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Abstract
Climate variability represents a significant risk to farming enterprises. Effective extension of climate information may improve climate risk decision making and adaptive management responses to climate variability on farms. This paper briefly reviews current agricultural extension approaches and reports stakeholder responses to new web-based virtual world 'discussion-support' tools developed for the Australian sugar cane farming industry. These tools incorporate current climate science and sugar industry better management practices, while leveraging the social-learning aspects of farming, to provide a stimulus for discussion and climate risk decision making. Responses suggest that such virtual world tools may provide effective support for climate risk decision making on Australian sugar cane farms. Increasing capacity to deliver such tools online also suggests potential to engage large numbers of farmers globally.

Keywords
Agricultural extension, climate risk management, discussion support tools, Second Life machinima

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Introduction

Climatic variability is a central challenge to farming in countries such as Australia where seasonal conditions and weather events may significantly impact crop production over the growing season, threatening farm profitability and viability (Everingham *et al.* 2002; Howden *et al.* 2007). Increasing climate variability with climate change, in combination with population growth and increasing competition for scarce resources, has potential to cause significant biophysical, environmental, social and economic disruption (Australian Academy of Science, 2010). Practice change made at the farm level is a critical component of adaptation to climate variability and risk in agricultural systems (Howden *et al.*, 2007; Hogan, Berry, Ng and Bode, 2011). Knowledge transfer ('extension') from agricultural researchers to farmers has long been seen as vital to ensuring farmers have access to information to support improved on-farm decision making (Vanclay, 2004). However, conventional agricultural extension services have proven limited in their capacity to cost-efficiently engage large numbers of farmers and to effect widespread adoption of agricultural innovations and recommended management practices (Vanclay, 2004; Warner, 2006; Rist, Chidambaranathan, Escobar, Wiesmann and Zimmermann, 2007; Leach, 2011; Vanclay and Leach, 2011; Hunt, Birch, Coutts and Vanclay, 2012).

Agricultural extension

Agricultural extension services have traditionally been institutionalised, 'top down' and focused on the transfer of technical knowledge—delivering specific, often commodity-based, advice to farmers about the practices and technologies they should adopt to increase production and profit and minimise environmental harm (Evenson, 2001; Vanclay, 2004). Recent decades have seen a move, in response to research into adult learning styles and effective knowledge exchange, towards a range of interactive participatory and social cooperative learning approaches in face-to-face extension which increasingly acknowledge farmers' existing knowledge and experience (Francis and Carter, 2001; Warner, 2006; Reed, 2008; Bartels *et al.*, 2013).

Contemporary extension is strongly focused on the importance of capacity building (Coutts and Roberts, 2011). It uses participatory learning processes to facilitate expert-farmer and farmer-farmer dialogue and discussion and has delivered improved farmer decision making and risk management (Warner, 2006; Reed, 2008; Cundill and Rodela, 2012; Bartels *et al.*, 2013). Such 'in-person' agricultural extension services deliver a good return on investment, resulting in a positive impact on practice change (e.g. the adoption of new technologies and more sustainable farm management practices) (Huffman and Evenson, 1993).

However, while reportedly effective for the small numbers of farmers engaged in face-to-face extension, in-person agricultural extension services face critical constraints, including: relatively small numbers of extension personnel relative to farmer needs and demands; variable levels of experience, training and communication skills; and lack of operational resources (funds, equipment) due to declining levels of government funding and policy support (Anderson and Feder, 2004; Warner, 2006; Rist *et al.*, 2007; Leach, 2011; Vanclay and Leach, 2011; Hunt *et al.*, 2012). This has been compensated to an extent by a shift towards delivery of extension by agricultural industry Research and Development Corporations (RDCs) and the private sector (Hunt *et al.*, 2012). However, farmer participation in face-to-face extension services is also limited by the often considerable distances and associated time and costs involved (e.g. in many parts of Australia); even in more densely populated countries, extension services can effectively reach only a small proportion of farmers (Anderson and Feder, 2004).

The scaling-up of agricultural extension programs to reach larger numbers of farmers presents a significant challenge to conventional expert-driven face-to-face agricultural extension and highlights the inherent limitations of these approaches. Advances in information and communication technologies (ICTs) and increasing access to these in many parts of the world suggest their significant potential to deliver extension services to large numbers of farmers, regardless of geographic location—potentially, thousands of farmers nationally and millions globally. However, ICTs have so far failed to bring about expected improvements in terms of increased adoption of innovation on farms (e.g. Chowdhury and Odame, 2013), in part because their use has been largely limited to supporting traditional communication tasks of information dissemination and training (Sulaiman, Hall, Kalaivani, Dorai and Reddy, 2012). Agricultural extension that is informed by leading edge advances in the social sciences and can effectively and cost-efficiently incorporate innovative digital platforms to enhance widespread delivery is needed.

Decision support

Over recent decades, technological advances in agricultural systems science have led to the development of a range of sophisticated ‘decision support’ tools which combine expert knowledge and complex biophysical modeling to derive optimal solutions to assist in specific crop management decisions (McCown, 2002b). Examples include SIRATAC (Hearn, Brook, da Roza and Ashburner, 1985), WHEATMAN (Woodruff, 1992), OZCOT (Hearn 1994), FARMSCAPE (Carberry *et al.*, 2002) and Yield Prophet (Hochman *et al.*, 2009). Such decision support systems have been widely tested in Australia (e.g. Hochman *et al.*, 2009; Carberry, Hammer, Meinke and Bange, 2000; Carter *et al.*, 2000) and elsewhere (Jame and Cutforth, 1996; McCown, 2002a). However, overall, there has been only limited adoption of these types of decision support tools by farmers (Keating and McCown, 2001; McCown, 2002a; McCown, Hochman and Carberry, 2002; Hayman, 2003; McCown and Parton, 2006; Jørgensen, Noe, Langvad, Jensen, Ørum and Rydahl, 2007; Jakku and Thorburn, 2010; Hochman and Carberry, 2011).

