Research Article

Can Digital Discussion Support Tools Provide Cost-Effective Options for Agricultural Extension Services?

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Abstract

Agricultural extension that delivers timely, targeted, and cost-effective support to farmers will help ensure the sustainability and adaptive capacity of agriculture, enhancing both food security and environmental security. Leveraging advances in agriclimate science and adult education, innovative digital technologies offer significant new opportunities to engage with farmers and to support decision making. In this study, animated video clips (machinimas), developed using the Second Life™ virtual world gaming platform, model conversations around climate risk and critical on-farm decisions in the Australian sugarcane farming industry. Early evaluation indicates that this is an engaging format that promotes discussion by leveraging farmers' natural modes of information gathering and social learning. Comparison with conventional extension practices indicates that these discussion support tools may be a cost-effective addition to existing approaches. The format's flexibility means machinimas are readily updated with new information and customized to meet the needs of different farmer groups. Rapid growth in digital access globally and the scalability of such approaches promise greater equity of access to high-value information, critical to better risk management decision making, at minimal cost, for millions of farmers.

Introduction

Agricultural extension services—defined here as services through which the adoption and application of new knowledge, technologies, and practices are promoted—deliver positive returns on investment (Araji, Sim, & Gardner, 1978; Benina et al., 2011; Huffman & Evenson, 2006). However, in today's competitive investment environment, current modes of agricultural extension face many challenges, including too few extension personnel and limited operational resources with declining levels of government funding and policy support (Hunt, Birch, Coutts, & Vanclay, 2012; Leach, 2011; Vanclay & Leach, 2011). In many parts of the world, extension services are further constrained by the often considerable distances, time, and costs involved for farmers

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accessing these services. As a result, conventional face-to-face extension services meet the needs of only a small proportion of farmers (Anderson & Feder, 2004; Graeub, Chappell, Wittman, Ledermann, Kerr, & Gemmill-Herren, 2015).

In developed countries, agricultural extension has largely been institutionalized, top down, and focused on delivering specific, often commodity-based, technical advice to farmers about practice adoption for increased production and profitability. This centralized transfer-of-technology model has inherent biases that tend to favor resource-rich farmers and may not be appropriate for resource-poor farmers (Chambers & Ghildyal, 1985). Over recent decades, and in response to enhanced understanding of adult learning modes, this traditional model has been increasingly replaced with interactive participatory, experiential, and social learning approaches (Francis & Carter, 2001; Mee, Katz, Alem, & Kravis, 2007; Warner, 2006). There has been an increased focus on farmer-to-farmer exchanges and, in some instances, on farmer-driven, bottom-up approaches (Chambers & Ghildyal, 1985; Francis & Carter, 2001; Swanson, 2008). However, while agricultural extension services in Australia and elsewhere have made significant efforts to incorporate such approaches, their delivery is still subject to a range of practical and logistical constraints.

Effective extension of agriclimate information to support on-farm decision making and risk management is critical, given predictions of exponential global population growth, increasingly uncertain climatic conditions, and potential food and environmental insecurity (Australian Academy, 2010; Haigh et al., 2015). Agricultural extension approaches that deliver timely, targeted, and cost-effective support to farmers will help ensure the sustainability and adaptive capacity of agriculture worldwide, increasing productivity while minimizing associated environmental impacts. To achieve this, these approaches need to incorporate the latest relevant developments both in climate and agricultural sciences and the latest research into education and learning.

The scaling-up of agricultural extension services to reach millions of farmers globally (Graeub et al., 2015; Lowder, Skoet, & Singh, 2014) presents a further challenge to conventional expert-driven face-to-face agricultural extension and highlights the inherent limitations of these approaches. On the other hand, recent advances in distance learning and e-learning on digital platforms indicate significant opportunities for the development of cost-effective agricultural e-extension systems (Stone, 2010; Stone, Reushle, & Reddy, 2012). Increasing global digital access and widespread uptake of digital technologies also indicate a significant potential for reaching large numbers of users (Diem, Hino, Martin, & Meisenbach, 2011) and for digital technologies to play an important role in the cost-effective delivery and communication of agricultural information (Aker, 2011).

