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Keywords

APSIM, Climate Variability and Change, Decision-making, Small-scale Farmers, Experiential Learning *doi:10.5191/jiaee.2015.22302*

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This study assessed the applicability of APSIM, a crop simulation model, to decision-making by small-scale resource-constrained farmers in Lower Gweru, Zimbabwe. Input data for APSIM were collected from 30 farmers through focus group discussions and resource allocation mapping. APSIM simulations were run to simulate the farmers' farming systems to establish model credibility and validate the model with the local data and to explore "what if" questions to discuss ways to improve maize yields in a below-normal season. After two years interacting with model outputs, semi-structured interviews were conducted with the farmers to assess their continued use of APSIM in decision-making, the form of information they value the most, and preferred sources of information. The study found a greater willingness to consider computer-based modeling because of the pressures of climate change and the waning adequacy of their indigenous systems. However, the study also found that farmers used APSIM when they saw for themselves its accuracy and relevance to their farming systems and found it useful for making decisions relative to climate variations. The study confirmed APSIM's limitations as the lack of accurate data, the need for expert support and access to computers, and found that indigenous indicators, although waning in reliability and accuracy, can be strengthened when revisited through a deliberate learning program designed to engage farmers in scientific enquiry. While preferring to obtain information from extension agents, farmers will not readily adopt significant changes unless they have hard facts that they themselves have participated in generating. Whether introducing a model like APSIM or other technologies, unless farmers are directly involved with its testing in the field they are unlikely to adopt what is offered.

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Introduction

This paper presents the findings of a study conducted among resource-constrained, small-scale farmers in Gweru, Zimbabwe to test the applicability of the Agricultural Productions Systems Simulator **(**APSIM) to their decision-making. Lower Gweru is a developed communal settlement in the Midlands province of Zimbabwe. Gweru's climate is semi-arid to arid with summer rainfall ranging from 450mm to 600mm annually but experiences periodic seasonal droughts and severe dry spells. Thus decision-making capacity to cope with these climatic fluctuations is critical to successful, profitable farming. Farmers traditionally use, almost exclusively, indigenous methods to predict weather and to inform their production decisions. If it is applicable to their farming and farm management systems, APSIM offers these farmers – and others like them – the opportunity to strengthen their decision-making capacity. This will, in turn, reduce risk and their vulnerability to climate variations.

Theoretical Framework

The context of this study was small-scale resource-constrained farmers. Specifically it was concerned with their decision-making processes relative to climate. It sought to learn how to engage these farmers with APSIM and to determine the extent to which farmers would be willing and able to engage with it as a part of their decision-making.

Small-Scale Resource-Constrained Farming Systems

Small-scale, resource-constrained farming systems are characterized by low productivity and widespread persistent poverty (Centro Internacional de Mejoramiento de Maíz y Trigo [CIMMYT], 1999; Selvaraju, Meinke, & Hansen, 2004). Their mixed cropping systems are characterized by small farm sizes, low investment in farming inputs, and intensive labor. Most of these farmers often fail to produce enough food to meet their own household needs (CIMMYT, 1999). They are faced with a number of challenges that threaten their livelihoods. Chief among them are infertile marginal soils and climate variability (Altieri & Koohafkan, 2008). Climate change has marked effects on the yields of crops produced on dryland small-scale, resource-constrained farming systems (Cline, 2007).

Small-Scale Farmer Decision-Making Processes Relative to Climate

Small-scale farmers often have their own local climate indicators to predict the nature of the season (whether it will be a good or poor rainfall season). These indicators include the position of the moon, wind direction, plants flowering at certain times, the color of the gathering clouds and changes in wells and springs (Mapfumo, Chikowo, & Mtambanengwe, 2010; Ziervogel, 2001). This local (indigenous) knowledge of indicators is relevant to rain-fed agriculture practiced by small-scale, resource-poor farmers in developing countries (Wang, 1988, as cited in Prasad, Kesseba, & Singh, 1996). It provides a platform for decision-making by small-scale farmers, related to both known and unknown problems affecting their farming systems and livelihoods (Beckford & Barker, 2007; Hurni, 1996). Local knowledge has been developed informally and is entrenched in local culture and traditions. Thus making it accessible and understood by all members of the community regardless of the level of education of farmers. Although this tried and tested forecast has been able to guide them for many years, it is emerging that this forecast's accuracy has been reduced due to climate change these indicators were not designed to predict (Roncoli, Kirshen, Ingram, & Flitcroft, 2000, as cited in Ziervogel, 2001). In other words, indigenous forecasting has not been updated and tested under the current climate variability and change.