Low levels of adoption of decision support tools by farmers may, in part, reflect the limited capacity of these tools to incorporate (i) the range of contextual (social, economic, and environmental) factors involved in farm management decision making and (ii) existing farmer knowledge (Francis and Carter, 2001; Pannell, 2006; Matthews, Schwarz, Buchan, Rivington and Miller, 2008). Evidence of the failure of decision support systems to effectively influence farm management decisions of large numbers of farmers has led to revised thinking around the need for information to both match farmers' needs and accommodate different styles of information gathering, reasoning and decision-making (McCown, 2002b; Jørgensen *et al.*, 2007). It has been suggested that those decision support systems which better engage with, and reflect, farmers' natural modes of learning through experience and discussion may be most effective (Nelson, Holzworth, Hammer and Hayman, 2002; McKeown, 2010).

Discussion support

A number of approaches which couple the 'hard' science of decision support systems with participatory processes have been trialed (Keating and McCown, 2001). One approach involved 'kitchen table' discussions in which a farming systems specialist presented the results of climate-crop simulations face-to-face to facilitate free discussions with farmers present (Keating and McCown, 2001; McCown *et al.*, 2002); others used decision support systems to develop a 'dialogue paradigm' to better link research and on-farm decisions and practices (Nelson *et al.* 2002). In such cases, the critical difference in this approach was the element of discussion and engagement with the social nature of farming (Vanclay, 2004). However, scaling-up the process to benefit greater numbers of farmers has remained a challenge and there has been little apparent progress to date in developing more cost-effective approaches to facilitate 'discussion support' and deploy the concept more widely—a role for which digital technologies may be ideally suited (Stone, 2010; Stone, Reushle and Reddy, 2012).

Research into effective distance learning environments, including 'eLearning' using digital platforms, in the education sector indicates significant opportunity for the development and delivery of effective, equitable and cost-efficient agricultural e-extension systems (Stone, 2010; Stone *et al.*, 2012). Extension systems which incorporate cutting edge advances in educational research and innovative applications of digital technologies might play a major role in enhancing the adaptive capacity of farmers thereby helping to maintain farm productivity and profitability while safeguarding future food security. This is particularly important with regard to the risk posed to agriculture by climate variability, where an effective means of supporting the integration of climate forecasts into core farming decisions is needed if farmers are to remain sustainable.

Developing discussion support tools

There have previously been only limited efforts to operationalise the concept of discussion support in agricultural extension. This paper describes research which uses an innovative application of the web-based virtual world Second Life™ platform to create 'discussion support' tools for improved on farm climate risk decision making. The research develops and evaluates the use of digitally animated video clips (machinima) in which characters (avatars) model conversations which integrate relevant climate information and industry recommended management practices in practical farm decision making scenarios. Informed by Bandura's theories of observational and social learning (Bandura, 1974; Bandura and McClelland, 1977; Siemans, 2005; Reed *et al.*, 2010), we hypothesise that these tools might work at a number of levels as a catalyst for change in farmers' thinking and practice. They may work with or without the presence of technical advisers to augment farmers' learning and provide stimuli for group (including family unit) discussions around how to incorporate an understanding of climate risk into operational on-farm decision-making; they may generate new cognitive schema or mental models (Merrill, 2000) for farmers in their operational decision-making; and, in some cases, they may also lead to the use of more complex decision support tools by farmers.

These tools are being developed for and evaluated within the Australian sugar cane farming industry (Reardon-Smith *et al.*, 2014), building on earlier experience in which we developed a prototype agri-climate discussion support machinima for cotton farmers in India (Stone, 2010; Stone *et al*, 2012). This paper presents preliminary results from a pilot evaluation designed to test acceptance of the approach within the Australian sugar industry. Responses from sugar industry personnel (17 farmers, managers and extension officers) indicate overall support for the concept and suggest it has potential to enhance the delivery of consistent targeted information to farmers and stimulate further discussion around on farm climate risk decision making.

Case study selection and methods

The Australian sugar cane industry operates in coastal regions of north-eastern Australia, from tropical north Queensland to the subtropical parts of north-eastern New South Wales (Fig. 1), a region of relatively high climatic variability hence substantial climate risk to agricultural enterprises. Farmers in the region experience conditions ranging from significant water shortages due to drought to major flood events associated with tropical storms and cyclones. Access to targeted climate information and the capacity to use this information to support improved decision making to mitigate risks and the impact of climatic events on farm productivity and profitability are vital to ensuring the sustainability of farming enterprises, agricultural industries and rural communities in such regions (Everingham *et al.*, 2002; McKinna and Everingham, 2011).

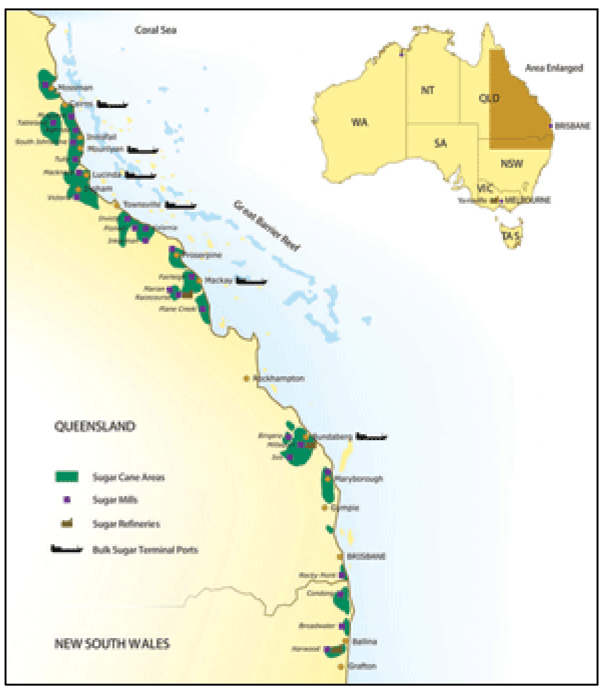

Figure 1: Australian sugar cane growing regions, major centres, sugar mills and port locations (Canegrowers Australia, 2010).