Agricultural extension programs have been keen to adopt new digital information and communication technologies (ICTs) to expand the dissemination of technological information to their stakeholders. Mobile devices such as feature phones have been in use in agriculture since the early years of this century (Aker, 2011). However, mobile agriculture, or m-agriculture as it is known (Gichamba & Lukandu, 2012), has largely been restricted to voice and SMS services, and technological constraints have necessarily limited its adoption (Aker, 2011). With the advent of smart technologies such as smartphones and tablets and the decreasing costs of voice and data services, the possibility now exists for the distribution of media-rich and contextualized content. In addition, a range of sophisticated decision support tools has been developed, many of which use complex biophysical modeling to derive optimal solutions to particular farm management problems (McCown, 2002). However, ICTs have so far failed to deliver the anticipated increase in innovation adoption rates on farms (Chowdhury & Odame, 2013; Hayman, 2003; Jørgensen et al., 2007; McCown, Hochman, & Carberry, 2002). Sulaiman and colleagues (2012) suggest that this is, at least in part, because their use is still effectively limited to the conventional tasks of top-down information dissemination and training. ICTs often fail, as in the case of many decision support tools, to adequately incorporate existing farmer knowledge and the range of contextual factors involved in farm management decision making or to engage farmers in farmer-to-farmer exchanges (Francis & Carter, 2001; Mee et al., 2007). This is not an issue in agriculture alone; more broadly, corporations and institutions have similarly failed to understand the importance of interaction in order to benefit from the use of social media (Beaudoin, 2008; Boag, 2014).

Agricultural extension approaches that are informed by advances in the social sciences are already recognized as important (Vanclay, 2004). The challenge is to further integrate these approaches into innovative digital education (e-learning) platforms in ways that enhance stakeholder engagement and learning, but do so in a more effective and cost-efficient way (Reardon-Smith et al., 2015). This article examines the potential for digital innovation to complement and expand conventional agricultural extension services. Specifically, this article evaluates the cost-effectiveness of prototype digital web-based discussion support tools (i.e., tools whose aim is to promote farmer–farmer discussion and social learning) developed for agriclimate extension in the Australian sugarcane farming industry. These tools are scripted and customized animated video clips (*machinimas*—from machine cinema) created using the web-based virtual world Second Life™ platform, developed in collaboration with stakeholders from the Australian sugarcane industry. They model conversations among a group of farming and extension personnel about climate risk and on-farm decisions relevant to specific planning and cropping scenarios (e.g., irrigation management, harvesting). The cost-effectiveness of creating these tools is analyzed and compared with that of other extension approaches (e.g., face-to-face extension, real-world videos) used in the Australian sugarcane farming industry. In terms of effective engagement and scalability, the opportunities these tools offer in reaching large numbers of farmers at minimal cost are also discussed.

Digital Technologies in Agricultural Extension

Over the last few decades, digital technologies have increasingly come to play a major role in the dissemination of agricultural information (Brennan et al., 2007; Mee et al., 2007) and provide a significant potential to complement and expand the reach of more conventional face-to-face extension services. In addition, increasingly sophisticated digital platforms and their application in learning environments—in combination with anytime/anywhere access to high-speed Internet available at many locations—provide opportunities for a range of novel approaches to be tested as alternative information exchange methods for agricultural extension.

The apparent failure of digital technology–based decision support tools to effectively influence farm management decisions of large numbers of farmers (Francis & Carter, 2001; Hayman, 2003; McCown et al., 2002) has led to revised thinking around the need for information to better match farmers' needs and to accommodate different styles of information gathering, reasoning, and decision making (Babu, Glendenning, Asenso-Okyere, & Govindarajan, 2012; Jørgensen et al., 2007; McCown, 2002). Evidence that discussion can play a critical role in effective adult learning (Kirkup, 2002) upholds calls for support systems for decision making to better engage with farmers' natural modes of learning through experience and exchanges within informal learning networks (Kroma, 2006; Nelson, Holzworth, Hammer, & Hayman, 2002). One approach to operationalizing this idea, tested in Australian agriculture, was the concept of "kitchen table" discussions that involved face-to-face discussions between small groups of farmers and a visiting farming systems specialist about how the outputs of decision support models might be used in key decisions (McCown, 2002). However, there has been little progress in developing more cost-effective approaches to facilitate this process and implement the concept more widely in agricultural extension programs—a role for which digital technologies appear well suited (Stone, 2010).

