SHORT NON-REFEREED PAPER

SUGARCANE MODEL INTERCOMPARISON: STRUCTURAL DIFFERENCES AND UNCERTAINTIES

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Abstract

Sugarcane is one of the world's main carbohydrates sources. The authors analysed the APSIM-Sugar (AS) and DSSAT/CANEGRO (DC) models to determine their structural differences, and how these differences affect their predictions of crop growth and production in Brazil. Both models initially under-estimated leaf area index (LAI) and hence interception of solar radiation, although both accurately predicted crop growth and production after calibration. The AS model under-predicted yield at the hotter sites. Average predictions from both models of stalk yield and LAI resulted in closer predictions of the data than from the models individually.

Keywords: modelling, simulation, model calibration, uncertainty

Introduction

Mechanistic crop models are only approximations of reality; therefore, uncertainty is inherent in their model parameters, model structure, and input data, which leads to uncertainty in their predictions (Wallach *et al*., 2012). One potential approach for reducing uncertainty that was recently proposed by the Agricultural Modeling Improvement and Intercomparison Project (AgMIP) (Rosenzweig *et al*., 2012) is to apply multiple models and use the mean or median of the ensemble as the predictors (Asseng *et al*., 2013). A more traditional approach is to ensure that models are thoroughly tested in the region in which they are being applied.

This paper analyses the APSIM-Sugar (AS) (Keating *et al*., 1999; Thorburn *et al*., 2005) and DSSAT/CANEGRO (DC) (Singels *et al*., 2008) models to determine their structural differences, and how these differences affect their predictions of crop growth and production. Following the analysis of their structural differences, the authors (i) assessed the relative skill of the two models in simulating sugarcane production in Brazil; and (ii) verified whether the average of the predictions from the two models gave more accurate predictions of sugarcane production in Brazil than predictions from each model separately.

Methods

Crop models were parameterised using field data from cultivar RB867515, which was planted over nearly 27% (or 1.7 Mha) of the sugarcane area in Brazil in 2012 at seven locations throughout the country (Table 1).

Table 1. Sources of experimental data used, and soil and climate characteristics of each site.

Site	Location	Planting and harvest dates	Climate*	Water management regime	Soil Type	Root depth (cm)
1	União/PI, 4°51'S, 42°52'W 68 m asml	09/29/2007 and 06/16/2008	27°C 1500 mm Aw	Irrigated and rainfed	Plintossolo (Oxisol)**	125
2	Coruripe/AL 10°07'S, 36°10'W 16 m asml	08/11/2007 and 11/15/2008	24.4°C 1400 mm As	Partial irrigation	Argissolo Amarelo Fragipânico (Fragidult)	40
3	Coruripe/AL 10°07'S, 36°10'W 16 m asml	08/16/2005 and 09/15/2006	21.6°C 1400 mm As	Rainfed	Argissolo Amarelo Fragipânico (Fragidult)	40
4	Aparecida do Taboado/MS 20º05'S, 51°18'W 335 m asml	07/01/2006 and 09/08/2007	23.5°C 1560 mm Aw	Rainfed	Latossolo Vermelho-Amarelo (Typic Hapludox)**	400
5	Colina/SP 20°25'S, 48°19'W 590 m asml	02/10/2004 and 12/01/2005	22.8°C 1363 mm Cwa	Rainfed	Latossolo Vermelho-Amarelo (Typic Hapludox)**	400
6	Olimpia/SP 20°26'S, 48°32'W 500 m asml	02/10/2004 and 12/01/2005	23.3°C 1349 mm Cwa	Rainfed	Latossolo Vermelho-Amarelo (Typic Hapludox)**	400
7	Piracicaba/SP 22°41'S, 47°38'W 540 m asml	10/16/2012 and 06/15/2013	22.4ºC 1280 mm Cwa	Irrigated	Argissolo Vermelho (Typic Hapludults)**	400

*Respectively: mean annual temperature, total annual rainfall, Koeppen classification.
**Soil classification by Brazilian Soil Classification System (Embrapa, 1999) and their nearest US Soil Taxonomy equivalent (in brackets).

The NCo376 cultivar coefficients available in both models were developed against robust experimental field data and assumed to be a reasonable starting point to verify the structural differences between the models. For both models, the crop parameters such as leaf size, partitioning and tiller and leaf size relationship, were set based on the observed data; the phenology, canopy structure, and partitioning-related parameters were set primarily based on observed data from Sites 2, 3 and 7, where these variables were measured. The parameter values were selected to minimise the RMSE between the predicted and measured data for the stalk fresh mass (SFM) and LAI

Results and Discussion

Simulations with both the DC and AS models using the standard parameters for the NCo376 cultivar were close to the experimental data for the RB867515 cultivar at Sites 2, 3 and 6 for SFM; however, the LAI predictions at Sites 2 and 3 were not close to the experimental data. For site 1, the DC model had better predictions of SFM than the AS model. Because of the different temperatures across the different sites (Table 1) and the effects of temperature in both of the models in terms of phenology, tillering and leaf area algorithms, the different responses between the models was a result of the air temperature. An important difference between the models was in their methods of integrating thermal time. The AS model was limited in its ability to accumulate degree-days in hot places because its optimum and maximum temperatures used a 'triangular' approach (i.e. a single maximum value), whereas phenology in the DC model has a trapezoidal function. União (Site 1) was the warmest site among those evaluated (Table 1), and it was where the largest difference (even for the irrigated treatment) in SFM between the two models was found.

