26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Multi-crop modelling framework for evaluating irrigation strategies and sowing window optimisation across Australian production environments

Jaba Sarker[1], Delwar Akbar[2], John Rolfe[3]

[1] Post-doctoral Research Fellow, School of Business and Law, Central Queensland University, Rockhampton, Qld 4702 Australia.
[2] Professor, School of Business and Law, Central Queensland University, Rockhampton QLD 4702 Australia.
[3] Professor, School of Business and Law, Central Queensland University, Rockhampton QLD 4702 Australia.
Email of presenter: j.sarker@cqu.edu.au (JS)

Abstract: This study developed a comprehensive framework to evaluate irrigation strategies and sowing window optimisation for five major crops (sorghum, wheat, mungbean, chickpea, soybean) across five contrasting production environments using 100 years of climate data. The framework revealed substantial irrigation benefits ranging from AUD176-1,450/ha, with sorghum consistently identified as the optimal crop choice followed by chickpea across all regions. This modelling approach provides a robust decision support system for optimising water use efficiency and crop selection strategies under long-term climatic and economic variability.

Keywords: *APSIM Next Generation, crop simulation modelling, irrigation, multi-crop systems, economic assessment*

1. INTRODUCTION

Agricultural water management decisions require robust tools that can quantify irrigation benefits across diverse cropping systems and environmental conditions. The APSIM (Agricultural Production Systems sIMulator) framework provides a comprehensive platform for simulating agricultural systems across diverse environments (Holzworth et al., 2014). While process-based crop models like APSIM provide powerful capabilities for assessing agricultural systems, systematic multi-crop frameworks for integrated agronomic-economic assessment remain limited. The challenge lies in developing modelling approaches that can simultaneously evaluate multiple crops, irrigation strategies, and sowing windows across contrasting production environments while accounting for long-term climate variability and economic risk. Environmental and economic pressures on agricultural systems necessitate decision support tools that can guide optimal crop selection and water management strategies (Rodriguez et al., 2014). This study addresses this need by developing a comprehensive APSIM modelling framework that systematically evaluates irrigation strategies and sowing window optimization across multiple crops and production environments, providing quantitative insights for agricultural water management decisions. This is a part of work for precinct level input-output model development in Lower Fitzroy areas of Central Queensland.

2. METHODOLOGY AND RESULTS

The APSIM Next Generation framework (version 2025.5.7753.0) developed by Holzworth et al. (2014) was implemented across five case study regions (Alton Down, Canoona, Gogango, Mornish, South Yaamba) in the Lower Fitzroy region in Central Queensland, representing diverse climatic and soil conditions. Model validation was conducted in the Alton Downs region using observed yield data to ensure simulation accuracy. For example, in the APSIM simulations, sorghum yield at Alton Downs ranged from 5.23 to 8.58 t/ha under irrigation and from 0.75 to 5.78 t/ha under rainfed conditions, with averages of 7.17 t/ha and 4.24 t/ha respectively. Observed yields at Alton Downs ranged from 5.0 to 8.0 t/ha for irrigated sorghum and from 1.0 to 5.5 t/ha for rainfed sorghum, with corresponding averages of 7.0 t/ha and 4.5 t/ha. The framework was configured to simulate both dryland and irrigated scenarios for five major crops: sorghum, wheat, mungbean, chickpea, and soybean, with 100 years of historical climate data to capture long-term variability and enable comprehensive risk assessment.

