-based simulation modelling to engage smallholder farmers in Africa on issues of soil fertility management. A three-day interaction with farmers in one village in Zimbabwe provided evidence that the farmers found the simulation outputs to be credible and meaningful in a manner that allowed 'virtual' experiential learning to take place. The paper concludes that simulation applied within an action research framework may have a role in direct interventions with smallholder farmers in such regions

Simulation modelling has struggled for relevance in real-world agriculture and for impact on farmer decision-making, as outlined in two recent reviews. McCown et al. (2002) reflected on the impacts and learning in developing and applying computerised decision-support systems (DSS) through the collated experiences from nine substantive efforts of researchers in delivering DSS to farmers. All case studies were from developed countries (Australia, USA, Europe), and most incorporated dynamic simulation models within the applied DSS. Based on these experiences, McCown (2002) concluded 'the DSS has fallen far short of expectations in its influence on farm management'.

Matthews and Stephens (2002) reviewed the application of simulation models in developing countries and sought examples of where such models have been useful in smallholder farming systems. Unfortunately, this extensive review largely failed to identify any noteworthy examples of where crop simulation models had impacted on the practices of smallholder farmers. The 11 examples presented to demonstrate possible impact (Matthews et al. 2002) were mostly via influence on research direction, e.g. designing new rice plant types to increase yield potential or weed competitiveness (Dingkuhn et al. 1997), or in the training of local researchers, e.g. the SARP project (ten Berge 1993).

In the past, model applications have generally meant abstract analyses whereby researcher-designed management scenarios are tested under hypothetical situations, and recommended actions are suggested on what managers should do, generally without any reference to real-world testing. Most attempts to justify modelling approaches refer to multitudes of such context-free analyses (Meinke et al. 2001; Hammer et al. 2002; Matthews and Stephens 2002), but few examples are provided on where farming practices have benefited from such modelling studies.

Given past failures in DSS implementation and the increasingly unenthusiastic reaction of journals and

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research peers to such simulation analyses, which are easily generated and relate to no place in particular, the future for many modellers has been to retreat from 'trying to be practical' and seek a 'market' elsewhere. Some argue that models used in a normative manner could have input into public policy (Goldsworthy and Penning de Vries 1994), but again there are few reported examples of where models have actually influenced policy implementation. More recently, Hammer et al. (2002) have promoted a new hope for modelling in directing plant breeding, through identifying and assessing plant traits through gene-to-phenotype modelling. Modelling input into setting research directions or in plant breeding, in education and training, or as input into public policy probably does provide sufficient rationale for the continued development and application of models. But what of simulation modelling as an aid to farm decision-making?

While realistic about the past impacts of simulation modelling, both McCown (2002) and Matthews and Stevens (2002) are not dismissive of the prospects of modelling contributing to improved farmer decision-making. Both suggest that simulation modelling using a participative approach may be the future. Farmer participatory research stresses the co-learning of researchers and farmers who work together to explore the different options open to farmers through conducting experiments to test new agricultural inputs and practices. Participatory approaches allow researchers and farmers to jointly learn about farmer conditions in order that both can help each other design sustainable development interventions (Ashby and Sperling 1994; Okali et al. 1994).

A substantive example indicating possible success with a participatory application of simulation modelling is the FARMSCAPE experience (Carberry et al. 2002). FARMSCAPE (Farmers, Advisers, Researchers, Monitoring, Simulation, Communication And Performance Evaluation) is a program of participatory research with Australian farming communities that explicitly researched whether farmers and their advisers could benefit from simulation modelling. Carberry et al. (2002) provide performance indicators of impact on farming practices and reflect on what was learnt from this experience. They suggest that the active participation of farmers and their advisers, who work with researchers in the context of their own farming operations, was the key ingredient in the design, implementation and interpretation of the FARMSCAPE approach to decision support.

Dimes et al. (2003) agree that there can be synergies between simulation models and participatory research and suggest that, for smallholder farming systems, there are four areas of possible application: (i) the interpretation of on-farm experiments, (ii) exploration of investment options and risk analysis, (iii) assessment of new technologies and (iv) engaging farmers directly with simulation models in order to create virtual 'experiential learning' opportunities that are difficult or risky in real life. While the first three areas are consistent with past proposals for model applications, it is the fourth suggestion which may surprise, especially in the case of smallholder farmers. Dimes et al. (2003) briefly reported on an experience of using models with a group of smallholder farmers in Zimbabwe. The purpose of this paper is to provide greater detail and analysis of this experience of engagement of researchers with smallholder farmers in semi-arid Zimbabwe.

Background

In October 2001, a workshop was convened at ICRISAT-Bulawayo in Zimbabwe to explore the complementarities between farmer participatory research approaches and computer-based simulation modelling in addressing soil fertility management issues at the smallholder level (Twomlow 2001). To test the complementarities of these two approaches, six teams were assembled, made up of computer simulation modellers trained in the use of the cropping systems model APSIM (Keating et al. 2003), participatory researchers (agronomists, economists and social scientists) trained in participatory rural appraisal and rapid rural appraisal tools and methods, and local researchers knowledgeable on African farming systems. The six teams then worked with farmers in six villages in the Tsholotsho and Zimuto districts, Zimbabwe, for three days. They used participatory tools to build realistic farm scenarios for the computer simulations, which were then run for the farmers to get their reactions and suggestions for improvements. This paper is the report on what happened and what was learnt from one of those teams which interacted with 30 farmers in the village of Mkhubazi, Tsholotsho, Zimbabwe.

The APSIM cropping systems model was selected for use in this study because it had been previously tested in simulating crops in smallholder farming systems in Zimbabwe (Robertson et al. 2000; Shamudzarira and Robertson 2000; Shamudzarira et al. 2000). Likewise, soil and agronomic data were available to parameterise APSIM for the analyses to be undertaken in this study (Dimes et al. 2003). Climate data collected at Tsholotsho (less than 20 km from Mkhubazi) were used in the subsequent simulation scenarios.

