Simulation-based decision-support tools in digital agriculture: Converting APSIM into point-and-click online tools

U Grewer[a,b,c*], R Anderson[a], Y Lai[a,b], B Lyons[c,d], A Zull[e,a], and K Pembleton[a,b]

[a] *Centre for Sustainable Agricultural Systems, University of Southern Queensland, Toowoomba, QLD, Australia, www.unisq.edu.au.* [b] *Cooperative Research Centre for High Performance Soils, Callaghan, NSW, Australia, https://soilcrc.com.au.* [c] *Rural Economies Centre of Excellence, University of Southern Queensland, Toowoomba, QLD, Australia, www.unisq.edu.au.* [d] *Southern Queensland Northern New South Wales Drought Innovation Hub, Toowoomba, QLD, Australia, www.unisq.edu.au/research/sqnnsw-hub.* [e] *Crop and Food Science, Queensland Department of Primary Industries, Toowoomba, QLD, Australia, www.dpi.qld.gov.au.*
Presenting author: uwe.grewer@unisq.edu.au

Abstract: The increased availability of temporal and spatial high-resolution data from gridded databases, remote sensing, drones, and tractor-mounted devices provides novel opportunities to inform the design of cropping systems. The expansion in data availability has to be translated into actionable advice of direct relevance for farmers and agronomists. Here, we present two novel decision-support tools that are based on the APSIM cropping systems model and provide farmers and agronomists with an intuitive point-and-click user interface to guide on-farm decisions. The recently released "Agricultural Risk Management of Crop Rotations" tool (RotationARM) assists growers in selecting a multi-year cropping system strategy that is most suitable for their circumstances. The forthcoming "Data-driven Yield and Nutrient Assessment for Soil Optimisation and Informed Landuse" tool (DYNASOIL) will provide growers with an assessment of the agronomic and financial benefits of soil amelioration options. The tools highlight how comprehensive cropping system models with complex data and skill requirements can be transformed into user-facing decision-support tools that are easy to utilise and require few inputs. Given the growing availability of agricultural data, we anticipate that the presented tool development framework and design principles will be highly relevant to the broader modelling community seeking to translate simulation models into practical digital tools.

Keywords: *Decision-support tools, digital agriculture, crop modelling, e-learning, APSIM*

1. INTRODUCTION

Major advancements have been made over the last two decades in increasing the availability of high-resolution temporal and spatial data in agriculture. This includes: (i) the availability of comprehensive database products such as the Scientific Information for Land Owners (SILO) and the Soil and Landscape Grid of Australia (SLGA); (ii) the expansion of satellite remote sensing datasets assessing surface temperature, soil moisture, crop health, plant and biomass development, and land use; and (iii) the increased diffusion of tractor- or drone-mounted sensors for in-field data collection. This major expansion in the availability of agricultural high-resolution data has motivated scientific analyses employing diverse data processing methods, including machine learning, deep learning, frequentist and Bayesian statistical models, expert-based decision algorithms, and process-based crop simulation models. While such data have been increasingly utilised for scientific analysis, comparatively fewer innovations have emerged in translating these data into user-oriented decision-support tools or machine-readable control files for precision agriculture equipment.

Existing decision-support tools and software applications have primarily concentrated on in-season crop management, such as generating variable-rate fertilisation maps or supporting spot spraying operations. In contrast, two areas that have traditionally received less attention from data-driven decision-support tools are: (i) cropping systems design, particularly the evaluation of how multi-year crop sequences and management strategies affect farm-level outcomes across agronomic, economic, and environmental dimensions; and (ii) soil amelioration, including the assessment of its short- and medium-term agronomic and financial returns. We showcase two contrasting approaches to the conceptual design of decision-support tools: one based on querying precomputed simulation databases via lookup operations, and the other on conducting real-time simulation runs initiated by user input. We discuss the functionality, implications, and comparative advantages of each approach.