A fixed amount of fertiliser has been applied at the sowing stage. Different row spacing and sowing density have also been maintained for dryland and irrigated crops. For example, For dryland sorghum, the crop was sown at a row spacing of 1000 mm with a density of 6 plants m^{-2}, applying 160 kg ha^{-1} of urea-N at sowing, while for irrigated sorghum, the row spacing was 750 mm with a density of 12 plants m^{-2}, also receiving 160 kg ha^{-1} of urea-N at sowing. Irrigation management was set up to trigger applications automatically when soil water deficit reached 50% of available storage capacity, representing realistic deficit irrigation practices. In this study, irrigation was triggered when the soil water content declined to 50% of its plant-available water capacity, applied at a maximum rate of 30 mm per day, and stopped once the soil water content reached 95% of plant-available water capacity. Three strategic sowing windows were systematically evaluated: November-January for summer crops (sorghum, soybean) with early (November-December) and late (January) categories, and April-June for winter crops (wheat, mungbean, chickpea). Cultivar-specific parameterisation included early and late sorghum varieties, Suntop wheat, Jade mungbean, Drummond chickpea, and Leichhardt soybean. Water use varied substantially between dryland and irrigated sorghum across the simulations. For example, in the APSIM simulations, dryland sorghum (April) used an average of 1.27 ML/ha of water (rainwater) (ranging from 0.10 to 3.82 ML/ha), while irrigated sorghum used an average of 2.67 ML/ha (ranging from 1.65 to 5.48 ML/ha). Water availability may be a further limitation influencing the choice of crops. The crop price data has been collected from AgMargin (Queensland Government, 2021). In this study, the optimality criteria were defined to identify management options that maximise long-term average yield while maintaining positive and stable gross margins and achieving above-median water use efficiency over the 100-year simulation period. The study will also assess environmental impacts to support a comprehensive risk evaluation.

The 100-year simulation framework revealed substantial economic benefits from irrigation, with gross margin advantages ranging from AUD176-1,450/ha depending on crop and location. Table 1 presents the irrigation benefit ranges and optimal crop rankings across the five study regions. Systematic comparison across all regions identified sorghum as the consistently optimal crop choice under both irrigated and dryland conditions, followed by chickpea, demonstrating robust performance across diverse environments and seasonal variability. In the Lower Fitzroy region, sorghum was identified as the optimal crop for both irrigated and dryland seasons due to its high and stable yields, better water use efficiency, and positive gross margins. The modelling highlighted dramatic regional variation in rainfed viability, from excellent production potential in the Mornish region to sub-viable conditions in the Gogango region (ground truthing is still required), emphasising the critical importance of location-specific crop selection strategies under climate risk.

Table 1 Irrigation benefits and crop performance rankings across study regions

Region	Irrigation Benefit Range (AUD/ha)	Optimal Crop (Irrigated)	Optimal Crop (Dryland)	Rainfed Viability
Alton Down	176-1,115	Sorghum (January)	Sorghum (November)	Good
Canoona	125-839	Sorghum (January)	Sorghum (November)	Excellent
Gogango	443-1,450	Sorghum (January)	Not Recommended*	Poor
Mornish	210-1,052	Sorghum (January)	Sorghum (November)	Excellent
South Yaamba	343-1,038	Sorghum (January)	Sorghum (January)	Poor

3. CONCLUSIONS

This APSIM Next Generation framework provides a robust modelling approach for irrigation decision support systems and demonstrates the model's capability for integrated agronomic-economic analysis across diverse multi-crop production environments. The systematic evaluation across 100 years of climate data offers valuable insights for optimising water use efficiency and crop selection strategies under long-term climatic and economic uncertainty. The framework's identification of consistent crop performance rankings across diverse environments, coupled with quantified irrigation benefits, provides practical guidance for agricultural decision-making. The methodology advances agricultural systems modelling by demonstrating how process-based models can be systematically applied for multi-crop economic assessment, contributing to more informed water management and crop selection strategies in variable production environments.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the APSIM development team for their exceptional technical support and responsive assistance provided through the GitHub platform. Their commitment to fostering a collaborative modelling community and providing timely guidance has been essential to the completion of this work.

REFERENCES

Holzworth, D., Huth, N.I., deVoil, P.G., Zurcher, E.J., Herrmann, N.I., McLean, G., et al. (2014). APSIM – Evolution towards a new generation of agricultural systems simulation. *Environmental Modelling & Software*, 62, 327-350.

Rodriguez, D., Cox, H., deVoil, P. and Power, B. (2014). A participatory whole farm modelling approach to understand impacts and increase preparedness to climate change in Australia. *Agricultural Systems*, 126, 50-61.

Queensland Government (2021). AgMargins. Accessed on https://agmargins.net.au/