Farmer Focus Group Meeting

On the first of the three days of interaction with a group of farmers in the village, a focus group meeting was held. About half the group were women. Over the three days, the number of farmers increased from 21 on day 1 to over 30 on day 3. All group discussions were mediated by a local interpreter. Some farmers in the group had a degree of English language competence.

The facilitator started the discussion by eliciting the local taxonomy of soils in the village. The smallholders in Mkhubazi recognise four types of soil. They crop two most frequently: *ihlabathi* soils, which are whitish sandy soils that do not hold water well and need large amounts of manure to be productive, and *iphane* soils, which are sodic, don't store much water and are prone to waterlogging, sometimes leaving maize plants standing in water for a week at a time. The less-fertile *ihlabathi* soils are the more common of the two. All villagers present at the focus group discussion have and plant crops on *ihlabathi* soils, whereas only 7 or 8 of the 20 villagers have *ipane* soils.

Given this picture of the local soil constraints, an agricultural activity calendar was then elicited from farmers, showing the details of dates of planting, weeding, and harvesting for different crops grown on both kinds of soils. It showed, for instance, that farmers plant crops of maize and sorghum first on *ipane* soils, if they have them, because they get poor germination on these soils if they plant late. Moreover, they plant early on these soils so that the plants are established to survive the waterlogging when the 'main rains' come in December. If *ipane* soils are planted after the main rains come, farmers might not be able to enter the ponded fields to plough. This means, for farmers with both kinds of soils, that maize and sorghum are planted first on *ipane* soils, followed by millet and legumes (groundnuts, cowpeas, and bambara nuts) on *ihlabathi* soils, as farmers report a striga problem with sorghum and maize planted on *ihlabathi* soils. Farmers with only *ihlabathi* soils can be expected to plant when 'the rains come' in the sequence specified by the activity calendar: maize and groundnuts in November, followed by sorghum and pearl millet and groundnuts in mid-December. Cowpeas can be planted from mid-November to mid-January.

Farmers say they weed maize, groundnuts, and bambara nuts twice, the first being 2 weeks after planting and the second depending on the amount of weed infestation. Millet and sorghum, however, are weeded once, four weeks after emergence. Different patterns of crop rotations on the same plot or portion of a big plot are reported, e.g. small 1 acre (1 acre = 0.4 ha) plots of legumes (groundnuts, cowpeas, bambara nuts) followed by 1–5 acre plots of maize followed by larger plots (4–8 acres) of millet followed by smaller plots (1–2 acres) of sorghum. Crops are also rotated in the homestead field or garden managed by women.

An hour's discussion ensued about inorganic and organic fertiliser use. Farmers say they do not buy chemical fertiliser from the trade store for use on grain crops; but all have been exposed to the nutrient advantages of chemical fertiliser. Farmers apply manure if they have cattle and/or goats, preferably on land planted to maize and then sorghum. Yet, when asked which soil should they put manure on, more farmers said *ihlabathi* (sandy) soils than *ipane* (sodic-like) soils. The amount of manure applied varied a great deal, from 3 to 8 scotch-carts (about 600 kg) hectare^{-1} every 2–5 years. These discussions were followed by small-group discussions with the eight team members interviewing small groups of four to five farmers. Some team members asked individual farmers about their individual farming practices, household food security, and household composition.

Work resumed on day 2 with a short summary by the team. The group then broke into small groups of four to five farmers to develop resource allocation maps (RAM) (Defoer and Budelman 2000). The RAM for each farm provided a diagrammatic representation of the farm infrastructure and assets and the seasonal flows of materials and labour between farm units (household, garden, fields etc.). A well-specified RAM for an individual farm enabled specification of actual and planned crop production strategies.

Describing a Computer Model to Smallholder Farmers

In the afternoon of day 2, the concept of a computer model was introduced to the farmers. Although many of the farmers had not previously seen a computer, a number had lived and worked in the city and had some understanding of a computer and its ability to calculate. These few provided valuable support to the interpreter in describing what followed.

Hand-drawn diagrams on flipcharts were used to help describe a computer model (Fig. 1). Firstly, the concept of measuring daily rainfall was discussed, with its accumulation representing what rain falls throughout the cropping season. Good and bad seasons were related to frequency and amount of rainfall events. Next, the process of growing a maize crop was discussed, starting with inputs of seed and manure applied to a particular field and the subsequent development and growth of the maize from seedlings to maturity. The linkage between rainfall events and crop growth was discussed.

Growing the same crop ‘on the computer’ was then proposed by providing it with the same information as what happened in real-life; i.e. what rain fell, how many seeds were planted to what field and soil type, how much manure was applied etc. A notebook computer, as drawn in Figure 1a, was displayed to the group. Once the interpreters and the few farmers with some knowledge about computers had completed long discussions with the less aware farmers, the idea of using the computer to ask ‘What if?’ questions was proposed (Figure 1b). If maize was planted in a field with a small amount of manure and yielded two bags, what yield would the computer suggest with more manure? Or with inorganic fertiliser?

In attempting to better relate computer simulation to the reality of farming at Tsholotsho, actual rainfall and simulated crop yields for maize, sorghum, and groundnut from 1991–2001 were presented as hand-drawn graphs (Figure 2). Yields were represented as number of 50 kg bags of grain acre^{-1}, units that appeared to be understood by the farmers during the RAM interviews. Crop management rules were aligned with information collected in interviews on the previous day, and soil characteristics were likewise informed by farmer information supplemented by local researcher knowledge. These simulations were completed before the meeting and the notebook computer was not used during this session.