The Second Life Platform

Second Life is a three-dimensional, multi-user virtual world environment, running on a computer-, server-, or Internet-based platform that allows participants to create virtual identities (*screen motional avatars;* Leeming, 2001) and interact with other users (Duridanov & Simoff, 2007; Maher, 1999; Ritzema & Harris, 2008). Since its release in 2003, Second Life has become one of the most well-known virtual worlds, currently boasting over 48 million user accounts, with up to 62,000 users online at any time (Voyager, 2016). The platform's content is almost exclusively user-created and it offers a highly flexible environment with significant creative possibilities. Not only can avatars be customized to reflect a wide range of identities, occupations, gender, and ethnicity, but realistic simulated settings can be developed in which the characters can move and interact (Salmon, 2009). This makes Second Life especially useful as a development platform for agricultural extension services, particularly those that work across a range of cultures and geographies, allowing almost unlimited variation in the character types, appearances, and settings. A key strength of this approach is that the technology is platform-agnostic once exported as a video file and does not require an investment in proprietary systems for dissemination. Once made available (e.g., on a website), machinima can be viewed on tablets, computers, smartphones, and even televisions, making it easy to use in informal settings and giving the user control over what, when, and how the material is used.

Educational applications of Second Life include virtual representations of learners and teachers in simulated classrooms in which interactive pre-service teacher training can be conducted (Gregory et al., 2011; Salmon, 2009), legal training using simulated courtrooms (Barnett & McKeown, 2012), nurse training (Miller, Lee, Rogers, Meredith, & Peck, 2011), religious studies (Farley, 2011), communications studies (Lester & King, 2009), and virtual digs for archaeology students (Nie, Edirisingha, & Wheeler, 2009). This study expands the application of these emerging platforms and technologies to developing digital agricultural extension tools, such as scripted animated video clips, for stronger engagement and communication with farmers.

Methodology

The cost-effectiveness analysis presented in this article constitutes part of a multimodal evaluation of the value—usefulness and cost-effectiveness—of the new digital discussion support system developed in this project. The project thus included creation of a set of virtual world video clips (i.e., machinimas) filmed in Second Life (Reardon-Smith et al., 2014, 2015), assessment of stakeholder responses to these tools (Cliffe, 2013; Reardon-Smith et al., 2015, article in preparation), and assessment of the relative cost-effectiveness of this approach compared with other, more conventional extension tools (this study).

Developing Machinimas as Digital Discussion Support Tools for Australian Sugarcane Farmers

Sugar production plays an important role in the national economy and communities of northeastern Australia. Australia is the world's third-largest raw sugar exporter after Brazil and Thailand (CANEGROWERS, 2015), exporting some 80% of its raw sugar production. On average, over 30 metric tons of sugarcane is harvested each year from the country's 4,000 sugarcane farms, 90% of which are family-owned and under 250 hectares in size (Valle & Martin, 2015). Sugarcane is grown along 2,100 kilometers of Australia's northeastern coastline, much of which lies adjacent to the World Heritage–listed Great Barrier Reef. This region is subject to significant seasonal climate variability (intense rainfall events associated with tropical cyclones and barometric lows as well as extended periods of below-average rainfall)—largely associated with the El Niño–Southern Oscillation phenomenon (Clarke, Van Gorder, & Everingham, 2010; Stone, Hammer, & Marcussen, 1996)—which poses significant threats to the productivity, profitability, and sustainability of sugarcane farming enterprises. For example, costs to the Australian sugar industry have been estimated at AU$65–305 million annually for water stress due to drought over the period 1992–2004 (Inman-Bamber, 2007) and AU$500 million in losses due to record rainfall over a six-month period in 2010 (CANEGROWERS, 2011). Threats to the reef of nutrient, sediment, and pesticide runoff from agricultural lands are also significant (Butler et al., 2013; Thomas, Gordon, Wooldridge, & Marshall, 2012) and a key driver of industry reform (CANEGROWERS, 2016). Hence, managing climate risk on Australian sugarcane farms is critical to both enterprise and industry sustainability and to protecting the vulnerable environment in which the industry is located (CANEGROWERS, 2012; Kealley & Quirk, 2016).

A set of four climate risk discussion support machinimas that depict key decision points for Australian sugarcane farmers was developed in this project. The primary objective of these machinimas was to engage and stimulate discussion between farmers and within farming families about climate risk and on-farm practices that could be adopted to improve climate risk management and adaptation. The machinimas featured lifelike avatar actors representing Australian sugarcane farmers and extension officers, customized Australian sugarcane farm settings (landscape, cropping systems, farm infrastructure, equipment), and real-world climate-based scenarios relevant to the experience of Australian sugarcane farmers: fertilizer application, irrigation scheduling, harvesting, and family holiday planning[1].

