Computers and Electronics in Agriculture 121 (2016) 260–268

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Beyond modelling: considering user-centred and post-development aspects to ensure the success of a decision support system

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ARTICLE INFO

Article history:
Received 12 May 2015
Received in revised form 9 December 2015
Accepted 4 January 2016
Available online 11 January 2016

Keywords:
DSS
Extension
Workshops
Learning behaviour
Weed management
Bio-economic models

ABSTRACT

RIM, or 'Ryegrass Integrated Management', is a model-based decision support system (DSS) for weed management in broadacre cropping systems that was updated to continue aid the delivery of key recommendations to manage herbicide resistance. This article complements earlier publications by documenting the rationales that underpinned the re-development efforts. The objectives are to inform the next development cycle of RIM and its delivery, as well as its adaptation to other situations. Specifically, the article aims at providing developers and project managers with key aspects to be considered before and after (re-)developing this type of model-based agricultural DSS. Reviewers report a lack of similar efforts, with modelling aspects generally better documented than underpinning rationales, including those related to implementation. Yet, this type of initiative is necessary considering that agricultural DSS can become expensive projects, and that uptake by target audiences is typically low in spite of known pitfalls and limitations. The key elements that contributed to the thought process behind upgrade choices are thus provided, as well as practical consequences for modelling. Clearly re-asserting cost-effectiveness objectives and favouring human aspects led to: retaining the 'what-if' learning strategy rather than developing optimisation features; renouncing added modelling intricacies; enhancing the software accessibility; and anticipating future maintenance and distribution requirements. Strategies to maximise the impact of RIM are also discussed, particularly the need for qualified workshop facilitators, as well as transparency and evaluation to build user confidence.

1. Introduction

Decision support systems (DSS) are computer-based tools which can aid complex managerial decisions. Weed management DSS are generally based on mathematical models combining weed population dynamics and agricultural practices (Holst et al., 2007). Despite considerable initial investment in modelling and calibration, mathematical simulations are popular tools among the weed research community as they offer the convenience of quickly testing multiple situations and management combinations, thus offering a convenient alternative to long-term experiments seldom conducted because of implementation difficulties, practical limitations, or lack of funding. Making such models accessible to farmers and advisors through a DSS format has been a substantial effort over the past few decades by scientists to go beyond the research scope and reach out to the industry. Numerous DSS have resulted – which often justify more modelling investment. However, despite research benefits, uptake by the target audience has been acknowledged to be mediocre (Hayman, 2004; Stone and Hochman, 2004; McCown et al., 2009; Hochman and Carberry, 2011).

RIM, or 'Ryegrass Integrated Management', was one such model-based weed management DSS which proved, contrarily, to be very successful. Developed during the 1990s–2000s for the Australian southern grainbelt (Pannell et al., 2004), RIM contributed to successfully advocate sustainable practices to reduce the risk of herbicide resistance, in addition to inspiring several other weed management models (Llewellyn et al., 2005; Llewellyn and Pannell, 2009; Lacoste and Powles, 2014). However, maintenance and delivery to farmers and industry professionals ceased in 2006 due to lack of resources. A decade after its release, the original RIM is still well-known but remained mostly unchanged with its use restricted to a limited number of universities and private educators (Long and Parton, 2012; Lacoste et al., 2013). An upgrade was undertaken considering both the substantial investment in the original program and the potential for further impact in cropping contexts still threatened by the onset of herbicide resistance (Lacoste and Powles, 2014, 2015).

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http://dx.doi.org/10.1016/j.compag.2016.01.003
0168-1699/

This paper complements earlier descriptions by documenting key elements that contributed to the thought process behind the DSS upgrade. This initiative was motivated by reviewers reporting a lack of similar efforts, model mathematics being more often published than the logic underpinning their construction (Holst et al., 2007; McCown et al., 2009). An effort is made here to open the upgraded software and the methodology used to critique, as well as to inform the wider application of RIM, its next development cycle, and similar agricultural DSS projects. This is particularly needed as adaptations to the new RIM version have already commenced (Table 1). The rationales motivating important upgrade choices are thus discussed, in light of the lessons learnt from early RIM evaluations and from reviewers. As with any model-based program, compromises had to be made to solve overarching problems with limited resources, while following recommendations in order to reach the desired outcomes. Following this, post-development recommendations for the optimal delivery of a model-based DSS such as RIM are provided.

2. DSS and re-development overview

The usefulness of the RIM model to investigate research questions had extensively been exemplified (e.g. Doole, 2008; references within Lacoste and Powles, 2014). However, the re-development of RIM was primarily motivated by the ability of the program to support the delivery of key messages to the agricultural community through its use as a DSS. Extension activities were thus resumed with the availibility of the new version (Table 1). RIM helps providing insights into the sustainable management of ryegrass (*Lolium rigidum* Gaud.) through a convenient way of testing and comparing the long-term performance and profitability of various control options through simulations, on the long-term and at field scale. Parameters are calibrated for the dryland broadacre cropping systems of the Australian southern grainbelt where winter cereals dominate (main crops: wheat, barley, canola, lupin; main livestock systems: sheep on volunteer or improved pastures).