Immediately after the Figure 2 graphs were presented, Sevi, a female farmer, asked the question:

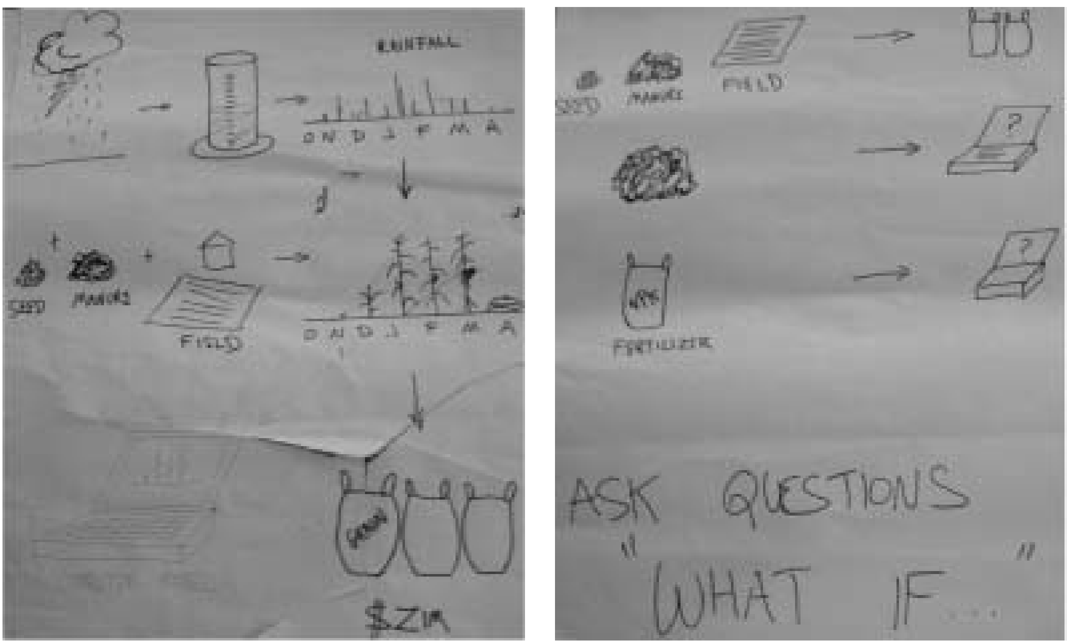

Figure 1. Photos of hand-drawn diagrams on flip charts used to help describe a computer model.

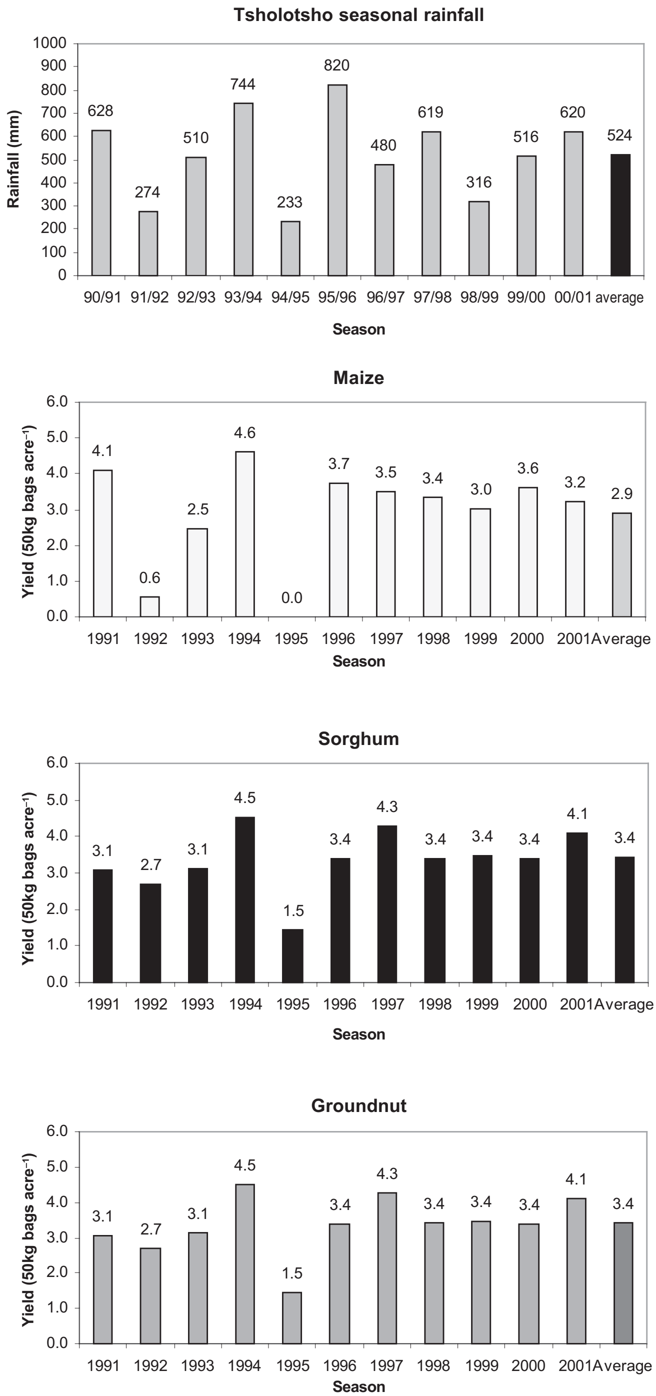

Figure 2. Seasonal rainfall for Tsholotsho and simulated crop yields for maize, sorghum, and groundnut for 1991–2001.

why was the simulated sorghum yield in a year with >800 mm rainfall (1995–96) less than the yield in a year of only 480 mm rainfall (1996–97)? This one unsolicited question was the catalyst for increased engagement between the researchers and the farmers. It 'broke the ice' for discussion about a range of issues on which both farmers and researchers had knowledge, the former with local knowledge, the latter with scientific knowledge.

Subsequent discussion concentrated around the matching of seasonal rainfall, simulated yields and farmer experience over the previous 11 years. We initially concentrated on the previous season (2000–01) by presenting the season's daily rainfall, and benchmarked simulated yields of maize and groundnut against experiences volunteered by a few farmers. Closest consensus was reached in relation to the simulated drought-affected maize yields in years 1992 and 1995. It was concluded that three types of years could be distinguished between 1989 and 1998: one very bad year (1992), four bad years and five normal years.

This second day's interaction ended without significant indicators that many farmers had understood the description of computing or crop modelling. The farmers were polite but mostly reserved. Some in the group did engage in comparing their experience over recent years with that presented by the researchers.