Despite the limitations of these indigenous indicators in the face of current climatic issues, small-scale farmers continue use them to guide their decisions leading to the adoption of conservative risk management strategies. Such strategies usually result in the inefficient utilization of the few resources they have, thereby leading to reduced productivity (Hansen, 2002; Hansen & Sivakumar, 2006).

Worth (2002) argued one of the functions of extension is to engage farmers in scientific enquiry. Drawing on this framework, Nyiraruhimbi (2012) posited indigenous knowledge can be categorized as local memory, local practice or local science. Local memory is the collection of practices handed down from predecessors but which, although remembered, have been discarded or substantially modified. Local practice is knowledge garnered over some period of time from various second-hand sources (including ancestors, extension agents and messages, and sales representatives) and/or through unstructured trial and error. Local science is knowledge and practices currently in use or not a result of deliberate and conscious innovation and experimentation conducted by the farmer(s) who use/do not use the practice (Nyiraruhimbi, 2012). Local science would result from an extension engagement that employs a learning posture with the primary aim of building capacity of farmers to learn, innovate and experiment (Worth, 2006) systematically, methodically and deliberately.

The persistent use of indigenous climate indicators by small-scale famers in the face of their declining accuracy and veracity suggests that this indigenous system falls into the category of local practice. It is a system that has evolved to a point, based largely on handed-down knowledge and some trial and error. This being the case, it opens the door to engaging farmers in a learning dynamic to challenge their local practice through deliberate engagement in scientific enquiry. APSIM affords a practical, topical and timely opportunity to take steps in this direction.

Official seasonal climate forecast (OSCF) information can be used to move from reliance on increasingly unreliable local practice to fostering better risk management through better-informed decision-making (Hansen, 2002; Hansen & Sivakumar, 2006) founded on a conscious program of learning and experimentation. Such a program will help farmers have confidence in seasonal climate forecasts and other new technology needed if they are to fully embrace the information in their decision-making. If, through a learning process, the farmers perceive the benefits of the innovation, it will evoke remarkable resourcefulness among the farmers (Hansen, 2002; Stroeken & Knol, 1999). However, this will be the case only if the innovations (in this study, APSIM and OSCF) can be adapted to suit the farmers' unique circumstances and are found to fit their farming and farm management systems.

The methods of dissemination of the OSCF include use of radio, television, and newspapers and through extension agents. According to Chikoore and Unganai (2001), the most efficient method of disseminating seasonal forecast information to small-scale, resource-constrained rural communities in Southern Africa is by radio broadcast. However, in a study by Ziervogel (2001) in Lesotho, most farmers preferred to get the forecast from the extension agents, citing that they do not have radios and also that the agents will even help them understand through demonstrations and explanations in their mother language. This again suggests the preparedness of farmers to learn in collaboration, rather than blindly adopt. Good extension practice will develop a "facilitated learning agenda" (Worth, 2006, p. 189) to engage the farmer in a conscious process of "investigation, application…and sharing" (Worth, 2006, p. 189), to determine the veracity of the innovation.

Agricultural Productions Systems Simulator (APSIM)

APSIM is a farming systems model designed to simulate various processes taking place in the soil during crop production under a range of management options in different climates (Probert & Dimes, 2004). The model requires long-term daily climatic data in the form of rainfall, radiation, and minimum and maximum temperatures. The model is set up in such a way that it has numerous templates where all the data can be entered against pre-determined start and end dates of the simulation. It accommodates climatic and soil description data and crop management data. APSIM has been used in different parts of the world for applications ranging from interpretation of on-farm experiments to risk assessment of a range of alternative management options. It aids farmers in decision-making by exploring various scenarios involving different management practices based on known climatological data. Dimes, Twomlow, and Carberry (2003) found APSIM simulations to be highly accurate in estimating yield and risk for the different application rates of nitrogen fertilizer. Similarly, Carberry, Gladwin, and Twomlow (2004) found the model to be credible as the simulated outputs match the actual yields reasonably well and because the farmers' own data were used in running the simulations. APSIM does, however, have limitations. In particular, its use is hampered by an absence of capable users as well as lack of reliable input data, especially in poor regions of Africa (Struif-Bontkes & Wopereis, 2003). Additionally, it does not include effects of pests and diseases (Holzworth et al., 2006). Finally, it is dependent on having or having access to a computer to run the model.

Purpose of the study

This study sought to achieve three objectives. Firstly was to determine small-scale resource-constrained farmers' perceptions of climate change. The second objective was to determine the farmers' crop management decision processes including what they used to guide their decision-making. Finally, after being introduced to official seasonal climate forecasting and APSIM simulations, the study sought to evaluate whether these farmers would use APSIM to guide their crop management decision-making after a two-year study period during which they were exposed to the model and its outputs.