2. METHODOLOGY

We utilised the cropping systems model Agricultural Production Systems sIMulator (APSIM) within two alternative approaches to designing decision-support tools. The RotationARM tool requires minimal user-input on selecting site characteristics, crop sequences, and crop management via a simple point-and-click user interface. All further bio-physical inputs are sourced from gridded databases, including SILO, the Agricultural Gross Margin Calculator (AgMargins) and further tool-specific parameters across a fixed set of predetermined locations, crop rotations, and management options. All simulation options have been conducted as part of the tool development process and are stored in a background Structured Query Language (SQL) database of 22.9 million separate APSIM simulations that are consulted via lookup operations. The tool covers 24 sites across southern Queensland and northern New South Wales. The RotationARM user interface guides users through an iterative process comparing various multi-year cropping strategies in terms of their performance across 10 comprehensive result indicators covering agronomic, financial, and environmental performance.

The DYNASOIL tool requires detailed user input on the past plot occupancy and management history for at least 4-years. The plot management history data, including past soil ameliorations, is needed to proceed to the next step in the tool user interface. Soil property information will be sourced from the SLGA database while allowing users to overwrite default values with location-specific data from soil sampling results. Users are further required to specify a forward-looking cropping plan as well as typical cost-benefit data for their operations. DYNASOIL conducts APSIM simulations in real-time on a Nectar-hosted virtual server for any arbitrary location within the predetermined tool boundaries across broadacre regions in eastern, southern, and western Australia. The DYNASOIL user interface will then provide an evaluation of the simulated agronomic and financial benefits of addressing a set of priority soil constraints.

3. RESULTS AND DISCUSSION

The RotationARM tool allows users to quickly and simply choose from a wide range of predefined cropping strategies. While the selection of input parameters is very simple, the guided iterative process of comparing alternative cropping strategies across multiple criteria (including diverse synergies and trade-offs) is highly complex and dynamic.

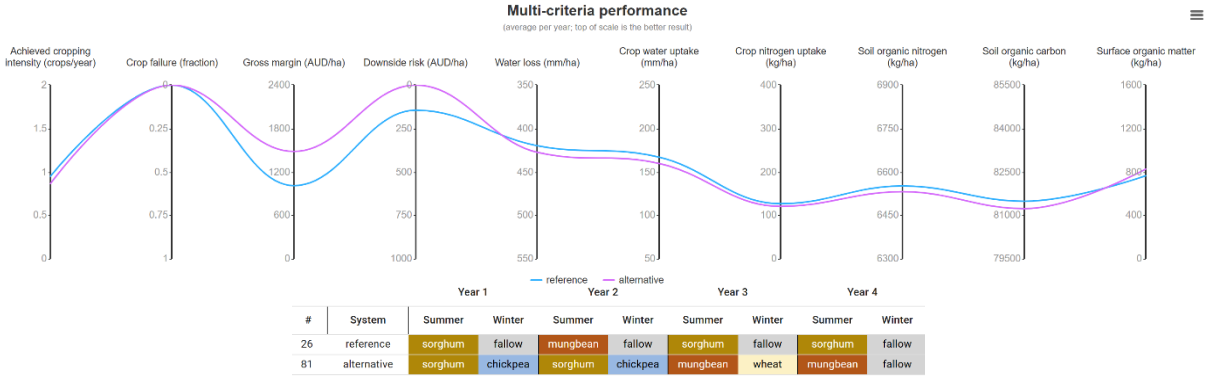

Figure 1: Results snapshot from the RotationARM tool

The DYNASOIL tool requires detailed and complex user input on crop management and cost-benefit data. The generated tool results are static and do not require any further complex iterative process of comparing alternatives across multiple performance indicators. The software implementation of conducting on-demand APSIM simulations is more complex and may lead to wait times in case of heavy traffic to the tool website.

Useful decision-support tools need to balance model complexity with being user-friendly to address the required outcome. Tools based on pre-defined simulation options are well-suited to structuring complex decision-making processes – as they can anticipate the major possible decision pathways and prepare corresponding guidance resources. In contrast, tools that support highly user-defined scenarios offer greater flexibility to reflect user-defined field-specific conditions. However, as the diversity of user-defined conditions cannot fully be anticipated, such tools are less able to guide complex, iterative decision-making processes via pre-prepared guidance materials.

ACKNOWLEDGEMENTS

The RotationARM tool was partially funded through the Australian Government's Future Drought Fund. The DYNASOIL tool has been supported by the Cooperative Research Centre for High Performance Soils (SoilCRC) whose activities are funded by the Australian Government's Cooperative Research Centre Program.