Running Simulation 'What If?' Discussions with Smallholder Farmers

Day 3 began with an intention to engage the farmers with simulation output. Preparation for the day involved selection of four case-study farmers and issues which emerged from the focus group meeting and the RAM exercise. Using these data, initial simulations were conducted overnight and results transferred to flip charts as pre-meeting preparations.

This day's meeting at Mkhubazi commenced without a concise agenda on how the farmers would be engaged using the simulation output. While some in the research group were sceptical of progressing beyond simple presentation of simulation results, all were hopeful of achieving higher levels of interaction. Therefore, the subsequent farmer–researcher engagement was guided by two hypotheses: that an action research approach, whereby what to do next would be informed by what was learnt from previous actions, could inform the engagement process, and that the engagement process employed in the FARMSCAPE experience (Carberry et al. 2002) would be a sensible framework for initiating the interactions with smallholder farmers using simulation output.

The selected case studies were conducted for four farmers:

- *Samuel*, the leader of the farmer group and a relatively wealthy farmer when judged by land area, cattle number and wives. Samuel had access to 14 scotch carts of manure year^{-1} which could be applied to 2.5 ha of cropland. Baseline simulations for Samuel covered the issue of the benefit of application of manure.
- *Sevi*, one of the leading and younger women farmers with modest farm resources. Sevi was clearly someone thinking about her farming system and she was an initiator of questions and contributed freely to discussions.
- *Derrick,* a farmer with less resources in the group with few cattle and low production.
- *Ester*, an older woman farmer with limited resources and cattle.

Each of these case studies and the interactions between farmers and researchers are described in the following section, with greater detail supplied on the first example.

(i) Samuel

The meeting started with presentation of simulated results from the overnight runs for the first case study farmer (Samuel). This baseline simulation, using climate data for Tsholotsho for 11 years (1991–2001), was for maize cultivar sc501grown on *ihlabathi* soil with no applications of manure or inorganic fertiliser. Also presented was the same simulation but with 14 scotch carts (8000 kg ha^{-1}) of good quality manure (C:N ratio of 20) applied to the maize crop before planting (results not shown).

This first presentation of hand-drawn graphs started as a lecture without feedback sought from nor volunteered by farmers during its interpretation by the presenting researcher. When asked for their reaction after presentation, Samuel and the other farmers remained detached and non-committal. The meeting was heading towards an early and frustrating ending! Then one of the older, clearly respected farmers stood up and, through the interpreter, commented that the maize cultivar sc501 was poorly adapted to the region and few in the village now used this variety. In his opinion, the results were not relevant to his farm. This was the opportunity needed to engage. Let's redo the simulations using the variety you recommend, was the suggestion put to the farmers. They agreed and chose cultivar sc401, a shorter season variety. The new runs were completed within minutes and the changes in bags acre^{-1} (relative to cultivar sc501) were presented on flip charts for each year of simulation and for the average. Figure 3(a,b) presents these simulation results, but with the baseline simulation using cultivar sc401.

The initiating farmer volunteered his reaction; that he expected sc401 to perform better than sc501 in most years and he was pleased that the presented results were now better aligned with his experience. Other farmers agreed and good discussion followed on why this was the case. The 1999 and 2000 seasons were remembered as low rainfall years when a short season variety was advantaged but last season (2001) had sufficient rainfall to support the longer season sc501. The farmers also seemed satisfied with the simulated yields — they expected to produce in the order of 5–6 bags acre^{-1} year^{-1}, but have had years with no production (1995 was well remembered as a bad drought) and other years when 9–10 bags acre^{-1} were produced.

The alignment of farmer experience with simulated output for a common experience (a change in maize cultivar) seemed to generate considerable credibility with the farmers and a subsequent willingness to proceed with further simulations. Let's see what difference other changes would make to the outcome was the suggestion accepted by the more proactive members of the group. When asked, Samuel asked that the impacts of manure application next be redone with the variety sc401.

The FARMSCAPE experience (Carberry et al. 2002) helped guide the process here. While the new simulations were being run, the farmers were asked to nominate what change they would expect from the manure application. Each farmer was asked in turn to nominate how many extra bags of grain would be produced with the application of 14 scotch carts of high quality manure (Table 1). The simulated yield change ranged from 0–1.5 extra bags acre^{-1} (Figure 3c), with an expected (average) value of 0.8 bags acre^{-1}. This result was less than the experience of most farmers. Comment was sought from those farmers who nominated the larger benefits (5–9 bags acre^{-1}) and it appeared that they included farmers without access to such large quantities of manure and so without relevant experience. Active discussion ensued for some time between the local farmers and the researchers on manure and its use within their farming systems. This discussion led to the possible use of inorganic fertilisers (undoubtedly introduced by the researchers). At this point, the question was asked whether the farmers wanted to redo the simulation with applied fertiliser. The response was an enthusiastic yes. Samuel nominated applying 1 bag of fertiliser acre^{-1} (44 kg N acre^{-1}).

Table 1. Number of farmers who nominated changes in bags acre^{-1} from manure and N fertiliser applications in case study 1.

	Yield difference (bags acre^{-1})									
	0	1	2	3	4	5	6	7	8	9
Manure application	0	2	14	10	1	2	1	0	0	0
N fertiliser application	0	2	6	4	8	4	0	0	2	1a

[a] This difference was volunteered by the modeller before he ran the simulation.

The same procedure was followed, whereby farmers were asked by a show of hands before presentation of simulation results to nominate their expectations for the change in yield with applied fertiliser (Table 1). At this point the engagement became more light-hearted, animated and inclusive of more farmers. Many started debating amongst themselves the likely outcome and several changed their nomination as a result. The modeller gained a great laugh by joining in and nominating a changed yield larger than anyone else — the farmers accused him of cheating through 'insider-knowledge'! As the changes in yield were read out and recorded– plus 22 bags acre^{-1}, –1, 19, 21 … (Figure 3d) – the farmers' reactions were a mix of amazement, disbelief and excitement. The simulated yield changes were significantly greater than any farmer had imagined. Great debate ensued, with most farmers asking if such returns could really be possible. One female farmer volunteered that she had once achieved 16 bags acre^{-1} and so she believed such yields were achievable. This discussion enabled input from several researchers on the mechanism of crop response to soil N and on-farm experimental evidence with fertilisers. The variability in yield change, with even a negative response, had to be emphasised by the researchers — high yields were not assured with applied fertiliser.