The Australian sugar industry invests, on average, over $826,000 per year (11 percent of the industry's average annual research and development budget) in its Extension and Outreach program (Sugar RDC, 2005–2012; SRA, 2013). Thus, the development of effective agri-climate extension tools and delivery mechanisms is important to ensure the effective use of industry resources. If successful, the new virtual discussion support tools developed by this project may provide a cost-effective option for the delivery of extension and communication activities and result in improved adoption outcomes by both complementing existing extension practices (e.g. Materia, Giarè and Klerkx, 2015) and expanding the reach to farmers whose access to conventional extension is constrained for any of a range of reasons (e.g. cost, time, personal preference etc.).

Virtual World tools development

The 'Sweet Success' discussion support tools for this project were created in Second Life, an interactive 3D virtual world (VW) platform. VWs are computer-, server- or internet-based simulated environments which are populated by motional 'avatars' (characters) whose actions and interactions can be manipulated (Duridanov and Simoff, 2007). Of the range of VWs, Second Life is one of the best-known, boasting almost 41 million user accounts at the time of writing and up to 60,000 users online at any time (Voyager, 2015).

Second Life is an ideal environment in which to film machinimas (i.e. digitally animated video clips). While filmmaking in Second Life, often using 3-D videogame technologies (Johnson, 2012), corresponds in many ways to the development of other video formats with real world actors, the VW environment has a number of advantages which make it highly flexible and relatively cost-effective. Content is created almost exclusively by users and can be purchased online at minimal cost, making it highly affordable. Users of Second Life are also able to manipulate the VW environment to create a variety of realistic simulated settings in which avatars, customised to represent a range of identities, can move, interact and form virtual communities (Salmon, 2009).

Scenario development

The current project has developed four machinimas for the Australian sugar cane farming industry, each representing a key decision point in sugar cane farming: (i) harvesting; (ii) fertiliser application; (iii) irrigation scheduling; and (iv) activity planning. These were filmed using lifelike avatar actors, customised settings and real-world, climate-based scenarios relevant to the lives and practices of Australian sugarcane farmers (Fig. 2).

Figure 2: Screen shot of the Harvesting agri-climate discussion support machinima developed for Australian sugar cane farmers showing a typical Queensland sugar cane farming landscape, farm vehicles, house, farm shed and avatars dressed and behaving in ways designed to appear familiar to sugar cane farmers viewing the machinima.

To ensure an engaging integrated storyline and consistency throughout the series, back stories were created for the key characters, based on the decision-making types described by Jørgensen *et al.* (2007), namely: (a) system-orientated farmers, (b) experience-based farmers and (c) advisory-orientated farmers. As in real life, farmers' family members also play a part in the discussions simulated in the machinimas. Short (3–5 minute) scripted conversations (discussions) between these characters were written by team members with knowledge of climate risk and recommended management practices in agricultural systems, and particularly cane farming systems, in Australia. The scripts relate to the experiences of Australian sugarcane farmers and model real-world conversations between farmers about the impact of variable weather conditions and the outcome of different management options.

The scripts use 'storytelling' (Taylor *et al.*, 2002; Abma, 2003; Ryokai, Vaucelle and Cassell, 2003; Barrett, 2006; Tsou, Wang and Tzeng, 2006) in a context that is relevant and credible to the target audience (Kok, Biggs and Zurek, 2007; Lamarque *et al.*, 2013)—in this case, sugar cane farmers and their families. Overall, the machinimas focus on challenging, engaging and entertaining viewers (Francis and Carter, 2001) while maintaining an aesthetic quality (Taylor *et al.*, 2002; Gesser-Edelsburg and Singh, 2013). Considerable care was taken to ensure that the machinima sets (the landscape, farm infrastructure and equipment) were representative of Australian cane farms and the avatars accurately represented, to the extent possible, Australian cane farmers in terms of their appearance, dress and mannerisms.

Research design

The project essentially uses an iterative design-based research approach (Reeves, 2006) to evaluate and incrementally improve the value of the digital discussion support tools to on-farm operational decision-making. This methodology is a blend of empirical research with the theory based design of learning environments (The Design-Based Research Collective, 2003). The method involves a systematic iterative process of design, development, implementation, and analysis in real-world settings of educational innovation designed to improve educational practice (Wang and Hannafin, 2005), following the framework outlined in Figure 3. A major strength of design-based research lies in its ability to modify the intervention based on feedback from participants.

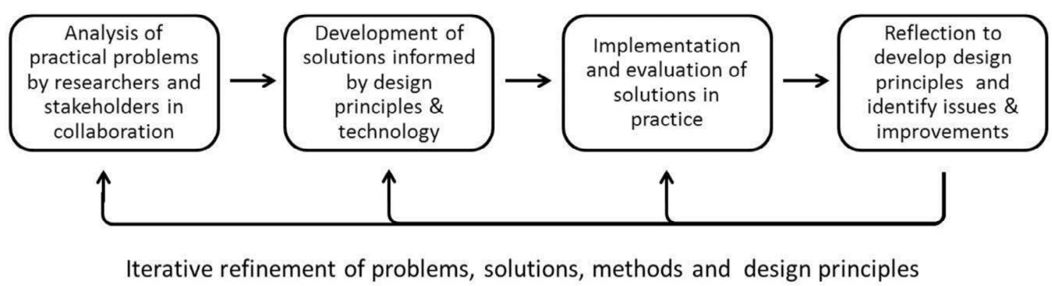

Figure 3: Design-based research approach (after Reeves, 2006)

Pilot evaluation

Implementing the iterative design-based research approach, we ran a pilot evaluation, amongst a small group of sugar industry stakeholders, of one of the machinimas created for the Australian sugar cane farming industry to gain feedback on the machinima and perceptions of their value as extension and engagement tools. The 'Harvesting' machinima was shown to a select group of 17 innovative sugar cane growers, extension personnel and cane industry managers. A semi-structured interview process was used to elicit feedback on the concept, identify issues and enable finetuning of the full set of machinimas. Responses were analysed both qualitatively using a thematic approach and quantitatively (Cliffe, 2013). Feedback from this pilot evaluation was then used to further refine the four machinimas developed through the project (Reardon-Smith *et al.*, 2014), in preparation for comprehensive empirical evaluation.

