Incorporating spatial and temporal effects into the sensitivity analysis of an agricultural systems simulator

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Introduction

The **A**gricultural **P**roduction **S**ystem s**IM**ulator (APSIM) is a widely used simulator of agricultural systems. It can be used to predict a diverse range of variables including yield, biomass, soil runoff and green house gas emissions. The simulator is highly calibrated and several techniques exist to find appropriate parameter ranges for a given crop and farming system. Less understood is the uncertainty associated with APSIM predictions and how parameter uncertainty is propagated through the simulator. In this poster we illustrate how a multivariate global sensitivity analysis (MGSA) technique can be used to understand uncertainty in APSIM estimates incorporating spatial and temporal effects. We demonstrate our method in three states across Australia over a two year period.

APSIM

- APSIM is a deterministic and dynamic simulator for agricultural systems
- Five predicted biomass time series' are plotted for New South Wales (NSW), Queensland (QLD) and Western Australia (WA) from January 1990 - December 1991 in Figure 2

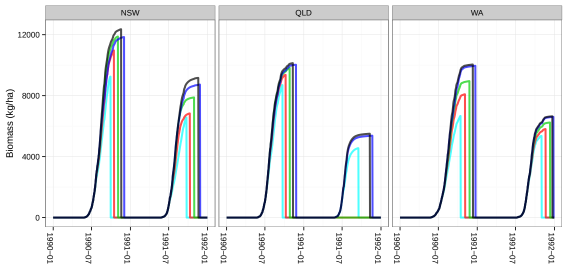

Figure 2: Biomass predictions from APSIM with different parameter values.

- 1991 was a drier year then 1990 so reduced biomass values are expected, see Figure 1 for rainfall amounts in the areas of interest
- The significant drop in QLD from 1990 to 1991 is of particular interest

MGSA

- We use MGSA to incorporate spatial and temporal effects into a sensitivity analysis (see Campbell et al. 2006)
- $y_i(s,t)$ represents the i^{th} $i = 1, \dots, N$ APSIM biomass estimate for state $s = 1, \dots, S$ on day $t = 1, \dots, T$

$$\boldsymbol{Y}_{N\times T}(s) = \begin{bmatrix} \boldsymbol{y}_1(s) \\ \boldsymbol{y}_2(s) \\ \vdots \\ \boldsymbol{y}_N(s) \end{bmatrix} = \begin{bmatrix} y_1(s,1) & y_1(s,2) & \cdots & y_1(s,T) \\ y_2(s,1) & y_2(s,2) & \cdots & y_2(s,T) \\ \vdots & \vdots & \ddots & \vdots \\ y_N(s,1) & y_N(s,2) & \cdots & y_N(s,T) \end{bmatrix}$$

- Combine matrices across states to form an $N \times ST$ matrix

$$\boldsymbol{Y}_{N\times ST} = \begin{bmatrix} \boldsymbol{Y}(1) & \boldsymbol{Y}(2) & \cdots & \boldsymbol{Y}(S) \end{bmatrix}$$

- MGSA uses a set of bases functions $\phi_1, \dots, \phi_K$, $K \leq ST$ to expand the the centered $\boldsymbol{Y}$ matrix

$$\boldsymbol{Y} - \overline{\boldsymbol{Y}} \approx \boldsymbol{H}\boldsymbol{\Phi}^\top \text{ or } y_i(s,t) - \bar{y}(s,t) \approx \sum_{k=1}^{K} h_{ik}\phi_k(s,t)$$

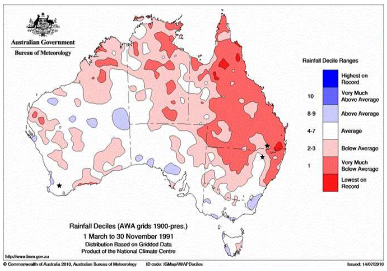

Figure 1: Rain deciles for Australia from March - November 1991

Results

- In our case study $N = 1620$, $T = 730$, $S = 3$
- The first four principal components account for 78.6% of the variability in the biomass matrix $\boldsymbol{Y}$
- PC interpretations: an up-down shift, a left-right shift, a kurtosis (peakedness) component, the El Niño effect
- Sensitivity indices for each of the cultivar parameters deemed significant by the Morris Method (results omitted) are computed using FAST

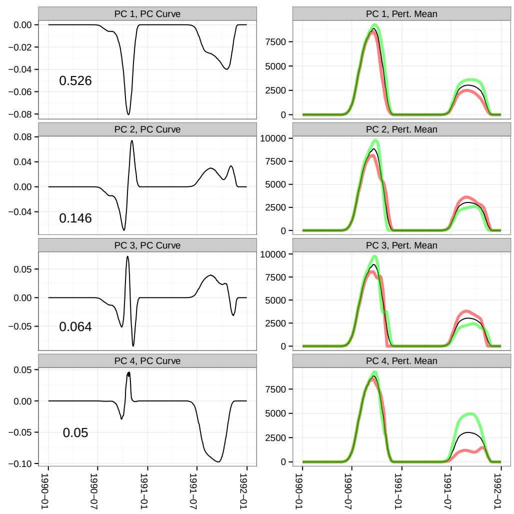

Figure 3: First four principal components with mean curve plus/minus each PC for QLD.

	PC1	PC2	PC3	PC4	Mean
Parameter	0.526	0.146	0.064	0.050	
grains_per_gram_stem	0.000	0.005	0.011	0.032	0.001
potential_grain_filling_rate	0.004	0.078	0.226	0.658	0.010
potential_grain_growth_rate	0.000	0.005	0.003	0.013	0.000
max_grain_size	0.000	0.001	0.009	0.012	0.000
tt_start_grain_fill	0.221	0.081	0.028	0.052	0.170
tt_floral_initiation	0.143	0.028	0.074	0.032	0.120
tt_flowering	0.007	0.023	0.058	0.002	0.006
tt_end_of_juvenile	0.232	0.406	0.334	0.006	0.267
vern_sens	0.227	0.256	0.074	0.148	0.258
photop_sens	0.165	0.117	0.183	0.046	0.167

Table 1: Sensitivity indices computed using FAST for the cultivar parameters for each of the first four PCs and for the average biomass over states and time.

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REFERENCES

Campbell, McKay, and Williams (2006). Sensitivity analysis when model outputs are functions. *Reliability Engineering & System Safety*, 91(10): 1468-1472.

FOR FURTHER INFORMATION

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