Methods

The study was conducted from 2008 to 2010 in two wards of Lower Gweru Communal area: Nyama and Mdubiwa. These wards were selected based on their accessibility, their representativeness of the whole Lower Gweru Communal area, and because of their contrasting nature with regard to wetness/water availability. Nyama ward is wetter as it has a higher water table; Mdubiwa is located at a higher altitude with less water availability.

Lower Gweru is a developed communal settlement in the Midlands province of Zimbabwe. It is located about 40 km north west of the City of Gweru, and stretches a further 50 km to the West. The area falls in the natural region (agro-ecological zone) IV of Zimbabwe, which is described as semi-arid to arid and receives rainfall from October to April ranging from 450mm to 600mm annually, with frequent droughts. The rainfall season is characterized by periodic seasonal droughts and severe dry spells.

To eliminate bias and ensure representivity from the two study areas, Nyama and Mdubiwa, stratified random sampling was used to select the study sample of 30 small-scale, resource-constrained farmers. Fifteen farmers were selected from each ward. These farmers participated throughout the two-year duration of the study.

Data were collected using four data collection tools: focus group discussions, resource allocation mapping, APSIM simulations, and semi-structured interviews. These methods were used sequentially, each building on the results of the previous data collection exercise, permitting validation of the data of the previous session. Further, data gathered at each session were reviewed with the relevant extension personnel to validate the data. The data were found to be consistent with information available to the extension personnel. The use of multiple methods and triangulating as outlined provided the framework for the validity and reliability of the data.

Focus Group Discussions (FGD)

Four focus group discussions (Krueger, 1994; Merton, Gollin, & Kendall, 1956) were used to gather information about climate change and seasonal climate forecasting – including the farmers' perceptions of climate change in their area. Facilitated by the lead researcher, the selected 30 farmers participated in each session. The first FGD explored climate changes they had experienced and introduced crop simulation modeling (APSIM) and OSCF as alternative guides to crop management decision-making. The second FGD developed resource maps and explored what guided their crop management decisions. The third FGD, held after the simulations were run, determined the on-farm experiments to be conducted in the 2009/10 season based on the APSIM simulation results and other climate data. The fourth FGD explored feedback from the on-farm experiments and farmer perceptions on APSIM as a decision-making tool. In each FGD, data were captured by the farmers and the researcher on flip charts.

Resource Allocation Mapping

Resource Allocation Mapping (RAM) is an interactive process in which farmers draw maps to represent their homesteads, their fields and how they allocate resources (Rudebjer, 2001). The information collected was used as input into the APSIM model to establish a baseline and validate the model with local data. RAM also helped in gaining an insight into farming systems and resources of different farmers. The baseline data included information on farming systems, farmers' fields, soil types, crops grown, allocation of resources (for example, fertilizer and seed), timing of farm operations and yields. Most importantly, RAM assisted in the formulation of "what if" questions to be explored using the APSIM model.

After the first FGD, all 30 farmers were asked to draw a map of their homesteads and fields showing how they had allocated their resources for the 2007/2008 season. The research leader outlined to the farmers the range and type of information to include in the map, for example, soil type, size of fields, varieties grown, dates of field activities and the actual yields obtained from each field. The other team members (including the extension agents) moved amongst the groups to assist the farmers.

APSIM Simulations

Introducing a new technology is often supported using approaches involving visual aids. Carberry et al. (2004) used hand drawn images on a flipchart to show all the agricultural processes involved during the rainy season as a part of introducing computer simulated crop production. In that study, images were used to show the link between the growth process and rainfall. The same approach was used in this study to help explain how APSIM simulates all the growth processes. Visual imagery, as a representation of reality, helped the participants understand the use of simulated production using the same information that would be used in a real-world setting (Carberry et al., 2004).

During the first and again the fourth FGD, it was explained further to the farmers that APSIM could simulate their various field practices from sowing to harvesting, but that it "performs" these operations faster and without committing any actual resources such as inputs or time. Through this exercise, the farmers understood that APSIM could show instantaneously the effect of actions or decisions. Thus it can be a useful tool to explore various strategies and alternatives before actually implementing them – learning by simulation rather than by actual outcome. To consolidate their learning, farmers took turns to work through a demonstration of how the model works on a laptop. Learning by simulation is an effective way of engaging farmers in learning (Carberry et al., 2004). In this instance it supports the notion of engaging famers in scientific inquiry (Worth, 2006).