Initial results

The pilot evaluation of the prototype harvesting machinima indicated a range of responses to the machinima and the information presented. Overall, feedback on the machinima was positive (Table 1). Many interviewees indicated that the format of the machinima was an appealing way to convey messages to farmers (Table 2). Interviewees across all three stakeholder groups made comments about the video having the potential to generate discussion in farmer group situations. Challenges identified were: (i) to ensure that the information presented in the machinima scripts was suitably targeted to ensure audience engagement with the modeled discussion; and (ii) the need for the tools to provide a seamless link between current climate forecasts and modeled discussions about specific decisions (Cliffe, 2013). Interestingly, in response to questioning, only 43 percent of participants felt that current information services to canefarmers were adequate, while 36 percent felt there was room for improvement (Cliffe, 2013).

Table 1: Frequency of responses to questions regarding the suitability of virtual world machinimas for agri-climate discussion support (n = 17).

Criteria	Good	Neutral	Improve	Total
Can you describe your reactions as you viewed the video?	52%	19%	29%	100%
How would you describe the length and pace of the video?	85%	5%	10%	100%
How would you describe the characters in the video?	44%	37%	19%	100%
How would you describe the setting for the video?	33%	56%	11%	100%
How appealing is this style of video format as a way to convey messages to cane farmers?	58%	17%	25%	100%

Table 2: A selection of comments from participants in the pilot virtual discussion support machinima evaluation.

Comment Category	Comment Count	Examples
Positive	28	**Farmers:** 'Very real, a good way of doing it'; 'Good tool for prompting and helping a discussion and opening a discussion up'; 'It gives an opportunity for questions to be asked in a discussion'; 'High value'; 'It will promote discussion, that is the strong point' **Extension Officers:** 'Excellent to use at a workshop or shed meeting to get discussion going'; 'It has the capacity to create interaction and discussion'; 'I'd like to see it tested' **Canegrowers Organisation:** 'Very innovative'; 'With increasing costs and climate change this information needs to be made available to growers to support their decision making'; 'I'm passionate about it'; 'Run by someone in a group, quite effective in the context of a group discussion'.
Neutral	8	**Farmers:** 'There might be a mixed reaction in a shed meeting, from some saying it's a joke to others saying it's useful'; 'Could be part of a package leading up to the start of the season' **Extension officers:** 'You'll get a mixed reaction'; 'More appeal for use by extension officers to take out and use it with growers, one on one or in groups'; 'It's more appropriate now to a normal group of farmers and less appropriate for more informed growers'.
Negative	12	**Farmers:** 'Older growers won't look at it on a computer'; 'Younger growers are more up to speed so you don't want to talk down to them'; 'Need other discussions related to forecasts, especially extremes of wet or dry'; 'you need more meat [in message]to promote a robust discussion'. **Extension officers:** 'If the characters flowed and moved more naturally, that would enhance the visual experience'; 'For a more knowledgeable audience, incorporate an expert character into the video'; 'If changes were made its usefulness as a tool for creating discussion and information transfer would improve and its value would go up'. **Canegrowers:** 'For individual growers, not as effective'; 'Younger growers will not need this prompting'; 'It's not appealing at all as farmers would relate more to real people than animations'.

When asked to rate (out of 10) the value of this sort of video in supporting canefarmers decision-making, responses were generally positive (Fig. 4). The average score over all participants was 6.9/10, with farmers in the group rating the tool 6.9/10 (range 5–9), extension officers 7.2 (6.5–8) and industry managers 6.4 (3–8).

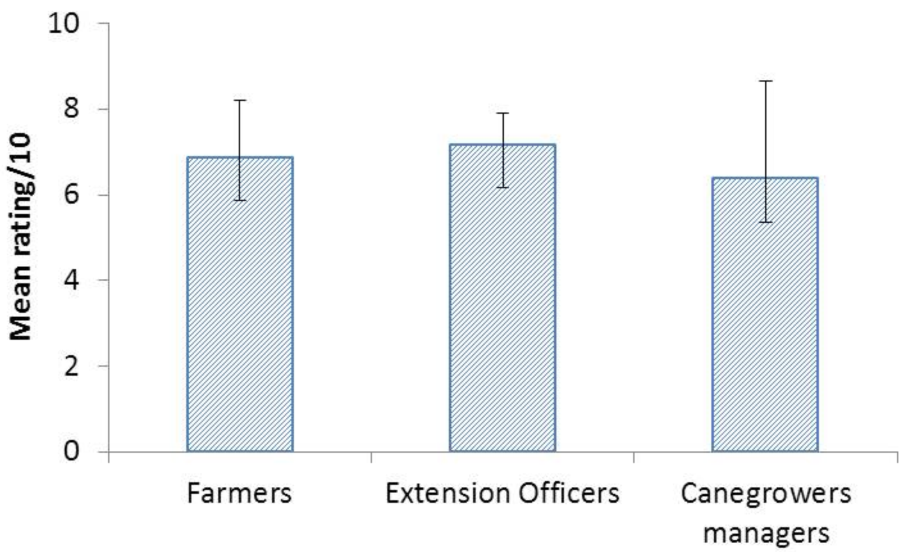

Figure 4: Overall rating of the value of machinima as an agri-climate extension tool to support discussion around climate risk management in the sugar cane farming industry. Values are means; error is standard deviation.

