ガウス過程エミュレータを用いた APSIM-Sugarcane モデルの品種パラメータの大域的最適化

Global Optimization of Cultivar Parameters in Agricultural Production Systems Simulator (APSIM) Sugarcane Model using Gaussian-Process Emulation

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1. Introduction

Process-based crop models are advantageous for identification of management strategies to cope with both temporal and spatial variability of sugarcane yield. However, when using a process-based crop model to simulate cultivar differences under given environments and management conditions, underlaying cultivar trait parameters need to be parameterized to obtain accurate model predictions. But It is difficult to measure a wide range of parameters practically due to high resource consumption and short commercial life of the cultivars. Therefore, current study was focused on conducting optimization of cultivar trait parameters to overcome the above constrain. Because optimization of cultivar trait parameters is useful when statistically approximation of difficult to measured cultivar trait parameters. But process-based crop models are often computationally expensive, carrying out the required number of simulations may not be feasible, and optimization may be extremely time consuming. Therefore, current study has incorporated Gaussian-Process (GP) emulation [1] for optimization to reduce the computational burden of the process. More importantly, up to date there is no research in which the GP emulator is used to optimize parameters and the accuracy of the optimization method is examined.

2. Materials and methods

Total above ground biomass (Biomass) and cane dry weight (CDW) at every 30 days from 90 to 390 days after planting of three sugarcane cultivars (KK3, LK92-11 and 02-2-058) of Thailand were optimized under Ir and Rf conditions. 50 emulators were generated using Gaussian process to approximate the simulation runs of widely used processed based crop model: APSIM-Sugarcane [2], and performances of the emulators were investigated.

Then generated emulators were used in optimization instead of the original simulator (APSIM-Sugarcane).Differential evolution (DE) [3] algorithm was implemented as the optimization algorithm. Parameter ensembles which provide lowest root mean squared error (RMSE) between observed and simulated values were selected as the best estimated parameters. The best estimated parameters were again simulated in APSIM-Sugarcane and validated. During the validation three parameter ensembles were selected to parametrize the three cultivars using APSIM-Sugarcane. R^2, normalized root mean squared error (NRMSE) % and Willmott's agreement index (AI) were used to evaluate the results.

3. Results and discussion

Emulator performance evaluation: All the emulators indicated better performances (R^2:0.90 - 0.99, CV_{RMSSE}: 0.74 and 1.01 and σ^2: 0.06 and 1.64) by indicating that emulators can usefully approximate the original simulator (APSIM-Sugarcane).

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Parameter optimization: All the parameter ensembles which were obtained during the optimization indicated better performances. Because optimized paraments were able to estimate corresponding observed values with R^2 ranged between 0.95 to 1, NRMSE% ranged between 1 to 11.32 and AI values ranged between 0.97 to 1.

Validation:

Three parameter ensembles were selected (**Table 1**) form the optimized parameter ensembles to parameterize APSIM-Sugarcane for cultivar KK3, LK92-11 and 02-2-058. Those parameters indicated higher performances when estimating sugarcane yield under each environmental and management conditions in KK. Because R^2 were ranged between 0.93 – 0.98, NRMSE% were ranged between 5 – 22, AI were ranged between 0.87 – 0.99.

More importantly, present study implemented GP process-based emulation to overcome the computation burden of the conventional optimization methods. Based on the results we can suggest that GP emulation can be efficiently implemented for parameterization of computationally expensive simulators.

4. Conclusions

Our study was focused on the use of GP-based emulators to optimize cultivar trait parameters in APSIM-Sugarcane model. The emulators we obtained indicated satisfactory results when approximating the simulator and can be used for optimization effectively. More importantly we estimated the best parameter ensembles for parameterization of APSIM-Sugarcane for cultivar KK3, LK92-11 and 02-2-058 in Thailand.

Table 1: A selection of estimated best parameters from the Optimization.

Parameter Name*	Unit	Cultivar		
		KK3	**LK92-11**	**02-2-058**
leaf_size_no 1	mm^2	1566	1792	1790
leaf_size_no 14		62686	56809	20252
leaf_size_no 20		47681	68364	61664
cane_fraction	g/g	0.65	0.66	0.68
sucrose_fraction_stalk	g/g	0.7	0.6	0.5
stress_factor_stalk	n/a	0.9	0.9	0.9
sucrose_delay	g/m^2	582	563	137
min_sstem_sucrose	g/m^2	432	1097	1420
min_sstem_sucrose_redn	g/m^2	19	0.26	2
tt_emerg_to_begcane	°C day	1537	1874	1397
tt_begcane_to_flowering	°C day	5404	5748	6523
tt_flowering_to_crop_end	°C day	2138	2153	1794
green_leaf_no	No.	14	15	14
tillerf_leaf_size_no 1	mm^2/mm^2	5	4	3
tillerf_leaf_size_no 4		3	4	3
tillerf_leaf_size_no 10		1	1	1
tillerf_leaf_size_no 16		4	5	3
tillerf_leaf_size_no 26		3	3	5
transp_eff_cf_1	kg kPa/kg	0.008	0.014	0.010
transp_eff_cf_2		0.007	0.014	0.011
transp_eff_cf_3		0.013	0.013	0.012
transp_eff_cf_4		0.014	0.009	0.014
transp_eff_cf_5		0.014	0.013	0.013
transp_eff_cf_6		0.011	0.014	0.010
Rue_3	g/MJ	2.50	2.24	2.49
Rue_4		2.46	2.34	2.48
Rue_5		1.14	2.40	1.84

*More details of APSIM-Sugarcane parameters could be found in Sexton *et al.* [4]

Key References

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