Implemented in Microsoft Excel®, RIM follows a 3-step progression with the user navigating between panels (Fig. 1). The steps involve customising a profile with field characteristics and economic information, building a 10-year rotation, and defining a ryegrass control strategy through a combination of field operations to choose from over 40 chemical, mechanical and cultural options. The main outputs include the impacts through time on ryegrass seed and plant numbers and on gross margins. Lacoste and Powles (2014) provide extensive examples of how results can be used to support extension messages and educate the farming community about herbicide resistance. An important feature of RIM is that notwithstanding customisation, the software provides general trends without environmental or year-to-year variations, which thus are not accurate predictions for a specific location. Therefore, RIM's simulations are to be used and understood as a comparative analysis tool, not as a forecast instrument.

RIM is essentially constructed with interlinked tables and formulas connecting input parameters, user's choices, equations and model outputs (Lacoste and Powles, 2015). The core components of RIM are a weed population dynamic model linked to a rule-based model. A software-like behaviour is provided with a Visual Basic for Applications (VBA) framework.

Prior to starting the re-development, issues limiting the overall lack of agricultural DSS adoption were investigated and found to be strikingly consistent (Wilkerson et al., 2002; Stone and Hochman, 2004; Holst et al., 2007; McCown et al., 2009; Hochman and Carberry, 2011). Typical pitfalls and limitations identified by the above reviewers include a general lack of definition of the DSS objectives and target audience, which result in various development issues. These issues include misdirected efforts, a lack of

Table 1
Projects extending from RIM 2013.

RIM 2013 and current adaptations			
Name and weed species	Cropping systems, location	Publications, contacts	Release date, funding agencies
RIM: Ryegrass (*Lolium rigidum*)	Dryland crop-livestock (wheat, barley, legumes, sheep), Southern Australia	Lacoste and Powles (2014, 2015), AHRI, University of Western Australia	2013, GRDC
BYGUM: Barnyard grass (*Echinochloa colona*)	Sub-tropical and temperate systems (cotton), Eastern Australia	Thornby and Werth (2015), Inokas Intellectual Services and DAF	2015, CRDC and DAF
PAM: Palmer amaranth (*Amaranthus palmeri*)	Row crops (cotton, corn, soy), Southern US	Bagavathiannan et al. (2014, 2015), Texas A&M University	2016, USDA and industry sponsors
Brome RIM: Brome grass (*Bromus* spp.) **Barley RIM:** Barley grass (*Hordeum* spp.) **Mallee Ryegrass RIM:** Ryegrass (*Lolium rigidum*)	Dryland crop-livestock (wheat, barley, legumes, sheep), South-Eastern Australia	Monjardino et al. (pers. comm.), CSIRO Adelaide	Late 2016, GRDC
Perennial ryegrass (*Lolium perenne*) Wild oat (*Avena fatua*) Fleabane (*Conyza bonariensis*)	Semi-arid cropping (barley, soybean, wheat, sunflower), Eastern Argentina	Chantre (pers. comm.), Universidad Nacional del Sur/INTA	Unannounced
RIM 2013 extension activities (Australia)			
Type	Location, dates, attendance	Contact, delivery	Funding agencies
RIM hands-on workshops and factsheets: Financial and non-financial costs of new integrated weed management tools based on regionally specific RIM outputs, update on weed management issues with farmers	Events around Australia: 4 in 2013, 7 in 2014, 1 in 2015, ongoing. 415+ attendees, farmers and consultants	Micallef and Newman (pers. comm.), AHRI extension and research staff with farmers	GRDC, WeedSmart Initiative
RIM presentations: RIM outputs presented and discussed as part of a larger weed management event	Events around Australia: 16 in 2014, 12 in 2015, ongoing. 1100+ attendees, farmers and consultants	Micallef and Newman (pers. comm.), AHRI staff	GRDC, industry companies
Online communication: RIM outputs of realistic scenarios based on farmer consultation using social media, videos and website, marketed mainly through newsletter (2 500 subscribers)	Online, 2015–2016, ongoing. For website, 670+ unique page views as of mid-2015	Micallef and Newman (pers. comm.), AHRI staff	GRDC