Discussion

Climate variability represents a significant risk to many farming enterprises. Effective extension of information about climate and sustainable management options may improve climate risk decision making and adaptive management responses to climate variability on farms. Digital technologies increasingly provide more equitable and potentially cost-effective access to agricultural extension materials, as well as opportunities for innovations which incorporate leading edge advances in education and the social sciences. The virtual world machinimas described in this paper incorporate digital technologies and draw on theoretical advances in teaching and learning to provide engaging story-based narratives around climate risk management to support discussion and decision-making on Australian sugar cane farms. While full evaluation of these tools is yet to be conducted, the results of initial testing with a small group of sugar industry leaders indicates the potential of this approach to engage and inform farmers. While participants in the pilot machinima evaluation expressed some reservations about particular aspects, overall feedback was that the tool held the interest of the viewers and the key messages in the simulated discussion were apparent (Cliffe, 2013). Comments indicating that minor improvements were needed to ensure the seamless integration of climate adaptation information have informed the refinement of the tools, as anticipated within the research design-based process employed in the project (Reeves, 2006). Further evaluation of machinimas as discussion support tools will explore their capacity to facilitate peer-to-peer discussion of management options and to deliver potential benefits such as increased adoption of sustainable farming practices and enhanced climate risk management on farms within the Australian sugar industry (e.g. Verhagen, Feldberg, van den Hooff, Meents and Merikivi, 2011).

Government agencies (e.g. agriculture departments) and, more recently, private industry and Research and Development Corporations (RDCs) in Australia make substantial investments in extension and outreach programs aimed at technical knowledge transfer, skills development and capacity building in farming. For example, over the ten years from 2004–2013, Australian agricultural RDCs (including Cotton RDC, Grains RDC, Horticulture Innovation Australia, Meat and Livestock Association and Sugar Research Australia) invested on average AU$3.4 billion per year, or 7.6 percent from an average annual RD&E budget of AU$44.5 billion, in extension and outreach (Table 3). Over recent decades, such programs have employed in-person participatory and social learning approaches to enhance capacity building and practice adoption. Such approaches can effectively engage farmers (Cliffe, Stone, Mushtaq, Reardon-Smith and Coutts, in prep); however, face-to-face extension programs draw in only a small proportion of the farming population and programs are delivered at a high cost per farmer (e.g. Quizon, Feder and Murgai, 2001). At an estimated unit production cost of approximately AU$6,800 per machinima (Reardon-Smith and Mushtaq, 2014), online delivery of the types of tools currently being developed through this project may also provide a cost-effective adjunct to in-person farmer engagement and agri-climate information extension programs, increasing any-time any-place access to extension materials.

Table 3: Australian agricultural Research and Development Corporation (RDC) investments in Research, Development and Extension (RD&E) and Extension & Outreach (E&O), 2004–2013. Values are means for the period 2004–2013.

Industry Body	Total annual budget (AU$m)	Annual RD&E budget (AU$m)	Annual E&O budget (AU$m)	RD&E proportion of total budget (%)	E&O proportion of total budget (%)	E&O proportion RD&E budget (%)
Cotton RDC[1]	12.81	11.14	0.41	86.91	2.98	3.39
Grains RDC[2]	135.13	120.77	5.73	89.37	4.24	4.74
Horticulture Innovation Australia[3]	89.81	66.85	0.62	74.43	0.69	0.93
Meat and Livestock Association[4]	156.61	16.45	9.41	10.50	4.7	38.83
Sugar Research Australia[5]	9.87	7.37	0.83	74.68	8.41	11.26

Data sources: [1] CRDC (2005–2014); [2] GRDC (2005–2014); [3] HIA (2005–2014); [4] MLA (2005–2014); [5] SRDC (2005–2013) and SRA (2014).

The ability to customise virtual world extension tools to specific contexts relevant to the particular experience of farmers suggests a significant opportunity to operationalise the concept of discussion support in a way that also engages effectively with farmers' natural social and observational learning modes (Bandura, 1974; Stone and Meinke, 2006; Stone *et al.*, 2012). This approach also represents a significant opportunity for the rapid and cost-effective dissemination of relevant climate information as it is developed and may provide a valuable complement to the delivery of targeted customised climate and weather information that is now increasingly available (Hansen, 2002; Meinke and Stone, 2005; Stone and Meinke, 2006). Improved access to the best available seasonal climate forecasts (i.e. information about what the future holds with regard to the cropping season) and capacity to use this information to make better operational decisions is likely to reduce the impact of climate risk and enhance the productivity and profitability of farming enterprises. Successful extension of such agri-climate information may deliver significant economic, social and environmental benefit through increased productivity, profitability, resilience and sustainability of farming enterprises and regions (e.g. Jakku, Everingham, Inman-Bambar and Thorburn, 2008). This is true of the Australian sugar cane farming industry and of other farming systems nationally and globally.

While currently being developed and trialed within the Australian sugar cane farming industry, virtual world discussion support tools have potential to significantly enhance the delivery of extension services more broadly, complementing conventional agricultural extension and outreach programs with new options for real-time information exchange at local, regional, national and even global scales. The tools are readily customised to particular farming systems and cultural contexts, making the development and deployment of web-based 'virtual' discussion-support systems, targeted to particular situations, increasingly feasible across many parts of the world. The capacity to for delivery of online extension tools such as these is also rapidly expanding. For example, while internet access in rural areas may be a limitation in some regions (Kim, Chan and Gupta, 2007), initiatives such as that of the Indian Government, which is providing thousands of computer terminals and facilities ('internet kiosks') across regional India, represent new and expanding opportunities to disseminate agricultural extension materials to farming communities, although significant challenges remain (Cecchini and Scott, 2003). In addition, significant uptake of mobile technologies and handheld devices such as smart phones and tablets globally means an expanding suite of opportunities to use digital platforms in the widespread and cost-effective delivery of extension services (Grimshaw, 2011; Roberts and McIntosh, 2012).

Tools such as the virtual discussion support machinima developed in this project—if acceptable to farmers (Im, Kim and Han, 2008) and proven effective in facilitating improved decision-making on farms—have potential to enhance the capacity for the delivery of timely, targeted support to large numbers of farmers. While complementing current agricultural extension services, they may also enhance knowledge sharing, capacity building and learning opportunities for farmers and land managers at scales not able to be realised by conventional extension and outreach activities due to issues such as physical accessibility, time and cost. Improved climate risk decision making and management on farms, supported by in-time access to relevant climate information, is vital for adaptation in agriculture to increasing climate variability. Such adaptation will ensure the maintenance of productive profitable farming systems and minimise adverse environmental impacts. At larger scales, it is also critical to enhancing the well-being and long-term sustainability of farming communities and ultimately ensuring future global food security (Australian Academy of Science, 2010; Hewitt, Buontempo and Newton, 2013).