APSIM was run with all 30 participating farmers collectively, that is, as one group with the researcher explaining all the steps while simultaneously entering data into the model on a laptop. The outputs were drawn on a flip chart for farmers to visualize the results clearly. The crop management information used came from the RAMs presented by the six representatives of the groups discussed earlier. The accuracy of the information was verified by the local extension agents who reside in the same villages with the participating farmers. The climatic data used were from Thornhill Met station in Gweru, which was the nearest station to the study site. In the absence of actual soil description data, the soil descriptions used were modified from the soils already in the model, based on the experience of the extension agents and the lead researcher. This is consistent with the practice that in cases where simulations are done without actual testing, the effectiveness of the simulation will be dependent on the partnership between the farmers and the extension agents (J. P. Dimes, personal communication, October 13, 2008). The modified parameters were the Plant Available Water Content (PAWC), initial soil nitrogen content and initial soil water. Initial soil nitrogen content was set at 6kg/ha in the form of nitrates and 3kg/ha as urea. The initial water content was set at 10% filled from the top layer. The simulation template used was the Continuous Maize and Weeds Simulation. The date range for the simulation was set at 1 October 2000 to 31 May 2008, although the 2007/2008 season was the only season used for the RAM session. The other simulated years had been included in the event that farmers might remember the yield they got during those years and how they compare to the simulated ones.

Semi-Structured Interviews

Following the FGDs, the lead researcher conducted semi-structured interviews (SSIs) (Barriball & While, 1994; Campion, Pursell, & Brown, 1988) with 24 farmers of 30 farmers who participated in the FGDs selected through stratified random sampling-; the reduced number was informed by the practical arrangements with the SSIs and based on previous experience which anticipated data saturation. The purpose of the SSIs was to solicit information from individual farmers (taking into consideration the socio-economic factors affecting them) about their application of the APSIM model to decision-making as well as their perceptions of climate forecasting and how they cope and adapt to climate variability and future change. The SSIs covered questions about current decision-making processes on crop management and climate, farmers' perception of climate change, the climatic and crop management information they value the most and their preferred source of this information, farmer perceptions of seasonal climate forecasts and APSIM as well as applicability of the model to decision-making.

Data Analysis

Data from the FGDs were straightforward in creating themes to be used for the SSIs, and, thus, did not require detailed analysis (Stewart, 2007). The data from the SSIs were analyzed using summarizing content analysis to surface critical issues in a manageable text (Mayring, 2004). Data from the on-farm trials were analyzed using the Genstat statistical package. Data from the RAMs, analyzed in the style of Rich Pictures, were "mined more for their explicit rather than implicit content" (Bell & Morse, 2010, p. 9) to help create the parameters for the simulation and planning of the on-farm trials.

Results and Discussion

Keys findings are reported and discussed under three major themes: farmers' perception to climate change, decision-making processes and APSIM use as a decision-making tool, as outlined below.

Farmer Perceptions of Climate Change

All the farmers noted that the climate of their area is changing. Their evidence was indicators they noted over the last 15 years living and farming in the area. From these observations, they were able to depict the following changes: increased number of seasons without adequate rains, increased rainfall extremes in the last 10 years, long dry spells during the rainy season, rains starting late into the season, rains ending earlier than what they used to do, temperature extremes, and drying up of perennial streams and rivers. This unreliability of rains, in terms of amount, start and end dates of the rainy season led farmers to be more interested in the OSCF. Further they would demand such climate information from extension agents earlier in the season to guide them on crop management decisions (including crop choice and varieties, fertilizer type and amount).

Decision-Making Processes

At the beginning of this study, in early focus group discussions, all the farmers highlighted that they exclusively used their knowledge of indigenous indicators to make crop management decisions. These farmers had, over many years of farming, actually developed indicators which signal both a low rainfall season and a good rainfall season as shown in Table 1.

Table 1

Indigenous Indicators of a Good and Poor Rainfall Season

Indicators of a Good Rainfall Season	Indicators of a Poor Rainfall Season
Plenty of raindrops from *Thithamuzi* (raining tree)	No raindrops from the tree
High temperatures towards onset of rainfall season	Low temperatures towards onset of rainfall season
Early ripening of indigenous fruit trees like *mugan'atsha*, *muchakata*, wild grapes (*tsambatsi)*	No or less fruiting
Presence of dew on trees	Less or no dew at all
Birds (*madendera*) arriving early in the season	Late arrival or total absence of birds
Prevalence of north-easterly winds in October-November	Absence of north-easterly winds in October-November

The indicators presented in Table 1 are similar to findings by Mapfumo et al. (2010) and Ziervogel (2001) that farmers can use their own indicators to predict nature of the season with regard to rainfall amount. Despite the small-scale farmers admitting their indigenous indicators were now failing to deal with the changes in climate they identified, they highlighted there were two major reasons why they continued using them. Firstly, they did not have any reliable alternatives. Secondly, their system had been tried and tested. Whilst they acknowledged that this indigenous local knowledge has not been updated to cater for current climate changes, they indicated that it would take some time for them to establish what works for them – given the fact that climate is becoming more variable. This corresponds with the risk-averse or conservative nature of small-scale farmers noted by Hansen and Sivakumar (2006). Further, only a small percentage (11%) of the farmers knew of the OSCF, which they said they got from the radio. However, they were not sure of the OSCF and how to apply the information and hence were not using it to guide decision-making.