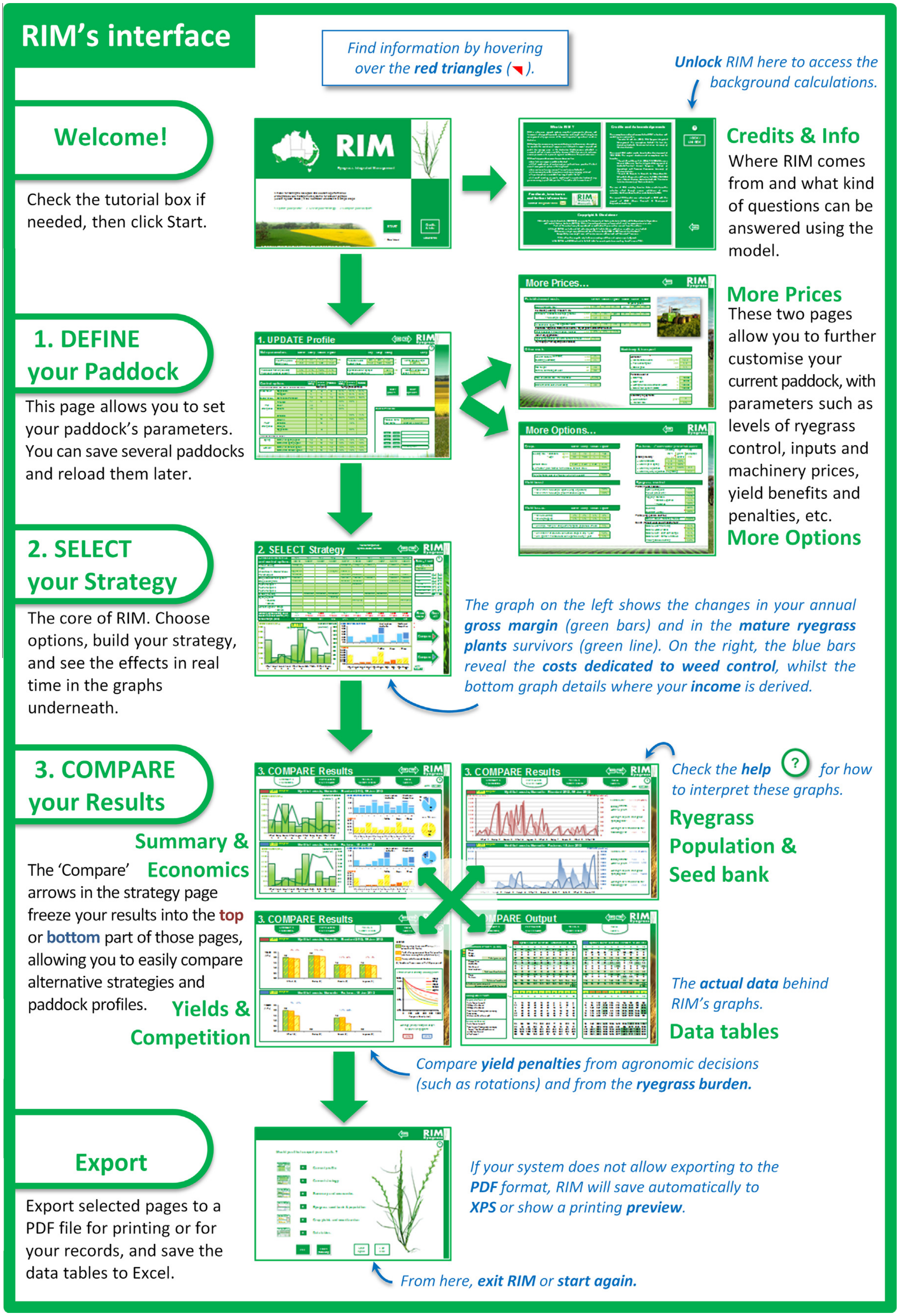

Fig. 1. RIM interface and the 3-step progression. For detailed screenshots see Lacoste and Powles (2014). *Source:* Lacoste (2013).

consideration for the needs of targeted users, and insufficient attention to post-development aspects such as maintenance and update requirements. Considering these elements, a review of the strengths and limitations specific to RIM was undertaken. Feedback from the preliminary workshops (Lacoste et al., 2013), evaluations of RIM's impacts (Llewellyn et al., 2005; Llewellyn and Pannell, 2009) as well as comments from past users and developers contributed to identify the direction of re-development efforts and upgrade requirements. In order to ensure cost-effective development, priorities were established early on as to which aspects of RIM needed to be retained, elaborated or simplified, considering both the substantial investment already made in the original program, and the elements which were indispensable for its end-use as an effective DSS.

Although the update seemingly called for updating practices and parameters first, key decisions were thus made prior to change any features of the program. The most evident one was to improve upon the existing version of RIM rather than starting anew or moving onto a new platform. Other decisions involved careful considerations which are developed thereafter, in particular whether the DSS's overall strategy should have been replaced by a more common approach (i.e. optimisation), and to which extent the modelling should have been improved. Only after these overarching aspects were considered could the primary objectives of the update be addressed, namely updating contents and appearance. This was done while catering as much as possible for future maintenance and for the adaptation of RIM to situations other than the Australian context. The program restructuring and redesigning were thus conducted alongside the model revision and parameter update. Although the main modifications to achieve were identified prior to start, practical solutions were often found through a continuous back-and-forth process between modelling, anticipating user's needs, and dealing with the implementation boundaries of Excel®. The in-depth understanding of these elements led to highlight some of the program specificities that are particularly important to ensure the adequate delivery, use and future of RIM.

These recommendations and the modelling compromises involved are little evident unless dwelling into modelling intricacies. Explanations are therefore required, and are likely to be relevant to other model-based agricultural DSS. The objective is thus to facilitate the tasks of future developers, advanced users, as well as extension and communication professionals.

