Identifying 'macro' drivers of cropping system performance

Li Luo [a], **Matthew J. Knowling** [a]

[a] *School of Agriculture, Food and Wine, Faculty of Sciences, Engineering and Technology, The University of Adelaide, Australia*
Email: li.luo@adelaide.edu.au

Abstract:

Crop selection and sequence decisions are often made to try to balance productivity, profitability, and sustainability outcomes. While many studies have evaluated how different cropping systems perform across a wide range of metrics, recommendations to growers regarding which systems to adopt that are made based on their findings are highly case-specific and likely not to generalize well (or at least their generalisability is unknown). Understanding is lacking in regard to how broader-scale system attributes (e.g., diversity of crops within system) influence various performance metrics. This study critically assesses whether system attributes can be used to more effectively identify strategies for improved performance, and if so, what attributes and their interactions drive improved performance.

To assess the relationships between cropping system attributes and various performance metrics, we evaluate the system design space systematically by developing and applying a computational framework as follows. Starting with agronomic rules derived from farmer practice (e.g., canola requires a return period of at least one year), we generate 564 feasible systems. For each rotation, we define a series of attributes describing crop diversity, crop/harvest intensity, and sequencing (e.g., whether a cereal follows a legume), by explicit input requirements that categorize crops into functional groups (cereals, legumes, oilseeds, fallow, cover crops, etc.). We also consider an 'innovation' attribute that quantifies the extent to which given system differs from most common grower practice. We then simulate these rotations using APSIM at three case study sites across Southern Grain Region: Manangatang (low rainfall zone, northern Mallee), Roseworthy (medium rainfall zone, mid-North SA), and Westmere (high rainfall zone, South-west Vic). Performance is evaluated with respect to metrics across four key objectives: (1) economic, evaluated through gross margin (GM) and GM at 20th percentile (GM@20%) over simulation periods; (2) productivity, measured by water use efficiency (WUE) and nitrogen use efficiency (NUE); (3) environmental, captured through CO_2-e emissions and nitrogen leaching; and (4) resiliency and reliability, where reliability is defined as the proportion of years in the simulation period in which crop energy remains above a specified threshold, and resiliency is defined as the proportion of years in which crop energy falls below the threshold but recovers above it in the following year.

Preliminary results suggest that some performance metrics are primarily driven by one or two attributes, such as legume proportion for GM and profitability, harvest intensity for NUE and WUE, and fallow proportion for CO_2-e emissions. Other metrics are driven by both direct and interaction effects. For example, cover crop proportion and harvest intensity impact GM@20% through their individual effects and their combined interaction with other attributes.

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