During the SSIs all of the farmers acknowledged they were now able to use the OSCF and other alternatives like APSIM model outputs after they were introduced to them in this study. The information obtained from climate forecasting, whether in the form of official or indigenous seasonal forecasting, is used for aiding crop management decision-making and planning coping or adaptation strategies for their farming. For example, indications of a poor rainfall season prompt farmers to look for early maturing varieties, avoid use of fertilizer or use fertilizer in low amounts, use ridges to keep the little moisture and weed regularly. With forecasts for a good season farmers prepare land early, invest in fertilizers and high yielding varieties while a few farmers (17%) indicated that they would dry plant (usually in October) in anticipation of good rains.

Identified Sources of Agricultural and Climatic Information

Sources of farming and climatic information identified were extension agents, other farmers through their farmers' clubs and, to a small extent, radio. The extension services were highly valued as farmers said they offered demonstrations and were much better trained than other farmers in their clubs, who sometimes did not have accurate information. All the farmers (100%) preferred the extension services (AGRITEX) as a source of information to radio and other farmers. This conflicts with a study in India where small-holder, poor farmers turned most often to other progressive farmers, followed by input dealers and the radio – with extension ranking sixth as a source of information (Birner & Anderson, 2007). However, it concurs with findings by Ziervogel (2001) that most farmers preferred to get the official forecast information from the extension agents, citing mainly that agents helped them understand by explaining in their mother language using units of measurements they understood and through demonstrations. It also concurs with Cavane and Donovan (2011) who found farmers who had obtained information from, "extension had stronger positive attitudes than farmers who learned… from neighbors" (p. 13). They argued "personal contacts between extension agents and farmers are more effective for delivering specific information to farmers" (Cavane & Donovan, 2011, p.13).

While the farmers acknowledged they received technical information about production, they all indicated that the extension agents had not been supplying them with any climatic information, with the exception of the last two years under this study. This was because the extension agents were themselves not familiar with the OSCF until they were trained in how to use the service during this study.

Further, 90% of the farmers stated they preferred or valued climatic information over soil treatment and agronomic information. They argued without climatic information one could not adequately plan or make decisions on crop choice and varieties, which fertilizers to invest in, and when to sow or carry out other farming operations.

Using APSIM as a Decision-Making Tool

The findings of the SSIs revealed 92% of the farmers remembered the model. Of those recalling the model, 86% chose to continue using it. Their reasons were that it helped in planning, offered quick testing opportunities without committing resources, guided farm resource allocation and helped in quantifying the risks of management strategies.

The farmers' reasons for using APSIM are consistent with earlier findings that APSIM does not pursue a single best management strategy, but rather aids the assessment of an array of alternative options suited to different seasons and priorities of the farmer (CIMMYT, 1999). APSIM creates a lot of (simulated) experience without the actual risk of real implementation of alternative strategies (Dimes et al., 2003).

The findings suggest small-scale farmers are really concerned about their livelihoods (farming) and can and will utilize help, including modern technologies, once convinced that they are useful and beneficial to their farming and fit their farming system. This confirms the view noted by Hansen (2002) and Stroeken and Knol (1999) that people are inclined to learn once they have seen the outcome of a practical experience in which they were personally involved or engaged. Furthermore, the farmers aim to make informed decisions provided they have relevant information, tangible evidence or experience, in this case, simulation outputs.

Fourteen percent (14%) of the farmers, who remembered using the APSIM, stated they would not be using it. One of these farmers was very clear that he would continue to use the indigenous indicators and method as he had managed to survive well without modern technologies like APSIM. However, for the rest who would not be using APSIM, the reasoning was conflicted. On the one hand, the main reason for not using APSIM was that they did not have access to computers to run the model. Beyond this, they did not really understand the science behind, or the complexity of, the model. And they do not have the confidence to use the model on their own without "experts." This aspect of their reasoning is consistent with the limitations noted earlier that APSIM use is hampered by absence of capable users as well as lack of reliable input data, especially in poor regions of Africa (Struif-Bontkes & Wopereis, 2003).

On the other hand, the remaining farmers who would not be using APSIM also said they understood the usefulness and advantages of the model. They acknowledged the farmers who really understand and will be using the model in decision-making will be better off due to its usefulness and advantages. They further pointed out that if given another opportunity to interact with the model and its outputs they might want to use it. This is consistent with views of Ngomane (2010) of supporting the use of envisioning approaches to developing technology – or in this case making technology decisions – which "incorporates the collective knowledge of key role players" (p. 66) and "increases the likelihood that research results shall be applied" (p. 66).