Scripted conversations were developed, for each scenario, that modeled discussions about weather events and climate variability, associated risks, and on-farm management options. These included elements of

1. See https://adfi.usq.edu.au/projects/virtual-extension.

everyday conversations, colloquial expressions, humorous elements, and references to the broader interests of Australian cane farmers (e.g., boating and fishing). As in the film industry, storyboarding was used to develop and communicate the composition and flow of each machinima (Goldman, Curless, Salesin, & Seitz, 2006) and to identify appropriate environments for filming. Scripts were pre-recorded in the University of Southern Queensland studios, with acting students and staff members providing the voices. Machinimas were then created with the assistance of specialist Second Life builders and machinima makers Top Dingo,[2] which created the avatars, crafted the environment, and filmed the machinimas using screen capture technology.

Evaluating and Refining the Approach

Development of the machinimas as discussion support tools for climate risk management was based on an iterative research design–based approach (Mee et al., 2007; Wang & Hannafin, 2005). The machinima concept was first tested by the project team with cotton farmers in the Indian state of Andhra Pradesh, where it was well received (Stone, 2010; Stone et al., 2012). While this tool was provided in three languages (English, Hindi, and a regional language), feedback from local stakeholders highlighted the importance of ensuring that the context and content were, to the greatest extent possible, reflective of the lives and experiences of the target farming community (Stone, 2010; Stone et al., 2012). This information helped further development of the tools assessed in the current study (Reardon-Smith et al., 2014) in which a prototype sugarcane harvesting machinima was evaluated in a pilot study by 17 stakeholders from the Australian sugar industry (Cliffe, 2013). Feedback (both positive and negative) from this group informed development of subsequent sugarcane farming climate risk management machinimas prior to full evaluation across the wider sugarcane farming sector in both face-to-face workshops and online (articles in preparation).

Cost Effectiveness Analysis

A cost-effectiveness analysis (CEA; Balana, Vinten, & Slee, 2011; Doole & Romera, 2013; Karamouz, Szidarovszky, & Zahraie, 2003) was applied to examine the relative cost-effectiveness of these and comparable alternative research and development (R&D) extension tools used in the Australian sugar industry. In a CEA, the decision maker's first task is to determine which R&D extension outcome to pursue. For example, in this case the outcome was to provide timely, reliable, and consistent information customized to a target canegrower population. Different extension approaches can then be evaluated insofar as they improve that outcome and at what cost. A CEA overcomes data constraints (Münich & Psacharopoulos, 2014), focusing instead on the relative costs of achieving or exceeding an objective that can be expressed in specific, nonmonetary terms. While the CEA of alternative plans may not identify an optimal solution, it can provide a basis for better-informed choices compared to cost-oblivious decision making (Yoe, 1992).

The relative cost effectiveness of the new virtual discussion support tools (machinimas) was compared with several extension and communication strategies recently used in the Australian sugarcane industry to address the climate information needs—timely and targeted contextualized agriclimate information—of sugarcane growers. This was conducted for a target population of 3,000 canegrowers, representing about 75% of the growers registered with the industry representative body, CANEGROWERS Australia. Alternative extension approaches included in the CEA were:

- Farmer bus trip and field days: Canegrowers participated in a five-day bus trip for farmer-to-farmer learning at individual farms, including on-farm shed meetings and presentations (Thomas, 2011);
- Virtual bus tour: A series of real-world videos, filmed on farms throughout the Queensland sugar-growing region (available online and accessible by smartphone and computer) that demonstrate best management practices (BMPs) implemented by innovative canegrowers on farms across Queensland (CANEGROWERS, 2010a);
- Climate clips: A series of short informative real-world video clips and a booklet for growers (available on DVD and online) that discuss the drivers of weather and climate variability, climate tools, and information on how these drivers can be applied in decision making on farms (CANEGROWERS, 2010b);

2. *www.topdingo.com*

- Best management practices (BMP) DVDs: Real-world video presentations (available on DVD and online) that convey personal accounts of Queensland sugarcane farmers who have adopted new technologies and practices on their farms (Thomas, 2011).

