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Towards an AI agronomist: Developing fast and efficient methods for predicting crop growth using machine learning

A. Powell [a], P. Kuhnert [b], D. Pagendam [b] and R. Lawes [c]

[a] *CSIRO Data 61, Perth, Australia*
[b] *CSIRO Data 61, Brisbane, Australia*
[c] *CSIRO Agriculture and Food, Perth, Australia*
Email: andrea.powell@data61.csiro.au

Abstract: Machine learning methods have strong potential to discover interesting features from complex data that can be used to drive prediction and forecasting models for agricultural systems. Growers make many decisions throughout the growing season that, in combination with factors such as weather and soil conditions, alter the outcomes they can attain from that season's work. Decisions such as what crop to plant, when to sow, and fertilization schemes can be driven by the grower's accumulated experience combined with advice from an agronomist. If we want to empower growers to make evidence-based decisions that improve their crop management, we must give them tools that allow them to quickly and easily forecast how their choices change the outcome of their crop. The desire for these types of forecasting tools is evident in the uptake of applications such as GrainCast (Lawes et al. 2022).

Machine learning methods are most suited to problems where large volumes of data are available. In general, agricultural survey data does not generate sufficient information for these methods to be appropriate. In addition, we would need to collect validation data through paddock scale experiments which can be difficult and expensive.

Biophysical agricultural models offer a source of data to use in the development of machine learning forecast tools. In the Australian context, the APSIM model is an extensively validated biophysical model that captures the complex processes underpinning crop growth and development (Holzworth et al. 2014). While APSIM is widely used by the research community, it has not been taken up by industry, in part, because it requires an expert user to calibrate the model for each new location and cropping scenario (Jakku et al. 2019). To enhance uptake, a new architecture needs to be considered that can still capture the cropping dynamics but in a simpler, easily interpretable representation. Further, the computational requirements need to be reduced, particularly if the tool needs to operate in near real time and create rapid what-if scenario analyses. Emulators are an approach for approximating biophysical models like APSIM using an alternative model, in this case a neural network.

Machine learning emulators have the potential to provide a bridge between complex biophysical models and in-situ decision making. By using data obtained from APSIM to train a machine learning biomass prediction model, we can provide tools to empower growers to make informed decisions about their cropping systems. As proof of concept, we used outputs from a series of APSIM simulation runs for a wheat crop in Dalby to develop a feed-forward neural network which predicts the above ground biomass curve from meteorology inputs and a minimal set of management decisions. The inputs to APSIM were designed to capture a variety of possible crop growth trajectories. The neural network output is used to produce a biomass growth curve and uncertainty estimates. The neural network can therefore be used in scenario analysis to quantify the change in the biomass trajectory under different management decisions.

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