The role of crop modelling in agricultural research

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Introduction

Over the last 30 years, modelling has provided fundamental understandings of interactions between plant genotype, environment and management (GxExM), with important implications for future agricultural research, investment and policies.

Uses of crop modelling

Crop models have long been powerful tools in unravelling physiological mechanisms that determine crop yield in relation to the environment. For example, Kropff et al. (1993) showed that nitrogen management was a key limiting factor for high-yielding rice varieties, using a model that explained yield differences reasonably well in terms of radiation, temperature, leaf N content and variety phenology types.

In the context of a global need to improve productivity, yield gap analysis is critical to identify the most important crop, soil and management factors; to effectively prioritize research and interventions; to evaluate the impact of changing circumstances such as climate change or disease; and to provide an agronomic basis to models assessing food security and land use at different spatial scales (Van Ittersum et al. 2013).

For example, Tesfaye et al. (2015) used CERES-Maize to project that in 2080, maize yields in SSA will decrease significantly in two-thirds of current growing areas. Such understanding can be used to recommend adaptation options to farmers, for example conservation agriculture (Ngwira et al. 2014).

Crop modeling of GxExM interactions can suggest potential breeding candidates or ideotypes. Cairns et al. (2013) showed that heat tolerance was at least as important as drought tolerance when breeding for climate change in Sub-Saharan Africa. In another approach, Kholová et al. (2014) virtually introgressed different drought tolerance traits in sorghum, showing how trait and environment interactions condition breeding success. Computer simulation is a powerful tool to help select optimal plant breeding strategies (for an overview, see Li et al. 2012).

Broader Implications

Crop modelling is of great utility in examining hypothetical or projected scenarios, helping build the case for investment in agricultural research and rational policymaking, especially in combination with economic analysis. This is one example of the multidisciplinary collaborations that crop modelling can ultimately facilitate.

Nelson et al. (2009) calculate that a further US $7 billion per year is needed to offset the impacts of climate change on food security and child health. Chung et al. (2014) showed how a repeat of the 2012 USA heatwave would impact developing world food security in 2050. In another common application, Negassa et al. (2013) analyzed how rainfed wheat production could increase food self-sufficiency in Sub-Saharan Africa.

Needs

More advanced models are needed to better understand and more precisely represent plant physiology and reactions to abiotic and biotic stresses. Broadly used varieties representing all crop mega environments need to be calibrated and shared with the global community, as well as the definition of virtual varieties to evaluate the value of certain traits to mitigate impact of climate change or biotic stresses.

A robust calculation of yield potential requires data-intensive field trials to calibrate the crop model for each field/year. For yield gap analysis, around 10 to 20 years of daily weather data is needed, along with 10 years of current yield or at least 5 where data is poor (Grassini et al. 2015), preferably sub-national. The lack of reliable yield data, along access to timely climate, soil and other relevant data is a major obstacle.

Given the clear benefits of enhanced use of crop modeling and integration in other research and policy activities, much more investment in modeling approaches and data sets is needed. Such investment would be soon repaid in terms of targeted research for development, increased breeding efficiency, and rational pre-emptive policies.

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