In addition, the extension and communication expenditures of major R&D corporations (RDCs) in Australia (e.g., Grain Research and Development Corporation, Sugar Research Australia, Cotton Research and Development Corporation) are briefly reviewed. The potential for contextualized Second Life virtual machinimas to complement existing extension programs is discussed.

Results

Machinima Development—Key Learnings

The development of the four short (3–5-minute) machinimas assessed in this study involved a range of people, including developers (researchers, machinima creators, voice artists) and industry stakeholders (members of the sugarcane farming sector). The key stages of machinima development included:

1. Technical information gathering (e.g., climate information relevant to key industry decision making): Research, information gathering, careful review, and verification of technical information;
2. Script development: Writing, verification of the technical accuracy of story lines, discussion, and editing;
3. Soundtrack recording: Selection of voices, recording, editing, and collation of soundtracks;
4. Storyboarding and filming scenarios: Storyboarding, creating suitable avatars, developing suitable farm settings, filming scenarios, adding the sound effects, review, and edit; and
5. Delivery of machinima: Uploading to a website and promoting the machinimas via email and other media.

Each step involved an iterative process of discussion, creation, evaluation, and revision (Reardon-Smith et al., 2014).

Pilot Machinima Evaluation

A pilot machinima evaluation indicated a positive response to the concept of using machinimas to share agriclimate information with a range of stakeholders (farmers, extension personnel, industry managers) within the Australian sugarcane farming industry (Cliffe, 2013). Over half the interviewees (58%) indicated that the animated video format was an appealing way to convey messages to farmers, with less than 30% expressing dissatisfaction with various aspects of the approach. Overall, most felt the videos had the potential to generate discussion among groups of farmers (Cliffe, 2013), a key objective of the project.

Most interviewees reported that the machinima accurately captured important aspects of a typical cane farmer shed meeting, that they could identify readily with the characters and settings depicted, and that the machinima represented a good cross-section of farmers in the sugar industry. Most participants identified key messages in the script, which were consistent with the machinima's informational objectives, indicating the overall effectiveness of this approach to knowledge sharing (Cliffe, 2013). Learnings derived from this evaluation included the need to more explicitly state where viewers could access more information to support decisions and for the information in the machinima scripts to be appropriately targeted to ensure viewers' engagement with the modeled discussion (Cliffe, 2013).

Critically, only 43% of interviewees stated that currently available information services adequately met the needs of cane farmers (Cliffe, 2013), indicating scope for improved delivery of agricultural extension.

Cost of Machinima Development in Second Life

The cost of machinima development (Table 1) was calculated from the average cost of producing the four short sugarcane farming machinimas on climate risk management. The cost was based on the estimated time involved for each of the development stages described above (and reported in detail in Reardon-Smith et al., 2014). The average cost was estimated to be about AU$6,800 per machinima, with the greatest cost associated with creating and filming the scenarios in Second Life (AU$3,000 per machinima).

Table 1. Average Costs of Machinima Production for the Australian Sugarcane Industry.

Key aspect of machinima development	Costs per machinima (AU$)	Details
Technical information gathering such as relevant climate information and management practices	$1,500	Average 8–12 hours to research, gather information, review, and verify
Script writing	$1,000	Average 6–8 hours to verify the technical accuracy of story lines and edit
Soundtrack recording	$1,000	Average 6–8 hours to select 3–4 voice actors, discuss roles with actors, record, edit, and collate soundtracks
Storyboarding and filming scenarios using the Second Life platform	$3,000	Average 2–3 days to create storyboards, create avatars, develop farm settings, film scenarios, add sound effects, review, and edit
Delivering machinima to websites, smartphones, tablets, etc.	$300	Average 1–1½ hours to upload to a website and promote through various media
Total cost per machinima	**$6,800**	

Costs of Alternative Approaches

The costs of alternative extension options previously tested with the Australian sugarcane farming industry (Table 2) were obtained from Thomas (2011) and CANEGROWERS Australia (Matt Kealley, personal communication). To compare the different extension approaches, estimates were based on opportunity costs rather than actual development costs. Hence, the opportunity cost of presenters' time for the preparation, development, and presentation of information and materials and for farmers' time spent participating in each of the activities was used (Thomas, 2011).

Costs for the bus trip were based on five field days (for details, see Thomas, 2011). Five extension specialists were responsible for organizing the events, including fact sheet preparation and presentations. Forty canegrowers participated in each day's event. This equated to a total of 400 hours of specialists' and canegrowers' time over five information-exchange opportunities, or two person-hours for each information opportunity for the group. Assuming an opportunity cost of AU$60 per person per hour, each information opportunity would cost about AU$120 per canegrower (Table 2).