3. Considering human-centred aspects

3.1. Addressing learning behaviour: experimentation vs. optimisation

Re-developing an outdated DSS provided the opportunity to reconsider the core principles of the program. Overall, the re-development effort followed the rationale that further investment is justified only if it serves the end-purpose of RIM as a DSS, i.e. in so much as it is useful for the decision making process of the end-users (Wilkerson et al., 2002). Part of taking user needs into consideration involves addressing farmer decision-making and learning behaviour (McCown et al., 2009). To do this, the first version of RIM allowed users to experiment with options through a 'what-if' principle, an approach that was deemed original at the time (Holst et al., 2007). A first, critical decision was to retain and improve this feature. Although the underlying extension paradigm is not new, this choice warrants explanations given the popularity of optimisation methods in agricultural DSS, especially for weed management (e.g. Neeser et al., 2004; Parsons et al., 2009; Gonzalez-Andujar et al., 2011). Optimisation methods make use of mathematical tools and computer power to process large amounts of information and produce recommendations and rankings. As such, they are valued research tools that are widely employed. However, their relevance to agricultural extension and education can be questioned.

A reason for the common use of optimisation and recommendations is the definition of most DSS as "tools that help farmers to find the best possible long- or short-term weed-control solutions" (Holst et al., 2007, pp. 6). RIM on the other hand is only "designed to provide information and insights to farmers to help them in their long-term decision making about management of annual ryegrass" (Pannell et al., 2004, 307). This statement concurs with the idea that farmers adjust their decision-making process through integrating new knowledge with experimental learning (Llewellyn et al., 2005; Wilson et al., 2009). RIM proposed to tap into this dynamic learning behaviour. Custom-built scenarios let the user experiment with options, explore scenarios, and assess the relative consequences of various management choices. The results can then be evaluated against previously held information (Vanclay, 2004). This approach essentially aims to contribute influencing the farmer's continuous problem-solving process, rather than to try replacing it (McCown et al., 2009). Also rejected is the idea that a DSS would have to overcome "cognitive shortcomings", a pre-conception that befell many DSS (Hayman, 2004). If the ultimate goal of a DSS is to eventually contribute to practice change through better informed decisions, then learning via experimenting stands a better chance than prescriptive recommendations that ignore, and even exclude, farmers' decision-making abilities (Stone and Hochman, 2004). Since the first release of RIM and the progresses of other agricultural DSS, evidence supports this reasoning. 'What-if' queries are often found to be the type of questions that farmers have, and their simulated scenarios generate discussion (McCown et al., 2009). Farmers and consultants do value tools that allow them to explore their options and examine the merit of potential strategies (e.g. Jakku and Thornburn, 2010). In the case of RIM, this was the feature, along with accessibility, that was originally most praised by users (Lacoste et al., 2013).

Another reason for renouncing optimal solutions is the limitation they put on the number of management options: if those are too numerous "a complete analysis of all scenarios becomes unpractical" (Holst et al., 2007, pp. 7), especially in the case of multi-year simulations. Furthermore, the reliability of optimisation methods rests on the comprehensiveness of those parameters deemed most important in influencing outcomes. However, the identification, compilation and prioritisation of those parameters is particularly difficult when considering farming realities. Modellers face issues related to the practicalities of data collection, the complexity of farming practices, and factors that are inherently highly variable (Wilkerson et al., 2002). Settling for known parameters can easily lead decision algorithms to mathematically sound yet biologically flawed solutions. When dealing with management, farming system considerations and whole-farm level, optimised solutions can similarly fail the test of practical relevance (McCown et al., 2009). For instance, optimisation/recommendation models driven by economic and environmental factors frequently advise reducing herbicide rates and allowing weed density thresholds, when significant evidence have shown that these practices actually select for herbicide resistance (Manalil et al., 2011; Norsworthy et al., 2012). This is less of a problem in a research context exploring and highlighting complexities, but unacceptable for a DSS aiming to promote relevant discussion and facilitate the implementation of best management practices. Consequently, given all the unknowns and uncertainties, letting the farmer integrate himself the pieces of information provided by a DSS with his own 'equations' and unique 'parameters' (i.e. experience, circumstances and inevitable trade-offs) as a manager would be expected to do seems a much simpler and more respectful approach (Hayman, 2004; Stone and Hochman, 2004; McCown et al., 2009).

Lastly, another reason to avoid optimisation and recommendations is their sheer mathematical complexity. An illustration is provided by an optimisation of RIM itself that was conducted for research purposes (Doole and Pannell, 2008). In a DSS context, the specific skills and knowledge required to deal with advanced decision algorithms and parameterisation requirements would hinder further adaptation and updates. Furthermore, a 'black box' issue arises: because of their complexity and integration, the mechanisms separating inputs and outputs are hidden away from the user, his/her understanding, and trust. Reducing the opacity between inputs and outputs motivated the choice of displaying intermediary results and additional outputs in RIM's interface. Similarly, new charts were part of an effort to illustrate the components that are integrated into the final economic results. Providing different angles to interpret results allows the user to better understand the processes involved.