After calibrations were performed well using the experimental data from the seven experiments throughout Brazil, both of the crop models proved capable of simulating crop phenology, total above-ground biomass, leaf area, and stalk fresh mass (r=0.94 for As and 0.95 for DC) in daily time steps for sugarcane grown in Brazil (Figure 1). The AS model does not represent tillering directly, and the stalk number was set to 13 stalks/m^2 and doubled the tillering factor for RB867515 because this resulted in the most accurate SFM and LAI predictions (Figure 1). In DC, the RUE value for the RB867515 cultivar was changed to 11.1 g/MJ to improve predictions (Marin *et al*., 2012). This revealed that both models under-estimated the canopy dimension for intercepting solar radiation, and the need for targeted experiments to understand the physiology of the RB867515 cultivar and how that is best represented in sugarcane models.

The average results from both models (hereafter referred to as the ‘mean’) produced better estimates of the SFM and LAI than the individual model estimations throughout the sites and seasons (Figure 1). This result was particularly true for the LAI predictions and consistent with the hypothesis of Asseng *et al*. (2013) that improved performance of the mean or median values from multi-model simulations compared with single-model simulations.

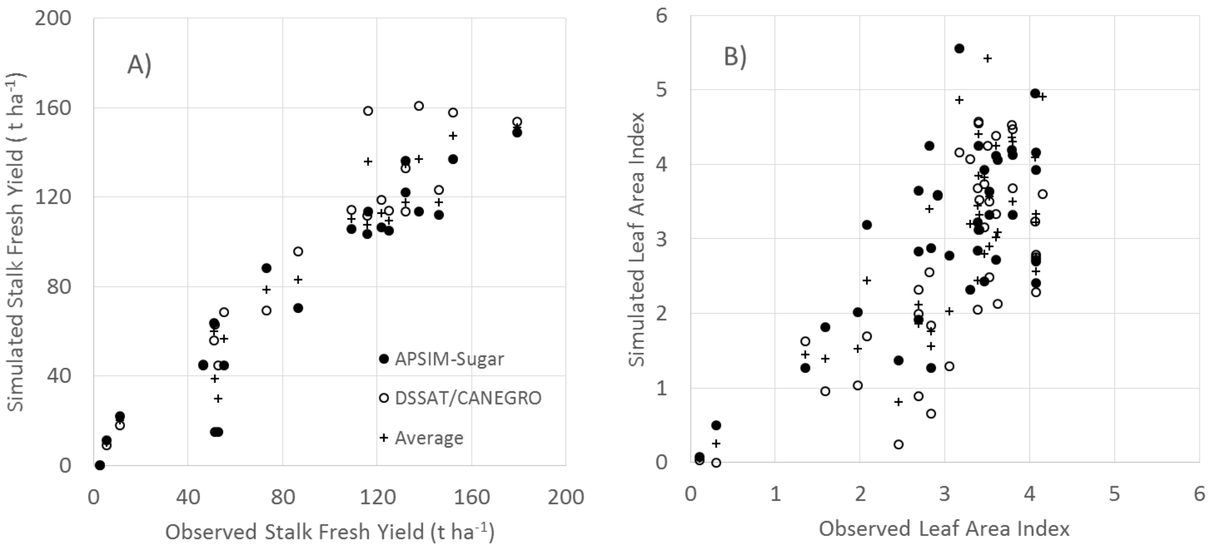

Figure 1. Simulated and observed stalk fresh mass (A) and LAI (B) for eight experiments around Brazil for DSSAT/CANEGRO and APSIM and multi-model means.

Conclusions

Both crop models were capable of simulating crop phenology, leaf area index, and stalk fresh mass of the Brazilian cultivar RB867515 with similar accuracy to that achieved in previous studies developing sugarcane cultivar parameters. However, both models under-estimated the canopy dimension for intercepting solar radiation, and there is a need for targeted experiments to understand the physiology of the RB867515 cultivar and how that is best represented in sugarcane models. Such field studies might show that the structure of one of the models is currently better suited for representing Brazilian varieties and conditions. The authors suggest this under-prediction may be caused by the thermal time integration algorithm used in the model, something that could be changed and tested in future studies. Thus, applying the two models (in their current form) is likely to give more accurate predictions than focusing on one model alone. This conclusion may change if either model is further developed for Brazilian conditions and/or varieties.

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