In the case of the virtual bus tour, assuming the cost of producing the DVD had already been covered, the marginal cost for each additional information opportunity was only AU$10 per individual (for details, see Thomas, 2011; Table 2).

The costs associated with the climate clips were similar to the virtual bus tour website (Table 2). Seven video clips were produced by CANEGROWERS Australia in collaboration with climate experts, at an estimated cost of AU$9 per information opportunity per individual (Table 2).

The cost associated with the BMP DVDs was based on the assumption that an efficient production team will produce one 60-minute DVD in eight weeks. These time estimates are based on two weeks to organize the production schedule, one week to videotape farmers, and five weeks to edit video clips (for details, see Thomas, 2011). Using these assumptions, 160 hours were allocated for pre-production with two people for two weeks, 80 hours for production, and 400 hours for postproduction. Adding the combined presenters' time of 25 hours gave a total cost of 665 hours per DVD. It was then assumed (as in Thomas, 2011) that of the 4,000 farmers who received the two DVDs, 77% (3,080) spent at least one hour watching the DVD. This gave a total of 865 hours for approximately 20 information-exchange opportunities, or four person-minutes per individual information opportunity. At AU$60 per hour, the cost of each information opportunity was AU$4 per individual (Table 2).

The detailed cost of machinima development is provided in Table 1. When the average cost of machinima

Table 2. Cost of Alternative Approaches Used in Extension in the Australian Sugarcane Industry.

Item	Bus trip and field days*	Virtual bus tour*	Climate clips**	BMP DVDs*	Machinimas
Preparation (hrs)	32	16	16	160	64
Production (hrs)	8	8	40	80	160
Postproduction (hrs)			32	400	128
Presenters' time (hrs)	40		8	25	32
Total fixed time (hrs)	**80**	**24**	**96**	**665**	**384**
Audience number (n)	40	20	3,000	3,080	3,000
Audience time (hrs)	8	2	1	1	0.5
Total variable time(hrs)	**320**	**40**	**3,000**	**3,080**	**1,500**
Total time (hrs)	400	**64**	**3,096**	**3,745**	**1,884**
Information opportunities (n)	5	20	7	20	4
Person-hours per opportunity (hrs)	2	0.1	0.09	0.04	0.09
Relative cost per individual information opportunity* **	**AU$120**	**AU$10**	**AU$9**	**AU$4**	**AU$9**

**Thomas (2011); **CANEGROWERS Australia; ***Assumes an opportunity cost of AU$60 per hour.*

production was converted into opportunity costs, and canegrowers' time spent viewing these videos was included, the estimated cost was AU$9 per information opportunity per individual (Table 2), which was similar to the climate clips and virtual bus tour.

Cost Effectiveness Analysis of Alternative Approaches

The results presented in Table 3 indicate that while bus trips and field days are popular activities in agricultural extension programs, they are a relatively expensive option, amounting to about AU$360,000 to meet the target canegrower population of 3,000 growers. On the other hand, these activities provide effective in-person opportunities for capacity building and learning and are probably the most universally used extension methods (Nicholson et al., 2003). The atmosphere of bus trips and field days is usually informal and relaxed, and farmers are able to benefit from group discussion as well as the information shared by experts. Field days provide opportunities to obtain farm-specific advice and recommendations through direct exchanges with expert advisors; however, only a small proportion of growers are able to participate in these extension opportunities, leaving the majority out of the loop (Thomas, 2011).

At the other extreme, DVDs, including supporting online websites, are the least expensive option, costing about AU$12,000 to reach the target sugarcane grower population (Table 3). Online access could enhance the time efficiency of this approach as farmers have more control over what they choose to watch, potentially further reducing the individual cost (Thomas, 2011). However, while farmers have indicated their interest in obtaining and watching new video clips, there is little evidence that they actually use these materials, and their learning outcomes from this activity are unknown and questionable (Thomas, 2011).