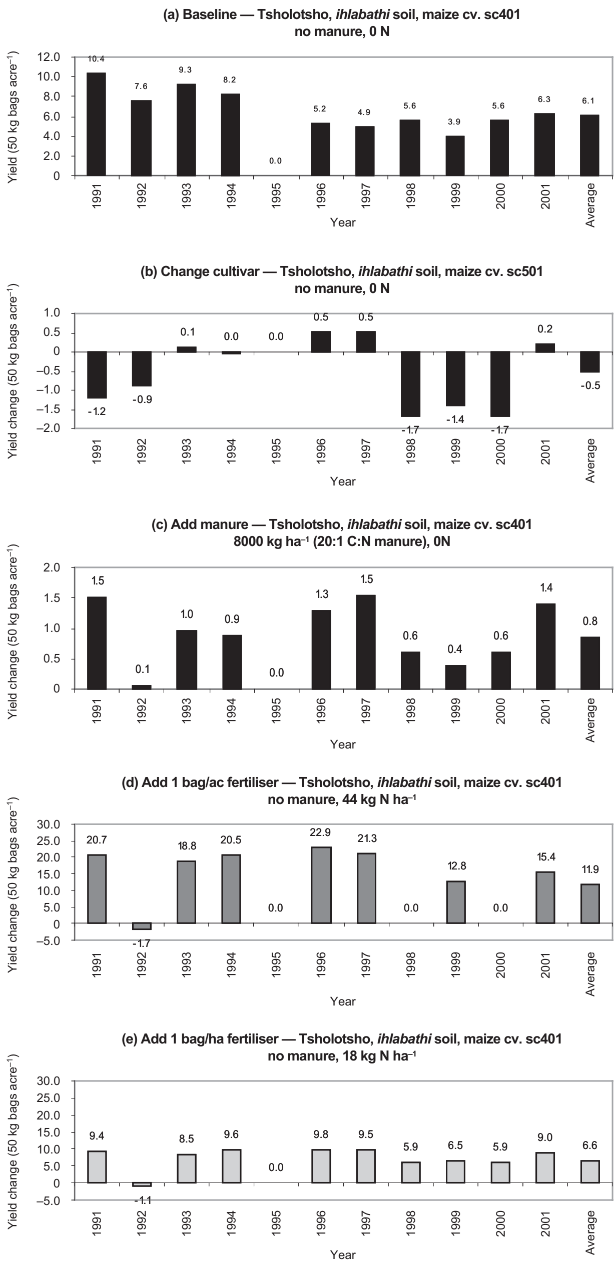

Figure 3. (a) Baseline simulation, using climate data for Tsholotsho for 11 years (1991–2001), was for maize cultivar sc401 grown on *ihlabathi* soil with no applications of manure nor inorganic fertiliser, and the changes in maize yields (bags acre^{-1}), (b) for cultivar sc501 relative to sc401, (c) for manure application, (d) for applying 1 bag fertiliser acre^{-1} (44 kg N ha^{-1}), and (e) for 18 kg N/ha applied as fertiliser.

When asked his reaction, Samuel said he found it too difficult to believe such high yields were possible and, besides, he could not afford such a high fertiliser rate. He asked what if he spread one bag of fertiliser over his whole farm (44 kg N $acre^{-1}$ over 2.5 acres)? The simulations were rerun with 18 kg N ha^{-1} applied as fertiliser (Figure 3e). This result (expected return of 7 bags $acre^{-1}$) greatly interested Samuel and other farmers. Small applications of N fertiliser could return significant benefits in most seasons. More requests were proposed, to try even lower rates of fertiliser, but close to 2 hours had been spent on the one case and three other farmers were waiting for their results. It was decided to change cases.

By the close of the first case study, the farmers seemed to now have little difficulty in participating in our evolved process: i.e. initially present the overnight runs for each case study as bags $acre^{-1}$ for a baseline and a new practice, calculate the difference in yield, discuss suggestions for alternative options, ask the farmers to nominate their answers, run the new simulations, write changes in bags $acre^{-1}$, discuss results in a manner which leads to the next iteration of simulations. Indicators of a consensual process were: not having to re-explain the request for their estimates, the ready volunteering of estimates with animated debate on likely outcomes between farmers, and the unsolicited queries on what the next simulation should be from different farmers.

(ii) Sevi

The second case study, for Sevi, aimed at benchmarking the performance of her maize and groundnut crops grown on *ihlabathi* soil in the previous 2001 season. On the first rainfall events in early November, Sevi was able to plant her garden plot to maize and field one to groundnut. However, due to labour shortages and delayed rainfall, she was not able to plant maize in field two until early December. The question, which had emerged through discussions the previous day, was: What if she had given priority to planting her main crop of maize in field two on the early rains and delayed planting the groundnut until December?