References

Abma, T.A. (2003). Learning by telling: storytelling workshops as an organizational learning intervention. *Management Learning*, 34(2), 221–240.

Anderson, J. R. and G. Feder (2004). Agricultural extension: good intentions and hard realities. *The World Bank Research Observer*, 19(1), 41–60.

Australian Academy of Science (2010). *Agricultural Productivity and Climate Change*. Canberra ACT, Australia: Australian Academy of Science.

Bandura, A. (1974). Behavior theory and the models of man. *American Psychologist*, 29(12), 859–869.

Bandura, A. and McClelland, D.C. (1977). *Social Learning Theory*. New Jersey, USA: Prentice Hall.

Barrett H. (2006). Researching and evaluating digital storytelling as a deep learning tool. *Society for Information Technology & Teacher Education International Conference 2006, Orlando, Florida USA*.

Bartels, W.-L., Furman, C.A., Diehl, D.C., Royce, F.S., Dourte, D.R., Ortiz, B.V., Zierden, D.F., Irani, T.A., Fraisse, C.W. and Jones, J.W. (2013). Warming up to climate change: a participatory approach to engaging with agricultural stakeholders in the Southeast US. *Regional Environmental Change*, 13(1), 45–55.

Canegrowers Australia (2010). *Sugarcane industry - now and then*. Brisbane QLD Australia: Canegrowers Australia. Retrieved 22 January 2015 from http://www.canegrowers.com.au/page/Industry_Centre/Publications/about-sugarcane/.

Carter, J.O., Hall, W.B., Brook, K.D., McKeon, G.M., Day, K.A. and Paull, C.J. (2000). Aussie GRASS: Australian grassland and rangeland assessment by spatial simulation. In: Hammer, G.L., Nicholls, N. and Mitchell, C. (eds.) *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems. The Australian Experience.* The Netherlands: Springer.

Carberry, P., Hammer, G., Meinke, H. and Bange, M. (2000). The potential value of seasonal climate forecasting in managing cropping systems. In: Hammer, G.L., Nicholls, N. and Mitchell, C. (eds.) *Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems. The Australian Experience.* The Netherlands: Springer.

Carberry, P.S., Hochman, Z., McCown, R.L., Dalgliesh, N.P., Foale, M.A., Poulton, P.L., Hargreaves, J.N.G., Hargreaves, D.M.G., Cawthray, S., Hillcoat, N. and Robertson, M.J. (2002). The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation. *Agricultural Systems*, 74, 141–177.

Cliff, N. (2013) Sugar industry prototype animation (machinima) evaluation report. Toowoomba QLD, University of Southern Queensland. (Unpublished).

Cliffe, N., Stone, R.C., Mushtaq, S., Reardon-Smith, K. and Coutts, J. (in prep.). Developing capacity of farmers to understand and apply seasonal climate forecasts through discussion and collaborative learning processes – a case study from the Australian Sugar Industry.

Cecchini, S. and Scott, C. (2003). Can information and communications technology applications contribute to poverty reduction? Lessons from rural India. *Information Technology for Development*, 10, 73–84.

Chowdhury, A. and Odame, H.H. (2013). Social media for enhancing innovation in agri-food and rural development: current dynamics in Ontario, Canada. *The Journal of Rural Community Development*, 8, 97–119.

CRDC (2005–2014) Annual Reports. Narrabri NSW, Australia: Cotton Research and Development Corporation (CRDC).

Coutts, J. and Roberts, K. (2011). Theories and approaches of extension: review of extension in capacity building. In: Jennings, J., Packham, R. and Woodside, D. (eds.) *Shaping Change: Natural Resource Management, Agriculture and the Role of Extension.* Wodonga VIC, Australia: Australia-Pacific Extension Network (APEN).

Cundill, G. and Rodela, R. (2012). A review of assertions about the processes and outcomes of social learning in natural resource management, *Journal of Environmental Management*, 113, 7–14.

Duridanov, L. and Simoff, S. (2008). 'Inner Listening' as a basic principle for developing immersive virtual worlds. *Online–Heidelberg Journal of Religions on the Internet*, 03.1: *Being Virtually Real? Virtual Worlds from a Cultural Studies' Perspective*.

Evenson, R.E. (2001). Economic impacts of agricultural research and extension. In: Gardner, B.L. and Rausser, G.C. (eds.) *Handbook of Agricultural Economics*, 1, 573–628. Amsterdam, The Netherlands: Elsevier Science.

Everingham, Y.L., Muchow, R.C., Stone, R.C., Inman-Bamber, N.G., Singels, A. and Bezuidenhout, C.N. (2002). Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. *Agricultural Systems*, 74(3), 459–477.

Francis, C.A. and Carter, H.C. (2001). Participatory education for sustainable agriculture: everyone a teacher, everyone a learner. *Journal of Sustainable Agriculture*, 18(1), 71–84.

Gesser-Edelsburg, A. and Singh, A. (2013). Enhancing the persuasive influence of entertainment-education events: rhetorical and aesthetic strategies for constructing narratives. *Critical Arts*, 27(1), 56–74.

GRDC (2005–2014). Annual Reports. Barton ACT, Australia: Grains Research and Development Corporation (GRDC).

Grimshaw, D.J. (2011). Beyond technology: making information work for livelihoods. In: Grimshaw, D.J. and Kala, S. (eds.) *Strengthening Rural Livelihoods: the Impact of Information and Communication Technologies In Asia*. Ottawa ON, Canada: International Development Research Centre (IDRC).

Hansen, J.W. (2002). Realizing the potential benefits of climate prediction to agriculture: issues, approaches, challenges. *Agricultural Systems*, 74(3), 309–330.

Hayman, P. (2003). Decision support systems in Australian dryland farming: a promising past, a disappointing present and uncertain future. *Decision Support Systems*, 4, 1.