The costs of the virtual bus tour, climate clips and discussion support machinimas are similar (~AU$30,000) for the target canegrower population (Table 3). However, in terms of effective engagement, machinimas may offer greater potential for learning and capacity building because of their contextualized built-in discussions and relevance to farmers' preferred modes of information gathering and learning (Reardon-Smith et al., 2015). The unit cost of producing machinimas is likely to decline where production efficiencies can be realized. An additional advantage of machinimas is that they can be contextualized for different farming systems and languages without incurring significant costs, thus, are readily scalable (Harris, 2000) to reach multiple other groups in the global farming community. Machinimas, in general, are also short, self-contained video clips that do not demand a large investment of viewer time, their key intent being to stimulate discussion and further information seeking, rather than technological information transfer.

Table 3. Cost-Effectiveness Analysis of Various Conventional and Digital Extension Approaches (Costs in AU$).

Options	Relative cost per canegrower	Cost for a target population of 3,000 canegrowers
Bus trip and field days	$120	$360,000
Virtual bus tour	$10	$30,000
Climate clips	$9	$27,000
Discussion support machinimas	$9	$27,000
BMP DVDs	$4	$12,000

Table 4. Average Estimates of the Proportion of RDC and CRC Organizational Budgets Allocated to Extension and Adoption Activities.

Activity	Corporate research centres (CRCs)	Rural development corporations (RDCs)
Marketing, promotion, public relation	2.0%	14.0%
Communication and engagement	4.0%	8.0%
Extension, advisory, adoption	7.0%	10.5%
Education and training	12.2%	7.7%
Monitoring and evaluation	3.0%	3.7%
Total	**28.2%**	**43.9%**

Source: QualDATA (2011).
Key definitions adopted to estimate extension and adoption figures: Communication–Keeping stakeholders up to date with policies, activities, outputs, information, and opportunities (without expecting feedback); Engagement—Providing opportunity for input into policy, strategies, and activities; Adoption—Active support to users to enable research findings, new approaches, and/or tools to be applied in practice by the intended users of that research output; Extension—Using a range of informal education approaches to encourage adoption and change; Advisory—One-on-one technical or business support usually provided by private consultants and/or agribusiness; or Natural Resource Management group personnel sometimes with support of state agencies; Training—Using formalized approaches to teach new approaches or skills.

Potential for Upscaling Extension Tools Within Australian Agriculture

Extension is a fundamental component of investment in rural R&D, aimed at accelerating the translation of science into practical applications. RDCs and Australian Cooperative Research Centres (CRCs) invest significant resources (44% and 28%, respectively) on extension and adoption activities (Table 4). For example, from 2003 to 2013, the peak body servicing the R&D needs of the Australian sugar industry—the former Sugarcane Research and Development Corporation (SRDC), now Sugar Research Australia (SRA)—spent on average AU$826,426, or 11% of its annual budget on extension, communication, and capacity building (SRDC, 2004–2014).

RDCs need to ensure that they employ cost-effective strategies in their extension programs to facilitate adoption and maximize returns on their R&D investment. While digital ICTs play a valuable role in RDCs' communication and capacity-building strategies, the adoption of innovative e-learning technologies and approaches that incorporate leading-edge advances in education and social science offer significant new opportunities for best practice extension (Reardon-Smith et al., 2015). Mobile technologies are also likely to play an increasingly major part in access to agricultural extension, given evidence of rapid and widespread uptake by farmers (Roberts & McIntosh, 2012). With rapid growth in 4G data traffic—an annual growth rate of 76% is predicted for 2013–2017—as well as growing acceptance of smartphones and tablets, the increased penetration of mobile broadband devices and the ongoing roll-out of the National Broadband

Network CIE, 2014), digital extension tools offer enormous potential for widely disseminating timely and reliable information to most stakeholders in agricultural industries.

Discussion

The discussion support tools reviewed in this article and elsewhere (Reardon-Smith et al., 2014, 2015) represent a cost-effective addition to the suite of tools available for use in agricultural extension programs. With declining government investment in agricultural extension services, digital extension technologies such as these offer a relatively low-cost option for delivering extension and communication activities, thereby supplementing traditional extension approaches, while potentially resulting in improved adoption outcomes. The indication from the pilot machinima evaluation study (Cliffe, 2013) that the animated video format appeals to industry stakeholders suggests machinimas are a potentially valuable way to engage with farmers. Where such tools incorporate customized regionally targeted climate information that is easily accessible and relevant to on-farm decisions, they have the potential to directly support enhanced decision making, climate risk management, and adaptation (Stone, 2010; Stone et al., 2012). Further evaluation is required (and currently underway) to test this.