The simulation used rainfall data for Tsholotsho for the 2001 season (Figure 4a) and showed simulated yields for the late-sown maize crop to be significantly less than for the crop sown early in the garden plot (Figure 4b). The simulation suggested that, if

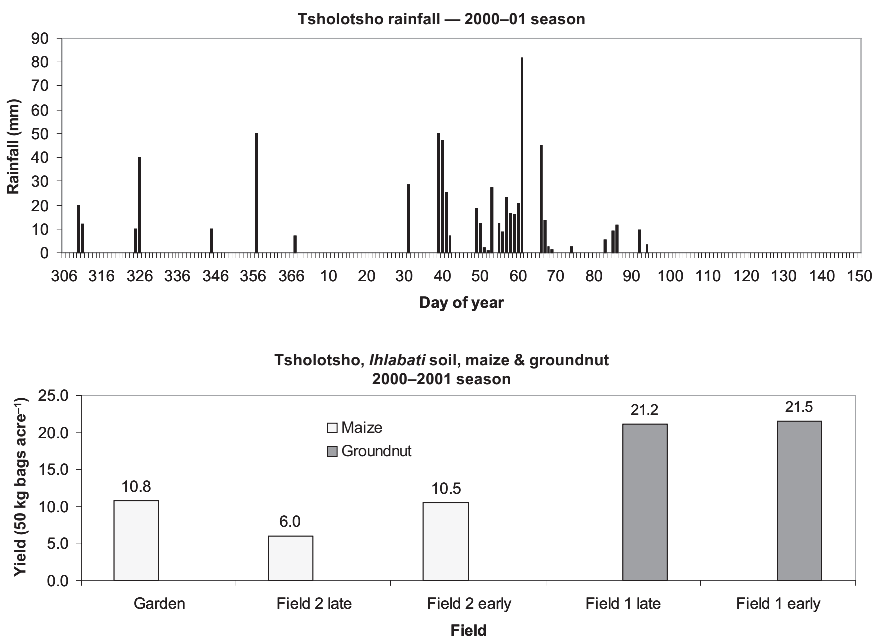

Figure 4. (a) Daily rainfall for Tsholotsho for the 2001 season, and (b) simulated yields for the garden plot and early and late sown maize and groundnut crops.

Sevi had given priority to sowing all her maize early, she would have achieved greater maize production without significant effect on the production of groundnut sown later (Figure 4b).

This case study challenged the planting priority for different crops, with the objective of planting the main maize crop before the lesser-priority groundnut crop. While this action appeared attractive to the researchers, as it did not involve additional resources, one farmer commented that early planted maize, outside the fenced garden plot, ran the risk of being grazed by cattle due to the scarcity of alternative feed.

(iii) Derrick

In the RAM interviews on day two, Derrick indicated that he did not use manure or fertiliser as he owned only two cattle and had few spare resources. His initial question was to ask about the value of four scotch carts (2500 kg) of low quality manure (C:N ratio of 35) applied to 1 acre of maize grown on a *ipane* soil.

Interestingly, during case study 1, where large returns from fertiliser were simulated, compared with small returns from manure, Derrick volunteered that his interest had shifted from manure to fertiliser ('*the effort from manure is not worth it*'). The first runs for Derrick's farm initially confirmed his new view that there was no return from the application of low quality manure (Figure 5a,b). The facilitated discussion then addressed why there was so little response to manure application and what he could do about it. All farmers joined this discussion with the researchers, on the N immobilisation phenomenon of such manure. The farmers and researchers together reached consensus to rerun the simulation but to concentrate the available 1000 kg manure on a smaller area (1/2 acre) and improve its quality (Figure 5c,d). These new runs showed modest returns to manure (0–2 bags acre^{-1}) which was attractive to Derrick as it involved no higher dollar investment and it was something new that he could do himself. He could collect manure in a manner that maintained its quality and this was something he could start on tomorrow. Derrick stated that '*this is what I will do*'.

(iv) Ester

The first three case studies had consumed close to five hours of discussion and lunch was ready. Even so, the fourth case study farmer, Ester, asked for her simulations. These were discussed over lunch with a smaller group of farmers huddled around the notebook computer. Ester wanted to explore the application of low versus high quality manure for her own circumstance (results not presented). These runs were undertaken and discussed one-to-one with Ester but limited time prevented exploration of further scenarios.

Farmer Meeting Conclusion

After lunch, the farmers and researchers reconvened to conclude the meeting, despite enthusiasm by some farmers for continuation – a female farmer interjected '*since this is our last day, we want to learn more*'. Samuel (our first case study farmer) gave a speech thanking the researchers for visiting him and his neighbours over the past three days. He identified record keeping by farmers of their yields and rainfall as an important learning from the meeting. He also asked for access to fertiliser and seed so that the village's farmers could increase their productivity in ways discussed over the previous days.

The leader of the research visitors responded with gratitude to the village farmers for attending the three days of the workshop and for their attention and interest. He offered to return the following week to discuss with interested farmers opportunities for follow-up, on-farm trials on issues raised during the discussions. He therefore asked that the farmers be proactive and meet themselves to discuss options for collaborative on-farm trials in the coming season.

The day was concluded with the villagers singing and dancing for the departing researchers.

Follow-up Activities

A week following the simulation workshop, ICRISAT researchers returned to the village of Mkhubazi to negotiate on-farm trials with interested farmers. The meeting started with a recap of what had been discussed during the simulation workshop. The farmers were then asked to present what they wished to do as a follow-up activity.

The discussions focused on the modelling results from the previous week's workshop and what could be done during the current season. Some of wealthier farmers referred to the huge potential benefit that the model showed when 1 bag of ammonium nitrate was applied acre^{-1} compared with the normal practice of no N fertiliser. However, this was quickly dismissed