Hearn, A.B. (1994). OZCOT: a simulation model for cotton crop management. *Agricultural Systems*, 44, 257–299.

Hearn, A.B., Brook, K.D., da Roza, G.D. and Ashburner, N.A. (1985). SIRATAC: a computer based crop management system. In: *Proceedings of the 44th Plenary Meeting. International cotton Advisory Committee on Cotton Production: Seminar on Crop Protection (emphasis on insect control). Sydney NSW, October 1985.* Washington DC, USA: International Cotton Advisory Committee.

Hewitt, C., Buontempo, C. and Newton, P. (2013). Using climate predictions to better serve society's needs. *Eos, Transactions American Geophysical Union*, 94(11), 105–107.

Hochman, Z. and Carberry, P.S. (2011). Emerging consensus on desirable characteristics of tools to support farmers' management of climate risk in Australia. *Agricultural Systems*, 104(6), 441–450.

Hochman, Z., van Rees, H., Carberry, P.S., Hunt, J.R., McCown, R.L., Gartmann, A., Holzworth, D., van Rees, S., Dalgliesh, N.P., Long, W., Peake, A.S., Poulton, P.L. and McClelland, T. (2009). Re-inventing model-based decision support with Australian dryland farmers. 4. Yield prophet® helps farmers monitor and manage crops in a variable climate. *Crop and Pasture Science*, 60(11), 1057–1070.

Hogan, A., Berry, H.L., Ng, S.P. and Bode, A. (2011). *Decisions Made by Farmers that Relate to Climate Change*. RIRDC Publication No. 10/208. Barton ACT, Australia: Rural Industries Research and Development Corporation (RIRDC).

HIA (2005–2014). Annual Reports. Sydney NSW, Australia: Horticulture Innovation Australia Limited (HIA).

Howden, S.M., Soussana, J.-F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences*, 104(50), 19691–19696.

Huffman, W.E. and Evenson, R.E. (1993). *Science for Agriculture: A Long Term Perspective*. Ames USA: Iowa State University Press.

Hunt, W., Birch, C., Coutts, J. and Vanclay, F. (2012), The many turnings of agricultural extension in Australia. *The Journal of Agricultural Education and Extension*, 18(1), 9–26.

Im, I., Kim, Y. and Han, H.-J. (2008). The effects of perceived risk and technology type on users' acceptance of technologies. *Information & Management*, 45(1), 1–9.

Jakku, E., Everingham, Y., Inman-Bambar, G. and Thorburn, P. (2008). *Moving from case studies to whole of industry: Implementing methods for wider industry adoption*. Final Report of SRDC Research Project CSE009. Canberra ACT, Australia: Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Jakku, E. and Thorburn, P.J. (2010). A conceptual framework for guiding the participatory development of agricultural decision support systems. *Agricultural Systems*, 103(9), 675–682.

Jame, Y.W. and Cutforth, H.W. (1996). Crop growth models for decision support systems. *Canadian Journal of Plant Science*, 76(1), 9–19.

Johnson, P. (2012). Introduction: documenting virtual life in machinima. In: Johnson, P. and Pettit, D. (eds.) *Machinima: The Art and Practice of Virtual Filmmaking*. Jefferson NC, USA: McFarland & Co.

Jørgensen, L.N., Noe, E., Langvad, A.M., Jensen, J.E., Ørum, J.E. and Rydahl, P. (2007). Decision support systems: barriers and farmers' need for support. *Bulletin OEPP/EPPO*, 37, 374–377.

Keating, B.A. and McCown, R.L. (2001). Advances in farming systems analysis and intervention. *Agricultural Systems*, 70(2–3), 555–579.

Kim, H.-W., Chan, H.C. and Gupta, S. (2007). Value-based adoption of mobile internet: an empirical investigation. *Decision Support Systems*, 43(1), 111–126.

Kok, K., Biggs, R. and Zurek, M. (2007). Methods for developing multiscale participatory scenarios: insights from southern Africa and Europe. *Ecology and Society*, 12(1), 16.

Lamarque, P., Artaux, A., Barnaud, C., Dobremez, L., Nettier, B. and Lavorel, S. (2013). Taking into account farmers' decision making to map fine-scale land management adaptation to climate and socio-economic scenarios. *Landscape and Urban Planning*, 119, 147–157.

Leach, G. (2011). Extension policy in Australia - challenges and solutions. In: Jennings, J., Packham, R. and Woodside, D. (eds.) *Shaping Change: Natural Resource Management, Agriculture and the Role of Extension.* Wodonga VIC, Australia: Australia-Pacific Extension Network (APEN).

Materia, V.C., Giarè, F. and Klerkx, L. (2015). Increasing knowledge flows between the agricultural research and advisory system in Italy: combining virtual and nonvirtual interaction in communities of practice. *The Journal of Agricultural Education and Extension* (ahead of print), 1–16.

Matthews, K.B., Schwarz, G., Buchan, K., Rivington, M. and Miller, D. (2008). Wither agricultural DSS? *Computers and Electronics in Agriculture*, 61(2), 149–159.

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

McCown, R.L. (2002b). Locating agricultural decision support systems in the troubled past and socio-technical complexity of models for management. *Agricultural Systems*, 74(1), 11–25.

McCown, R.L. and Parton, K.A. (2006). Learning from the historical failure of farm management models to aid management practice. Part 2. Three systems approaches. *Australian Journal of Agricultural Research*, 57(2), 157–172.

McCown, R.L., Hochman, Z. and Carberry, P.S. (2002). Probing the enigma of the decision support system for farmers: learning from experience and from theory. *Agricultural Systems*, 74(1), 1–10.

McKeown, L. (2010). *Overview of the breakthroughs in distance education systems.* Asia Pacific Network (APN) Project Workshop, ANGRAU University, Hyderabad, India, 28 September 2010 (unpublished).

McKinna, L. and Everingham, Y. (2011). Seasonal climate prediction for the Australian sugar industry using data mining techniques. In: Funatsu, K. (ed.) *Knowledge-Oriented Applications in Data Mining*. Rijeka, Croatia: InTech.