3.2. Renouncing added complexity by re-asserting objectives

The primary requirement of the update was to reflect current farming practices better. Part of this involved considering modelling improvements. The model description could have been enhanced in order to increase the accuracy and representativeness of the simulations. For instance, other major weeds could have been added (e.g. Monjardino et al., 2003); the influence of crop rotations and management on population dynamics developed further (e.g. Canner et al., 2009); a probabilistic component incorporated to go beyond deterministic effects and cater for some of the environmental variability (Holst et al., 2007); or bio-physical elements included to improve the very simple agronomy model. Instead, besides restructuring and adjustments, very little core modelling was added. Most of the original compromises between simplicity and representativeness were retained, leaving the ryegrass population model and the principles underlying the associated rule-based model essentially unchanged. There may be objections to this decision as improving core modelling represents a very logical path for a model-based DSS. In fact, the preferences of individuals vary greatly, between users who value details, accuracy and specific predictions, and others who favour DSS providing general trends and guidance (e.g. Kragt and Llewellyn, 2014). RIM purposefully stands on the latter end of the spectrum. Contrary to other more elaborate agricultural DSS (e.g. Renton et al., 2008), it was re-asserted that simulating with absolute accuracy or generating specific recommendations were not the objective nor the ambition of RIM. Instead, the DSS emphasis was to engage users with broader principles.

The decision to remain approximately right rather than be precisely accurate was mainly justified by cost-effectiveness concerns. Some users may believe that greater detail means increased accuracy or that greater complexity might increase the credibility of the model. However agricultural relationships are generally characterised by a flatness of responses. In other words, refining options with additional parameters and relationships may not necessarily result in much increased explanation of the variation output. With prior sensitivity analysis indicating that a limited number of parameters are critical for RIM results, more detailed modelling was likely to achieve little contribution while increasing "the risk of being precisely wrong" (Hayman, 2004, pp. 7). The benefit of little extra accuracy would thus have come at great additional resource commitment not only in development but also in collection of additional data that are difficult to obtain. This would have resulted in a poor cost-effective investment of the limited upgrade resources available – unless resolving to settle for anecdotal evidence, subjective values or ballpark estimations. Even then, farming predictions remain highly uncertain, especially in dryland cropping conditions. The accuracy and precision of simulated predictions, and therefore the complexity of the underlying modelling, should be acknowledged as being limited by the inherent variation scope of parameters that are out of control or simply unknown (e.g. weather variability, price volatility, imponderable farm-level trade-offs). Otherwise, the DSS incurs the risk of becoming "a small rock of precision" in an ocean of uncertainty, more hurtful than useful (Stone and Hochman, 2004, pp. 9). Furthermore, limited accuracy may not be as damaging for decision making as perceived (Wilkerson et al., 2002). Hayman (2004) even argued that precise decision-points are not crucial because there can be remediation of 'wrong' decisions: farmers continuously adjust their strategy in light of the consequences that the previous decisions had. Moreover, there is growing academic consensus that other factors are as important, if not more, for the success of a DSS than high levels of accuracy. Both human and technical aspects have to be considered, including a user-centred approach (ease of control, simplicity, adapted to learning behaviour, credibility) and post-development matters (maintenance, distribution, delivery) (Wilkerson et al., 2002; Stone and Hochman, 2004; McCown et al., 2009; Hochman and Carberry, 2011).

4. Considering post-development aspects

4.1. Enhancing accessibility through clarity, efficiency and flexibility

Almost a decade after its last release, RIM was hindered by both outdated contents and an archaic format, making implementation enhancement more important than improving an already advanced model. Before 2006, RIM's accessibility was highly praised by users (Lacoste et al., 2013), but had become obsolete by current standards. As declared by Holst et al. (2007, pp. 8), for "models that are part of decision support systems, the user will expect the same quality and ease of use as of commercial software." In fact, accessibility is a requirement for any computer-based tool (Wilkerson et al., 2002; Hochman and Carberry, 2011). The new RIM interface thus thrived to facilitate the user's experience through a modern, user-friendly design focusing on clarity, efficiency and flexibility.

Efforts were made to design the new interface with a variety of end-users in mind, including people with minimal computer literacy. To achieve this, the layout was meant to be as simple and intuitive as possible, with a focus on overall clarity. Features included a straightforward progression, prominent navigation buttons and panel titles, colour-coded elements, non-cluttering help features, results fitting on one page, display adjusting automatically to any screen size, etc. Aesthetics are rarely ever considered in model and DSS presentations, yet the practical importance of the interface's general appearance for ease of control should not be neglected: agreeable pictures rest the eye; colours enhance the visual experience; well-drawn graphs and schematics are more effective than tables loaded with numbers. Furthermore, design consistency is essential for fast familiarisation, and contrasted layouts favour intuitive use. This allows diminishing the learning investment from the user who can focus on contents and input information relatively fast, a characteristic that is consistently valued highly (Kragt and Llewellyn, 2014). Setup was further accelerated by simplifying the input required and by providing several pre-loaded profiles and strategies to be modified according to needs, rather than having to start from a blank canvas. Complete profile customisation can thus be completed in ten to thirty minutes. Similarly, several VBA functionalities allow swiftly obtaining, modifying and comparing results, thus moving quickly from the production of results to their discussion (Lacoste and Powles, 2015). Another acknowledged problem of RIM was the rigidity of the original version that recurrently generated errors. To limit user's frustration, flexibility was increased. A wider diversity of situations was catered for, option choices were better-structured and a majority of incompatibility rules were deleted, letting the user decide what is logical and applicable. Incidentally, this simplified an important part of the background modelling. Extensive compatibility checks between the most common Excel® versions were also conducted.