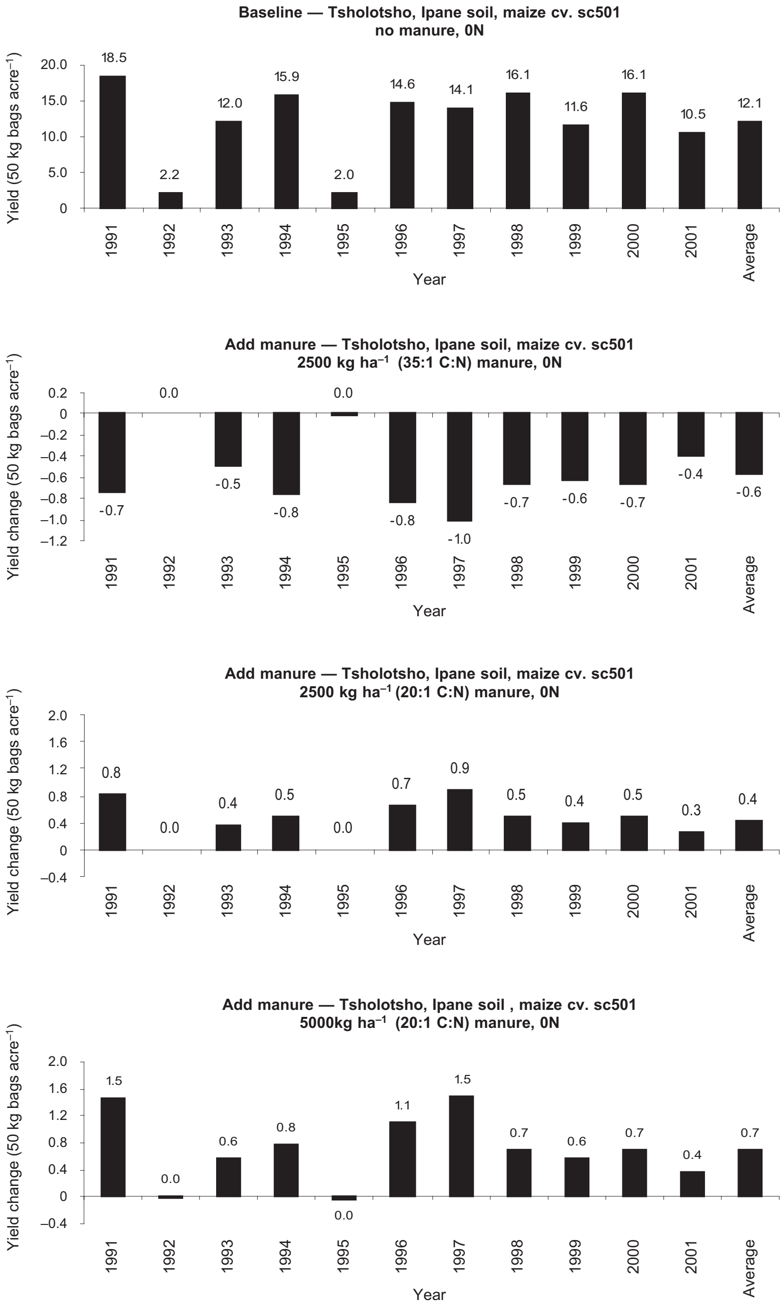

Figure 5. (a) Baseline simulation, using climate data for Tsholotsho for 11 years (1991–2001), was for maize cultivar sc501grown on *ipane* soil with no applications of manure or inorganic fertiliser; and the changes in maize yields (bags acre^{-1}); (b) for the application of low quality manure; (c) for the application of high quality manure; and (d) for the application of high quality manure concentrated on a smaller area (0.5 acre).

as a possible experimental treatment, as the farmers agreed that they could not afford to apply such high rates. In addition, such high returns to N fertiliser may not be achievable in these systems if other constraints were also evident (e.g. P deficiency, weeds etc.). When the rate of fertiliser was reduced to a realistic 10 kg acre^{-1}, the simulations had showed a yield advantage of an additional 3–4 bags acre^{-1} indicating that investment in fertiliser pays in many years.

During this discussion, the issue of the cost of fertiliser was approached by suggesting that 10 kg of fertiliser at then current prices equated to seven bottles of beer. The beer comparison posed the question, is beer an investment in the future? Women farmers responded by saying that it would be better to invest in crops than in beer, while some male farmers were not keen to answer the question, although they did make it clear that inorganic fertilisers were not available locally and asked could ICRISAT help? A local trade store owner was subsequently identified by the group and ICRISAT included him in an agents program supplying ammonium nitrate fertiliser in 10 kg bags rather than the standard 50 kg bags.

The ICRISAT team now referred to the workshop, at which farmers had indicated an interest to do trials on manure and fertiliser interactions. From the ideas farmers had suggested in discussions, five researchable areas emerged:

- how much manure?
- how much nitrogen?
- seed variety?
- anthill soil?
- ash?
- legume responses to phosphorus?

The farmers then broadly divided themselves into three groups. Eleven farmers would look at manure and inorganic nitrogen interactions; eleven would look at legumes (groundnuts or bambara) and their responses to various forms of phosphorus; and five would continue with their original ideas.

Despite a significant drought in Zimbabwe and the political upheavals associated with the 2002 presidential elections, which severely restricted travel by researchers, the farmers in Mkhubazi implemented and managed the trials that had been agreed (Twomlow 2003). These results support the southern African teams investment in participatory approaches linked with simulation modelling, and the empowerment it gives to rural communities and change agents.

What Did We Learn?

The experience recounted here centred around the use of a cropping systems simulator with smallholder farmers in Zimbabwe as a way of allowing the farmers to experiment with alternative management options for their own farms. While this approach has proved successful with commercial farmers in Australia (Carberry et al. 2002), it was a surprise that computer simulation was apparently relevant to smallholder farmers in Zimbabwe. Evidence of relevance included the ready participation of farmers in specifying questions to be simulated, in volunteering likely outcomes, in rationalising their expectations with simulated outputs and in re-specifying the question for the next simulation run. The farmers in this engagement were not passive participants, rather they acted as experts in their own domain, using the simulator to explore possible consequences of altered management. All the researchers left the focus meeting with the feeling that real engagement and learning had occurred.

What Process for Engagement?

The farmer meeting commenced with a feeling amongst the researchers of being uncomfortable about planning to use APSIM with farmers, of whom few would have prior knowledge of computers let alone a cropping systems model. However, by day 3, the researchers were readily engaging with the farmers using the model. The approach was to ensure that simulations were presented in a manner that facilitated thinking by all participants— the process was equivalent to playing a farming game. Using a particular farmer for the runs, eliciting his questions, getting other farmers' views, confirming the specifics of the run to be done, asking for their assessment of the outcome, revealing the results and debating what had happened, appeared an appropriate process for this engagement.