Overall, the study found APSIM is useful and, within specific limitations, an appropriate aid to decision-making for smallholder farmers. APSIM adds value to OSCFs since it predicts crop yields for any given forecast. This contrasts with the farmers' indigenous indicators, which, in essence, only give an indication of the amount of rainfall received and can also misinform farmers and might not be clear. The study, however, also suggests there is need for encouraging the combination of exogenous (like crop simulation modeling) and local knowledge.

Given the increased access to and confidence in using OSCFs, there is potential for engaging farmers in an exercise of revisiting their indigenous indicators alongside the data from OSCFs to strengthen their reliability and accuracy. Given that reliability of data is a key limitation in using APSIM, more reliable indicators developed through a process of scientific enquiry could contribute to overcoming this limitation in areas where data from OSCFs are less available or less accurate due to distance between the source of the data and the place of their application. Such an approach is consistent with the view of Prasad et al. (1996) that some small-scale farmers use modern climatic and market information obtained from radios and extension agents, in addition to indigenous knowledge. It is more broadly consistent with Okorley, Gray, and Reid (2009) who argued that by understanding the indigenous knowledge of farmers better positions extensions to meet farmers' needs "because it can build on what they already know" (p. 39).

Conclusions, Recommendations, and Implications

The study suggests an interplay between local knowledge and so-called modern technologies, in this case APSIM. It found continued reliance by small-scale farmers on local knowledge and indicators that are admittedly unreliable and ill-suited to interpret current climate change conditions is due to a lack of clear proven alternatives that are understood and tested by the farmers through first-hand experimentation. The study found a greater willingness to consider computer-based modeling because of the pressures of climate change and the waning adequacy of their indigenous systems. However, the study also found farmers used APSIM when they saw for themselves its accuracy and relevance to their farming systems and found it useful for making decisions relative to climate variations.

The study further suggests APSIM cannot and should not replace or displace the use of local indicators or OSCF, but can add value by quantifying risks associated with strategies identified to manage climate change. It acknowledges APSIM is a model that requires trained personnel, modelers and access to computer technology. However, farmers can actively participate in identifying and otherwise developing the input data and running the simulations. And they can, of course, use the information outputs to aid them in making decisions relative to more accurately predictable changing climatic conditions. As Birner and Anderson **(**2007) and Worth (2002; 2006) suggested, engagement is the key; when farmers are genuinely engaged and working within their indigenous framework will create the demand (Birner & Anderson**,** 2007) and foster learning (Worth, 2006). It requires "intimate interaction with farmers" (Vreyens, 1999, p. 44) and "facilitating the farmers' innovation decision process" (Vreyens, 1999, p. 44), to advise farmers effectively and effect change.

Similar to George, Birch, Clewett, Wright, and Allen (2005) who submitted that "exercises, which simulated a 'real' problem are…seen as beneficial" (p. 25), this study confirmed the willingness of the majority of the farmers to use APSIM together with OSCFs data to support their decision-making. Thus it showed working first-hand with new technologies – even sophisticated computer-based technologies – enables farmers to learn in their individual contexts the value of those technologies and their applicability to their farming systems. In this case their experience and learning with APSIM - changed the farmers' perceptions of the risk they attributed to fertilizer use in semi-arid environments by showing that yields are guaranteed when fertilizers are used, whereas when fertilizers are not applied, in some seasons yields cannot be guaranteed.

The APSIM model on its own does not guarantee good decision-making. However, it does give insights into the potential results of a number of alternatives in quantifiable terms which are easy for farmers to understand once they have had first-hand experience with it. Use of APSIM should be supported by other tools, such as cost benefit analysis, and enterprise and partial budgeting, to enable farmers to predict crop yields as well as determine their impact on profit and thereby select their best option(s) from a number of alternatives.

The study confirmed farmers value the services they get from the extension agents and are willing to learn from them particularly if they farm in their area. Thus extension agents are critical in the uptake and adoption of new technology by farmers, and they are most effective when they engage the farmers in a program of experiential-based learning. When the new technologies are complex, as in the case of APSIM, it is also important that the extension agents are well trained in the operation and use of the new technology before it is introduced to the farmers.

Finally, the study demonstrated farmers' keen interest and willingness to learn when their livelihoods are at stake. However, being risk-averse and perceiving themselves as highly vulnerable to the many influences on their farming activities, including climate change, the farmers proceed with caution and wisdom. They will not rush to adopt any significant change unless they have hard facts that they themselves have participated in generating. This again supports a learning approach to extension which deliberately engages farmers with experimentation and scientific enquiry.