Efforts to increase the accessibility of RIM proved effective during the testing sessions, with very few participants requiring assistance despite a very short introduction to RIM (Lacoste and Powles, 2014). Nevertheless, several sources of help and information were implemented to assist users. These included a succinct in-built tutorial accompanied by numerous comments, a concise and illustrated user guide (Lacoste, 2013), and further on-line information provided in a dedicated website (www.ahri.uwa.edu.au/RIM).

4.2. Anticipating future requirements: maintenance and distribution

To avoid the common pitfall that little attention is usually given to the post-development phase of a DSS, these issues were considered early and made an integral part of the re-development effort.

The first problem to be solved was to ensure that RIM could be easily modifiable, for both maintenance and adaptation to other weeds and cropping systems. RIM maintenance had suffered from two problems already identified by Wilkerson et al. (2002) for other modelling projects. Extrinsically, academic funding and interest is generally more readily available for new projects than for the maintenance of existing ones. Intrinsically, RIM's modelling was challenging to access to anyone but the original development team. Maintenance was hindered by the complexity of the model's linkages and its large number of parameters, which resulted in superficial and incomplete adjustments. To address this issue, simplifications were made whenever deemed not to impact the quality of outputs (Renton, 2011). These decisions were guided by the comprehensive sensitivity analysis conducted on previous versions of RIM. Furthermore, an exhaustive clean-up and restructuring was undertaken involving new linkages, parameter prioritisation, deletion of redundancies, contraction of intermediary calculations as well as the addition of extensive in-built comments (Lacoste and Powles, 2015). Although time-consuming and invisible to users, this task could not be ignored for its long-term benefits.

Future maintenance and adaptation issues have also led to renounce transporting RIM to a more professional and powerful platform than Excel®. First, this software benefits from external, near-guaranteed continuous improvements. Second, VBA coding is a simple language holding the double advantage of requiring only basic programming skills and minimising programming errors (Holst et al., 2007). Retaining Excel® also proved a cost-efficient choice as the improved functionalities and slicker features of the new versions met all implementation and design requirements. New Excel® versions are also better coded, resulting in a very light file in spite of much additional contents. Importantly, Kragt and Llewellyn (2014) found that Excel® was one of the platforms most favoured by DSS users, probably because of its near universal use on personal and professional computers.

Aside from easing modifications, the re-development aimed at facilitating the distribution of the program. Like any other product, the impact of a DSS can be significantly increased through a comprehensive marketing strategy (Hochman and Carberry, 2011). To support marketing efforts, a visual identity was created for RIM with the aim of making the program and related promotion material instantly recognisable (Fig. 2). Otherwise, copyright terms were re-defined to make RIM open-source, with free and direct access online. Incidentally, this removed the need to keep track of individual licences and financial records, and facilitated recording basic user information through web statistics. Then, the RIM file was kept as light as possible to facilitate downloads (3 Mb). Parenthetically, when download is initiated from mobile phones, tablets or other operating systems not fully supporting Excel® for Microsoft Windows®, an automatic email is send instead with RIM as an attachment. A simplified version of RIM compatible with tablets and smart phones was considered given the increasing popularity of these technologies among the farming community. However, portage costs proved excessive. The benefits of using RIM in a simplified yet portable format would have to be demonstrated to justify the required investment.

Fig. 2. RIM visual identity: logo, layout, colour code, funding bodies and QR download code.

5. Considering delivery aspects

5.1. Delivering the DSS: engaging users through facilitated workshops

As shown above, the development phase of a DSS can impact several post-development aspects. Other elements, such as delivery modalities, are not in the hands of modellers. Yet, recommendations ought to be made in light of the program's history, background and modelled mechanisms.

Notwithstanding its success with students and the potential to raise herbicide resistance awareness in other spheres (Lacoste and Powles, 2014), RIM is primarily meant for the farming community. Evidence suggests that agricultural DSS users are likely to be private consultants and advisors, with a snow ball effect to farmers, the actual target audience (Hochman and Carberry, 2011; Long and Parton, 2012). RIM can certainly be used for one-on-one extension, with private consultants using RIM with their clients who can then investigate the program further by themselves. However, for maximum impact the active delivery of RIM via workshops ought to be on-going. Past experiences demonstrated that the direct delivery of RIM to both advisors and farmers was highly successful in a workshop format where the use of the software was preceded by a presentation and update on herbicide resistance (Llewellyn and Pannell, 2009; Lacoste et al., 2013).

