Quantifying and reducing uncertainty in biophysical models for agricultural GHG mitigation

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Agriculture is a necessary aspect of modern society in order to provide sufficient food for the populous, but often faces many challenges, such as environmental influences and economic issues. With the interrelated nature between agriculture and climate change, such challenges can be hard to understand, particularly related to greenhouse gas emissions and its effects on both agriculture production and agriculture influencing the climate. In order to better understand this relationship between agriculture and greenhouse gas emissions, agricultural scientists will use biophysical models (such as the **A**gricultural **P**roduction **S**ystems s**IM**ulator, or APSIM for short) to seek ways to mitigate impact. However, such models are imperfect and generally will have uncertainty associated with the impact of model components (such as management practices, soil/water conditions, climate, and crops) and output (such as crop yield and biomass). This project addressed methods for quantifying and reducing uncertainty in these agricultural models.

Over the course of this John Stocker SIEF project, two postdoctoral fellows were involved in developing efficient methods for quantifying uncertainty in agricultural models. Dr. Bryan Stanfill first looked at methods for determining which input variables were significant for mean wheat yield. He focused specifically on developing a general sensitivity analysis method that addressed the sensitivity of average yield to different components of an agricultural simulator. He specifically developed a method that was computationally efficient and yet also simple to implement. This is critical for agricultural modellers in order to better understand the effects of different agricultural scenarios for crop production, with the ability to successfully apply these methods simply and quickly. Dr. Stanfill focused on the APSIM model applied to rural Queensland. APSIM is an Agricultural Production Systems sIMulator (APSIM) recognised internationally by researchers and industry as a highly advanced simulator of agricultural systems. APSIM is the engine behind agricultural decision-support tools such as "Yield Prophet". Further, Dr. Stanfill also worked on developing a method for calibrating an agricultural model to observed yield. This is critical to understanding the error of an agricultural model to real observations, allowing modellers to determine sources of uncertainty in assimilating the simulation to physical observations.

After two years, Dr. Stanfill left CSIRO, and Dr. Dan Gladish continued the project to extend the work. Specifically, Dr. Gladish extended the methods of calibration and sensitivity analysis to multivariate outcomes. This work relates uncertainty associated with observational error in biophysical/agricultural models (such as yield and biomass) with parameter uncertainty (such as management practices and crop parameters), and in particular how uncertainty relates to the interactions in a multivariate system. Dr Gladish pushed the methodology and applicability of the calibration problem further by understanding how spatial and temporal dependencies affect model uncertainty. This is critical as it allows agricultural scientists insight into the effects of different scenarios while accounting for correlation in space and also the dependency through different harvesting years, thereby improving the precision of crop prediction models.

Currently, the methods derived by Dr. Stanfill and Dr. Gladish are being implemented in new projects. The developers of APSIM are currently planning way to integrate sensitivity analysis methods in the agricultural simulator, including those developed by this project. Additionally, CSIRO scientists are embedding the emulator and sensitivity analysis developed from the project into an uncertainty toolbox developed specifically for the Digiscape future science platform with plans for a robust toolbox applied to several applications.

The project resulted in publications by both Dr. Stanfill and Dr. Gladish, as well as opportunities to present the work at several national and international conferences. Dr. Stanfill published in Environmental Modelling and Software and the European Journal of Agronomy as well as developed the R package "apsimr". Dr. Gladish's development during the postdoctoral has provided him the tools and skills to complete the publications listed here with flow-on benefits to his broader work. Additionally, he mentored an undergraduate student, giving both him and the student valuable work experience. In November 2017, Dr Gladish presented a talk titled "Efficient Multivariate Sensitivity Analysis Of Agricultural Simulators" at the International Biometrics Society (Australasian Region) Conference. Both postdoctoral fellows have since successfully obtained research scientist positions: Dr. Stanfill at Pacific Northwest National Laboratory in Richland, Washington, USA; and Dr. Gladish at CSIRO Data61 in Brisbane.