These tools also offer an opportunity for a significant scaling up of extension services. The unit cost of producing machinimas is likely to decline where production efficiencies can be realized. Such efficiencies are likely to emerge where the process of producing machinimas can be modularized. For example, machinimas designed for Australian sugarcane farmers may be relatively easily contextualized for sugarcane farmers in other parts of the world by modifying, as necessary, elements such as the background landscape, farm infrastructure, and the appearance and dress of avatars. Script revisions would be required to ensure local relevance, followed by new voice recordings (including recordings in regional and local languages) and re-filming, but the cost of the new machinimas should be reduced, thereby ensuring their ongoing cost effectiveness. Similarly, machinimas created for one industry sector may be customized to another where there are at least some common elements. In this way, multiple market demands across different sectors and regions might be relatively easily accommodated. Such scaling up of agricultural extension represents an opportunity to reach larger numbers of farmers and provide more equitable access to engaging and effective agricultural extension materials (Reardon-Smith et al., 2015).

Within an agricultural sector such as the Australian sugarcane farming industry, machinimas may also be readily updated to accommodate changes in the technical information presented, such as new recommendations for BMPs, without the need to produce new machinimas, increasing their cost effectiveness over time. At an estimated unit cost of approximately AU$9 per person, such digital tools offer a cost-effective complement to existing in-person and online farmer engagement and agriclimate information extension programs, potentially enhancing both the effectiveness of and anytime/anyplace access to extension materials (Reardon-Smith et al., 2015).

However, there are also challenges in using digital tools such as machinima-based discussion support systems in agricultural extension programs. First, their effectiveness depends on the availability of suitable technology for dissemination into rural areas, both in Australia and elsewhere, including developing countries. Access to high-speed Internet and wider uptake of smartphones and tablets will be crucial factors for the delivery of industry-wide extension services (Baldemair et al., 2013; Jespersen et al., 2013). Mobile phone technologies have reasonably good penetration in many developing countries (Aker, 2011; Mittal, 2012; Patel & Shukla, 2014), indicating the potential value in digital tools such as machinimas; however, lack of agricultural advisors to provide follow-up advice and assistance could constrain the tools' effectiveness in terms of the adoption of new farming practices and technologies (Aker, 2011). Despite this, increasing availability of and access to information through the World Wide Web may also mean that motivated farmers or groups of farmers will search out further advice. This may be facilitated by government programs, such as in India, where there are moves to create learning hubs in rural communities to enhance access to the Internet and other learning opportunities (Mittal, 2012; Senthilkumar, Chander, Pandian, & Sudeep-Kumar, 2013). The discussion support aspect of the scripted conversations in the machinimas is designed to enhance this type of collaborative social learning behavior.

Second, the effective use of innovative digital tools such as machinimas for agricultural extension is largely dependent on the type of information provided and the context in which it is provided; for example, a focus on machinima content is as important as the technology. For instance, while broader climate information may be available from national climate center websites, the value of such information in decision making is significantly increased where it is targeted, timely, and reliable (Halewood & Surya, 2012). Complex information (such as the probability of rainfall) must be presented in simple, consistent, and accurate ways to enhance understanding, build trust, and avoid information overload (Beaudoin, 2008), thereby ensuring its incorporation into decision making and longer-term adaptation.

Third, the context in which the information is provided is critical when developing regionally relevant, locally targeted discussion support tools such as machinimas, which appropriately engage with stakeholders from diverse cultures, traditions, and farming systems (Stone, 2010; Stone et al., 2012). Well-made machinimas, available on a range of devices (e.g., smartphones, tablets, PCs), will likely offer enhanced extension outcomes in terms of capacity building, improved decision making, and adaptation.

Fourth, while machinima-based discussion support agricultural extension services might fundamentally change the way in which information is provided to farmers, there remains the need to evaluate whether such discussion support systems influence decision making and result in measurable changes in real-world outcomes on farms.

In conclusion, virtual world machinimas add to the suite of available agricultural support tools from which extension programs might choose, depending on the availability of trained personnel, finances, and technology. Assuming these digital tools are acceptable to the wider population of farmers (as was indicated in the pilot evaluation reported by Cliffe, 2013), discussion support tools such as customized Second Life machinimas have the potential to enhance the cost-effective delivery of timely, targeted support to large numbers of farmers in Australia and globally, facilitating information transfer and potentially increasing the uptake of improved farm management practices. ■

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