The primary reason for the success of workshops is that group sessions are more adapted than top-down approaches (Vanclay, 2004), particularly for a DSS based on a 'what-if' exploration principle that stimulates discussion (McCown et al., 2009). As such, RIM supports social learning, by which participants are led to an improved understanding of a problem and its context through interactions and shared learning (Jakku and Thornburn, 2010; Hochman and Carberry, 2011). A workshop format is costly to organise but is ideal to discuss with peers, to place concepts back into context, and to debate the significance and scope of results through debriefing sessions. The evaluation of RIM's first workshops corroborated the need for a skilled and knowledgeable presenter, who was deemed a highly valued component of a successful workshop. Participating farmers and consultants emphasised the importance of interacting both between themselves and with the presenter and invited experts; the hands-on use of RIM was a highlight of the workshop, but so were the introductory presentations on herbicide resistance.

The crucial facilitating role of a versed presenter should here be highlighted. Beyond simply providing technical assistance, a presenter who is able to engage users is essential to maximise the social learning process. As user-friendly and interactive as a DSS can be, only a facilitator can stimulate an audience to confront ideas and perceptions, which is as much if not more important to decision making than providing facts (Hayman, 2004). Additionally, the presenter has to relate to the audience, recognising that needs vary among users and explaining how applicable the DSS results are to individual circumstances (Hochman and Carberry, 2011; Norsworthy et al., 2012). In order to do this, a presenter must access local knowledge (Wilson et al., 2009; Jakku and Thornburn, 2010) and identify which information may be essential to promote. This may include targeting perceptions, supporting specific knowledge acquisition, and elaborating on appropriate incentives – even when awareness of herbicide resistance evolution already exists. In the case of herbicide resistance and the adoption of integrated weed management, examples of misconceptions include the use, availability and environmental impacts of herbicides, as well as the importance of weed seed dispersion (Llewellyn et al., 2005; Llewellyn and Pannell, 2009; Wilson et al., 2009; Norsworthy et al., 2012).

In addition to engaging and educating audiences, a presenter must be familiar with RIM's key assumptions and mechanisms to ensure that results are not misinterpreted (e.g. variation scope of results, meaning of technical terms), that questions are adequately answered (e.g. why is there no rainfall variation, and what enters the competition equation?), and that full use is made of the available options (e.g. approximating a sprayed volunteer pasture to a chemical fallow, simulating a herbicide-resistant crop variety, etc.). Furthermore, as straightforward as RIM was meant to be, it remains a relatively complex tool which is best used if its scope and core assumptions are explained. For instance, it should be insisted upon that: RIM is not a knowledge-based or expert system nor a forecast model but a comparative tool focusing on a particular aspect of farm management; trends are highly dependent on the appreciation of what 'long-term average yields and prices' means; weeds other than ryegrass are assumed to be controlled; and that higher emphasis is put on first year revenues because of discounting.

Put simply, a DSS such as RIM does not replace extension needs, nor costs. In fact, RIM complements the effort of delivering messages to the agricultural community. Proper delivery requires a wide array of skills and expert knowledge that go beyond simply generating DSS outputs. In a workshop context, roles would probably have to be shared between several facilitators, ideally one presenter and two experts. Consequently, continuing adequate delivery is more than ever subject to both the availability of competent personnel and continuous funding (Wilkerson et al., 2002). This could prove challenging considering the direction taken by Australian extension context (Hunt et al., 2012). As argued by Hochman and Carberry (2011), a solution could be found in the development of an on-going, committed, multi-party delivery network.

5.2. Building confidence: from credibility to evaluation

Learning with computers has the benefit of allowing rapid, simple and cost-free feedback of trial and error, but virtual experiences are prone to generate scepticism (McCown et al., 2009; Hochman and Carberry, 2011). Farmers and advisors need to value the product so that outputs can be taken seriously.

A first point to ensure confidence in RIM's results is to honestly acknowledge the limitations of the program. RIM will not replace the user's expert judgement; it will only provide additional evidence to encourage practice change, and does not pretend to provide silver-bullet solutions to a problem as complex as herbicide resistance. For instance, addressing profitability is certainly a strength of RIM; not always integrated into DSS because of update difficulties, economic considerations are essential when trying to modify farmers' perceptions towards integrated weed management (Llewellyn et al., 2005; Llewellyn and Pannell, 2009). Nevertheless, it should be recognised that profit is not the only driver of practice change (Vanclay, 2004). Achieving long-term profitability is of course crucial, however any decision involves multiple short, medium and long-term compromises (e.g. Ervin and Jussaume, 2014). Within the vast number of managerial issues and uncertainties to be dealt with such as adequacy, convenience, treasury cash flow, etc., RIM only tackles a very specific problem. Generally speaking, it should be acknowledged that a DSS can only offer a partial analysis and thus remains inferior to experienced human judgement.