MLA (2005–2014). Annual Reports. Sydney NSW, Australia: Meat & Livestock Australia (MLA).

Meinke, H. and Stone, R. (2005). Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations. *Climatic Change*, 70(1–2), 221–253.

Merrill, M.D. (2000). Knowledge objects and mental models. In: Kinshuk, J.C. and Okamoto, T. (eds.) *Advanced Learning Technology: Design and Development Issues*. Los Alamitos CA, USA: IEEE Computer Society.

Nelson, R.A., Holzworth, D.P., Hammer, G.L. and Hayman, P.T. (2002). Infusing the use of seasonal climate forecasting into crop management practice in north east Australia using discussion support software. *Agricultural Systems*, 74(3), 393–414.

Pannell, D.J. (2006). Flat earth economics: the far-reaching consequences of flat payoff functions in economic decision making. *Review of Agricultural Economics*, 28, 553–566.

Quizon, J., Feder, G. and Murgai, R. (2001). Fiscal sustainability of agricultural extension: the case of the farmer field school approach. *Journal of International Agricultural and Extension Education*, 8(1), 13-24.

Reardon-Smith, K., Farley, H., Cliffe, N., Mushtaq, S., Stone, R., Doyle, J., Martin, N., Ostini, J., Maraseni, T., Marcussen, T., Loch, A. and Lindesay, J. (2014). The development of virtual world tools to enhance learning and real world decision making in the Australian sugar farming industry. *International Journal of Advanced Corporate Learning*, 7(3), 17–23.

Reardon-Smith, K. and Mushtaq, S. (2014). The viability of digital technologies in delivering effective agricultural extension services. *Symposium on Broadband-enabled Communities and Regional Development*. University of Southern Queensland, Toowoomba Q (10th–11th November, 2014).

Reed, M.S. (2008). Stakeholder participation for environmental management: a literature review. *Biological Conservation*, 141(10), 2417–2431.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C. and Stringer, L.C. (2010) What is social learning? *Ecology and Society*, 15(4).

Reeves, T.C. (2006). Design research from a technology perspective. In: van den Akker, J., Gravemeijer, K., McKenney, S. and Nieveen, N. (eds.). *Educational Design Research*. London, UK: Routledge.

Rist, S., Chidambaranathan, M., Escobar, C., Wiesmann, U. and Zimmermann, A. (2007). Moving from sustainable management to sustainable governance of natural resources: the role of social learning processes in rural India, Bolivia and Mali. *Journal of Rural Studies*, 23(1), 23–37.

Roberts, K. and McIntosh, G. (2012). Use of mobile devices in extension and agricultural production - a case study. *16th Australian Agronomy Conference "Capturing Opportunities and Overcoming Obstacles in Australian Agronomy"*. Armidale NSW, Australia (14th–18th October, 2012).

Ryokai, K., Vaucelle, C. and Cassell, J. (2003). Virtual peers as partners in storytelling and literacy learning. *Journal of Computer Assisted Learning*, 19(2), 195–208.

Salmon, G. (2009). The future for (second) life and learning. *British Journal of Educational Technology*, 40(3), 526–538.

Siemens, G. (2005). Connectivism: a learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*, 2(1), 3–10.

Stone, R. (2010). *Web-based 'Discussion-support' Agricultural Climate Information for Regional India. Project: CBA2010-07NSY-Stone*. *Final Report submitted to APN.* Kobe, Japan: Asia-Pacific Network for Global Change Research (APN).

Stone, R.C. and Meinke, H. (2006). Weather, climate, and farmers: an overview. *Meteorological Applications*, 13(S1), 7–20.

Stone, R.C., Reushle, S. and Reddy, R. (2012). Web-based 'discussion-support' agricultural climate information for regiona India. *APN Science Bulletin*, 2, 55–58.

SRDC (2005–2013). Annual Reports. Indooroopilly Qld, Australia: Sugar Research & Development Corporation (SRDC).

SRA (2014). 2013–2014 Annual Report. Indooroopilly Qld, Australia: Sugar Research Australia (SRA).

Sulaiman, V.R., Hall, A., Kalaivani, N.J., Dorai, K. and Reddy, T.S.V. (2012). Necessary, but not sufficient: critiquing the role of information and communication technology in putting knowledge into use. *The Journal of Agricultural Education and Extension* 18, 331–346.

Taylor, S.S., Fisher, D. and Dufresne, R.L. (2002). The aesthetics of management storytelling: a key to organizational learning. *Management Learning*, 33(3), 313–330.

The Design-Based Research Collective (2003). Design-based research: an emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5–8.

Tsou, W., Wang, W. and Tzeng, Y. (2006). Applying a multimedia storytelling website in foreign language learning. *Computers & Education*, 47(1), 17–28.

Vanclay, F. (2004). Social principles for agricultural extension to assist in the promotion of natural resource management. *Australian Journal of Experimental Agriculture*, 44(3), 213–222.

Vanclay, F. and Leach, G. (2011). Enabling change in rural and regional Australia. In: Jennings, J., Packham, R. and Woodside, D. (eds.) *Shaping Change: Natural Resource Management, Agriculture and the Role of Extension.* Wodonga VIC, Australia: Australia-Pacific Extension Network (APEN).

Verhagen, T., Feldberg, F., van den Hooff, B., Meents, S. and Merikivi, J. (2011). Satisfaction with virtual worlds: an integrated model of experiential value. *Information & Management*, 48(6), 201–207.

Voyager, D. (2015). *Second Life Grid Stats 2015*. Retrieved 22 January 2015 from: https://danielvoyager.wordpress.com/sl-metrics/.

Wang, F. and Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5–23.

Warner, K.D. (2006). Extending agroecology: grower participation in partnerships is key to social learning. *Renewable Agriculture & Food Systems*, 21(2), 84–94.

Woodruff, D.R. (1992) 'WHEATMAN' a decision support system for wheat management in sub-tropical Australia. *Australian Journal of Agricultural Research*, 43, 1483–1499.