Asking the farmers for their estimate of the simulation outcome before presentation worked very well. This process had the farmers thinking about the question. In trying to rationalise the presented attributes of the simulation, it maintained involvement of all farmers, as opposed to just the case study farmer, and it provided them with a challenge which was mildly competitive with their peers. There appeared little sign that a consensus view dominated, as answers varied among groups and between simulations.

Once, when not all views were recorded for an upcoming simulation, the farmers drew attention to their answer for recording. On many occasions, farmers were volunteering their answers before being asked. Answers for early runs (range 1–4 bags, no zeros, no high returns) showed a far narrower range in distribution than the later simulations (0 to >10 bags, included low and high returns). Initially, the farmers seemed to be reluctant to risk being too different from prevailing views, but later this attitude dissipated as they started to think more about the outcomes; they became caught up in the questions being asked rather than worrying about the views of others. These observations were regarded as indicators of learning and confidence in the simulation approach.

Using recent historical rainfall, simulations for each year and asking questions such as '*what is your expected (average) benefit?*' and '*how often one would win or lose?*' worked well. Presentation of the yield difference between the base practice and a new practice worked better than just presenting yields for both practices and expecting farmers to visualise the contrast from graphs and assuming that all will do their own calculations on the difference. The presentation process evolved into not presenting the yields for added simulations but just presenting the differential in bags acre^{-1} and this worked well.

Why Did Farmers Give the Simulations Credibility?

The participating farmers had no prior knowledge of computer modelling, yet appeared to readily engage in a process of using the model to explore their farming practices. Initially they undoubtedly accommodated the visit because the researchers came to the village as ICRISAT representatives and were joined by the local extension person who was known to the farmers. However, the energy and eagerness of farmers to participate, the ready emergence of new questions, the willingness of farmers to predict the likely results and to explain why certain results occurred, were indicators of real engagement and acceptance of the process.

The process of 'credibility generation' commenced by concentrating on last season (2000–01) as a benchmark. The general pattern of daily rainfall was depicted and the performance of maize and groundnut crops was simulated, with simulated yields matching farmer experience impressively well. Next, the past 11 years of annual rainfall amounts were presented and the focus of discussion was on correspondence of rainfall and simulated yields with farmer experience (e.g. the 1992, 1995 droughts). Again, simulated yields generally conformed with farmer experience.

The meeting changed dramatically from a traditional presentation approach to one of inquiry and discovery-learning during the first case study, when one game farmer challenged the relevance of the information being presented due to use of an inappropriate cultivar in the analyses. By shifting from cultivar sc501 to sc401 at the request of the farmers, rerunning the simulation and simulating their expected change, significant approval seemed to be created, both in giving legitimacy to local knowledge and in demonstrating a process for using the simulator interactively in a discussion.

Farmers' behaviour indicated that, in addition to finding the simulation outputs to be credible, they found them *meaningful,* apparently because the simulations were specified in the context of a particular farmer and a relevant question. A process in which they could ask questions and related results were available immediately and in a manner where follow-on queries could be addressed was clearly appreciated by the farmers and effective in achieving the researchers' aims. Researchers to whom this approach was new were comparing this to field experimentation, which often relates to no individual farmer and where results are not available for months and are biased by the influence of one season.

As the meeting progressed the farmers tended to be less critical, accepting the simulation results without due questioning. For example, after the 50 kg fertiliser simulation (yields simulated > 20 bags acre^{-1}), the farmers had to be reminded to be sceptical of simulated results and to reflect on whether such yields are indeed possible and why. The researchers' intent was to instil in the farmers a view that the simulations were not truth but rather an approximation that is close enough to allow 'virtual' experiential learning to take place. Even if such learning were only tentative, it might play an important role in farmers' future adaptation of their practices.

The Role of Researchers

There can be a clear difference between the approach of external experts trying to think of solutions for farmer clients and an alternative approach of facilitating farmers to explore their own options. Some researchers in the group initially wanted to recommend practices in response to simulations rather than ask farmers for their reaction and encourage them to explore the results by questioning them. The idea of such engagements is to make it interactive and an opportunity to learn using the simulator to gain 'virtual experience'. For some research experts, unaccustomed to a facilitation approach, to see the power of this approach and not jump too quickly into lecturing mode proved to be a significant learning experience.

The issue of what is a relevant question emerged as important and problematic amongst the researchers during the farmer interaction. One view was that the high fertiliser option (44 kg N $acre^{-1}$) in the first case study was not appropriate, as it was beyond the resources of all the participating farmers. Yet, the farmer, Samuel, nominated this option. This simulated scenario actually sparked significant interest and debate amongst the farmers (see description in case study one). Here was an example of taking advantage of simulations which created discrepancies between farmer expectation of results (return on fertiliser 1–5 bags $acre^{-1}$) and simulated output (1–30 bags $acre^{-1}$). This helped facilitate discussion and learning about the issue of investing scarce cash resources in fertiliser. It also highlighted the importance of allowing the dialogue among farmers and researchers to *unfold* in accordance with farmers' inquiry, rather than to be overly designed and directed by scientists.

A Learning About the 'Best Place' for the Computer

Over lunch the offer of doing more runs for individual farmers did not create great demand. While one farmer requested an additional run, which was undertaken with her and several other observers, the interaction was clearly not as rich as when the simulations were undertaken as part of a group activity. The results were also presented on the computer rather than transferred to flip charts. This created a distraction of the computer, with the farmers wanting to touch the computer themselves (e.g. to write their name). Having the computer central to running and presenting the results clearly distracted from the results themselves. The process of transferring simulation outputs to flip charts avoided the problem of the computer getting in the way.

Conclusions

Why does a short, three-day interaction warrant such reporting? As a group of research and extension professionals coming from a range of disciplines and perspectives, we started this activity all sceptical that simulation could be directly relevant to smallholder farmers. Our three-day interaction tested this hypothesis and provided evidence that challenges the prevailing view that models may be relevant only as an implement for policy research in smallholder systems (Lynam 1994). Our engagement of smallholder farmers with simulation modelling provided a unique, surprising and exciting experience from which there is opportunity to rethink the role of simulation within an action research framework for direct intervention with farmers in such regions.

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