The implications are fairly straightforward. Farmers are unlikely to adopt what is offered. Whether introducing a model like APSIM or any other technology, unless the farmers are directly involved with its testing in the field – preferably on their own farms. The question remains as to whether extension practitioners are adequately trained to approach farmers in an iterative process of inquiry, rather than to inform and otherwise demonstrate and promote the use of any given technology. Research into such capacity in iterative engagement with farmers, among existing extension practitioners is recommended, as is an investigation into the training and education of extension practitioners to ensure that they have the necessary knowledge, skills, attitudes and behaviors to implement this kind of extension among small-scale resource-constrained farmers. As Veryens (1999) argued, such approaches would require extension service, systems and practitioners to develop new competencies.

References

Altieri, M. A., & Koohafkan, P. (2008). *Enduring farms: Climate change: Smallholders and traditional farming communities.* Malaysia: Third World Network.

Barriball, K. L., & While, A. (1994). Collecting data (using a semi-structured interview: a discussion paper). *Journal of Advanced Nursing, 19,* 328–335.

Beckford, C., & Barker, D. (2007). The role and value of local knowledge in Jamaican agriculture: adaptation and change in small-scale farming. *Geographical Journal, 173*(2), 118-128. doi: 10.1111/j.1475-4959.2007.00238.x

Bell, S., & Morse, S. (2010). Rich pictures: A means to explore the 'Sustainable GroupMind'?. *Proceedings of the 16th annual International Sustainable Development Research Conference, Hong Kong, China*. Retrieved from http://www.kadinst.hku.hk/sdconf10/Papers_PDF/p56.pdf

Birner, R., & Anderson, J. R. **(**2007). *How to make agricultural extension demand driven–The case of India's Agricultural Extension Policy* (Discussion Paper No. 00729). Washington, DC: International Food Policy Research Institute (IFPRI).

Campion, M. A., Pursell, E. D., & Brown, B. K. (1988). Structured interviewing: Raising psychometric properties of the employment interview. *Person Psychology, 41,* 25-42.

Carberry, P., Gladwin, C., & Twomlow, S**.** (2004). Linking simulation modelling to participatory research in smallholder farming systems. In R. Delve, & and M. E. Probert (Eds.), *Modelling nutrient management in tropical cropping systems* (pp. 32-46). Australia: ACIAR Proceedings No. 114.

Cavane, E., & Donovan, C. (2011). Determinants of adoption of improved maize varieties and chemical fertilizers in Mozambique. *Journal of International Agricultural and Extension Education, 18*(3), 5-21. doi: 10.5191/jiaee.2011.18301

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). (1999). Risk management for maize farmers in drought-prone areas of Southern Africa. *Proceedings of a workshop* *held at Kadoma Ranch, Zimbabwe.* Mexico: CIMMYT.

Chikoore, H., & Unganai, L. (2001, October). *Integrating climate forecast information in agricultural management. A perspective from Southern Africa*. Paper presented at the Open Meeting of the Global Environmental Change Research Community, Rio de Janeiro. Retrieved from http%3A%2F%2Fsedac.ciesin.org%2Fopenmeeting%2Fdownloads%2F1005837863_presentation_hchikoore_riopaper1.doc

Cline, W. R. (2007). *Global warming and agriculture: Impact estimates by country*. Washington, DC: Centre for Global Development and the Peterson Institute for International Economics.

Dimes, J., Twomlow, S., & Carberry, P. (2003). *Application of new tools: Exploring the synergies between simulation models and participatory research in smallholder farming systems. Global Theme 3: Water, soil and agrodiversity management for ecosystem resilience* (Report No. 5.). Bulawayo, Zimbabwe and Queensland, Australia: CSIRO Sustainable Ecosystems/APSRU.

George, D. A., Birch, C., Clewett, J. F., Wright, A., & Allen, W. (2005). Major issues and solutions to applied climate education in Australia. *Journal of International Agricultural Education and Extension, 12*(3), 21-31. doi: 10.5191/jiaee.2005.12302

Hansen, J. W. (2002). Realizing the potential benefits of climate prediction to agriculture: issues, approaches, challenges. *Agricultural Systems, 74,* 309-330.

Hansen, J. W., & Sivakumar, M. V. K. (2006). Advances in applying climate prediction to agriculture. *Climate Research, 33,* 1-2. Retrieved from http://www.int-res.com/articles/cr_oa/c033p001.pdf.

Holzworth, D., Meinke, H., DeVoil, P., Wegener, M., Huth, N., Graeme, H., … Murphy, C. (2006). *The development of a farming systems model (APSIM) – a disciplined approach.* Australia: CSIRO Sustainable Ecosystems/APSRU. Retrieved from http://www.iemss.org/iemss2006/papers/w4/Holzworth.pdf

Hurni, H. (1996). *Precious Earth: From soil and water conservation to sustainable land management. Generating and disseminating knowledge: The role of science, local knowledge and education.* Berne: International Soil Conservation Organisation and Centre for Development and Environment.