The reputation of the development team and funding body can also contribute to the credibility of extension efforts, in particular the ongoing involvement with the industry and the consistency of the message delivered (Bennett and Cattle, 2013). In that regard, benefits are drawn from the sustained mandate of the AHRI group and the continued efforts of its extension team in raising awareness about herbicide resistance, that culminated with involvements in a communication program of national scope (Mayer et al., 2014, Table 1). Relying on reputation alone, however, has limitations. There should be an active commitment to demonstrate to users the credibility of the DSS itself. Early trials and external expert appraisals contributed to this (Lacoste and Powles, 2014), however the ability of the updated model to approximate reality has to be tested and demonstrated (Lacoste and Powles, 2015).

Aside from credibility and validation, confidence can be established through transparency. Providing extensive documentation and thriving for accessible modelling is one way of achieving it (Renton, 2011), however transparency should also reach end-users through more accessible means than scientific publications or reference manuals. The latter are mostly used by developers and tend to be extended versions of academic papers without the scientific scrutiny (Holst et al., 2007). The chosen alternative was to design a short, particularly accessible user guide without equations or lengthy paragraphs. Recognising that a large number of users would nevertheless only access the DSS itself, significant efforts were placed on in-built information. As mentioned earlier, providing intermediary results was also part of an effort to increase user confidence in the DSS, through making some of its underlying logic more transparent.

6. Evaluating the development effort: the essential next step

Achieving transparency is important as it allows the DSS to be more easily scrutinized – and critiqued. This can lead to useful adjustments, or to a new cycle of development for an enhanced product (Holst et al., 2007; McCown et al., 2009). Any additional development effort, however, should be preceded by a relevance and impact assessment. This is necessary since DSS evaluations are seldom conducted, because of a more common interest in developing the models and answering research questions than assessing their actual impact (Stone and Hochman, 2004). Evaluation and feedback of the original version of RIM were taken into account for this upgrade, focus was put on impact rather than on the technology only (Hochman and Carberry, 2011), and every precaution was taken to avoid other DSS pitfalls commonly identified by reviewers. Nevertheless, the adequacy of implementation and post-development efforts can only be assessed through a rigorous evaluation. Evaluation should be conducted during the first step of the delivery process, so that besides providing information for the next development cycle, any major issues can be identified and corrected as early as possible. Both the software and the delivery methods should be evaluated, to identify or confirm the direction of future extension efforts (Llewellyn et al., 2005; Llewellyn and Pannell, 2009). Evaluation criteria should be well defined, probably by multiple parties external to the development team to ensure exhaustivity and objectivity (Stone and Hochman, 2004). Amongst other improvements, the evaluation could provide ground to further tailor different versions of RIM to different audiences, and suggest novel methods to use RIM to complement the delivery of key herbicide resistance extension messages (Hayman, 2004; Vanclay, 2004). These could include the use of internet such as online videos and social media (Hunt et al., 2012; Table 1). Evaluation should also determine if niche audiences are to be specifically targeted, rather than diluting effort towards already exposed users (Long and Parton, 2012).

Another path to explore could be to initiate a participatory approach, where users provide their own interpretation of the DSS use and underpinning concepts, identify barriers, and thus contribute to further developments (Wilkerson et al., 2002; Jakku and Thornburn, 2010). The idea of a formal and close multi-party collaboration involving farmers, extension personnel, consultants and researchers is attractive, however it should be remembered that such initiatives are complex and can be resource-demanding.

7. Conclusions

Upgrading or developing a model-based DSS is not limited to deciding parameters and refining equations. The primary purpose of the program should be regularly reasserted so as to dedicate careful consideration to other matters than modelling intricacies. This includes implementation and, in a broader sense, all aspects related to the end-user. Upgrading RIM while emphasising a user-centred approach and keeping in mind the future of the software resulted in renouncing added complexity and instead restructuring the whole program. Identifying implementation issues led to the examination of matters as trivial as interface and modelling accessibility and as complex as learning behaviour.

The authors argue than optimisation in a DSS context is a relic of former attitudes towards extension, and that an approach emphasising the trial of ideas is more likely to succeed in contributing to learning and practice change. Also essential is to acknowledge that a DSS like RIM only tackles a very specific problem and does not replace the user's expert judgement; it can only aim at contributing to the user's decision-process. The impact of RIM would be maximised by workshops run by presenters whose critical role, beyond delivering information, encompasses encouraging discussions, promoting interactions and engaging users. Hence, impact will largely be determined by the quality of delivery and extension funding.

Lastly, a rigorous evaluation is the indispensable next step in this development cycle, so that the validity of the approach can be assessed.

Acknowledgements

This work was funded by the Grains Research and Development Corporation of Australia (GRDC). The authors thank all of the many individuals from various institutions who contributed to RIM throughout its development, particularly from the University of Western Australia (notably from the Australian Herbicide Resistance Initiative and the School of Agricultural and Resource Economics) and from the Department of Agriculture and Food of Western Australia. The authors also thank Brogan Micallef for comments on the manuscript, and Christopher Preston for his support.

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