Krueger, R. A. (1994). *Focus groups. A practical guide for applied research.* Thousand Oaks, CA: Sage Publications.

Mapfumo, P., Chikowo, R., & Mtambanengwe, F. (2010). *Lack of resilience in African smallholder farming: Exploring measures to enhance the adaptive capacity of local communities to climate change*. Final Technical Report to the IDRC-DfID Climate Change Adaptation in Africa (CCAA) program. Harare: University of Zimbabwe.

Mayring, P. (2004) Qualitative Content Analysis. In U. Flick, E. von Kardorff & I. Steinke (Eds.), [Translated by B Jenner], A Companion to QUALITATIVE RESEARCH (pp. 266-269). London: Sage Publications.

Merton, R. K., Gollin, A. E., & Kendall, P. L. (1956). *The focused interview: A* *manual of problems and procedures*. New York: The Free Press.

Ngomane, T. (2010). From a deficit-based to an appreciative inquiry approach in extension programs: Constructing a case for a positive shift in the current extension intervention paradigm. *Journal of International Agricultural Education and Extension, 17*(13), 57-68. doi: 10.5191/jiaee.2010.17305

Nyiraruhimbi, A. (2012). *Indigenous approaches to maize production and soil management in Msinga KwaZulu-Natal, Province* (Unpublished master's thesis). University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Okorley, E. L., Gray, D. I., & Reid, J. I. (2009). Improving agricultural extension human resource capacity in a decentralized policy context: A Ghanaian case study. *Journal of International Agricultural Education and Extension, 16*(2), 35-46. doi: 10.5191/jiaee.2009.16203

Prasad, C., Kesseba, A. M., & Singh, S. P. (1996). *Extension strategy for resource poor farmers in rainfed agriculture.* India: Macmillian India limited.

Probert, M. E., & Dimes, J. P. (2004). Modeling release of nutrients from organic resources using APSIM. In R. Delve, & and M. E. Probert (Eds.), *Modelling nutrient management in tropical cropping systems* (pp. 25-31). Australia: ACIAR Proceedings No. 114.

Rudebjer, P. G. (2001). *Training course on participatory on-farm experimentation and integrated approaches to land management*. Indonesia: International Centre for Research in Agroforestry Southern Asian Network for Agroforestry Education.

Selvaraju, R., Meinke, H., & Hansen, J. W. (2004). Approaches allowing smallholder farmers in India to benefit from seasonal climate forecasting. In R. A. Fischer (Ed.), *New directions of a diverse planet: Proceedings for the 4th International Crop Science Congress*. Australia: Australian Society of Agronomy.

Stewart, D. W. (2007). Analyzing Focus Group Data. In D. W. Stewart, P. N. Shamdasani & D. W. Rook (Eds.), *Focus Groups: Theory and Practice.* (pp. 109-133) London: Sage Publications

Stroeken, J. H. M., & Knol, W. H. C. (1999). *The stimulation of the diffusion and adoption of information technology in small and medium-sized enterprises through IT scenarios.* Research report of Eindhoven Centre for Innovation Studies, Netherlands: Eindhoven University of Technology.

Struif-Bontkes, T. E., & Wopereis, M. C. S. (2003). Opportunities for the use of decision support tools for smallholder agriculture in Sub-Saharan Africa. In T. E. Struif-Bontkes, & M. C. S. Wopereis, (Eds.), *Decision support tools for smallholder agriculture in Sub-Saharan Africa. A practical guide, 1-23.* Shoals, USA: International Centre for Soil Fertility and Agricultural Development.

Vreyens, J. R. (1999). Facilitating change in Senegalese rice production: Learning Serer women farmers' decision making. *Journal of International Agricultural and Extension Education, 6*(2), 39-46.

Worth, S. (2002). Sustainable extension: Not transformation but renewal.

Proceedings of the 18th Annual Conference of Association for International Agricultural and Extension Education (AIAEE), Durban, South Africa. pp. 118-120.

Worth, S. (2006). Agriflection: A learning model for agricultural extension in South Africa. *The Journal of Agricultural Education and Extension, 12*(3), 173-193. doi: 10.1080/13892240600915488.

Ziervogel, G. (2001, October). *Global science, local problems: SCF use in a Basotho village, southern Africa.* Paper presented at the Open Meeting of the Global Environmental Change Research Community, Rio de Janeiro. Retrieved from http%3A%2F%2Fsedac.ciesin.columbia.edu%2Fopenmeeting%2Fdownloads%2F1002573617_presentation_riopaper.doc.