Identifying key process parameters in a sink-source interaction model for energy crops

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Background & Objectives

The 'design' of novel crops and selection of ideotypes is relevant for bioenergy crops as these have not yet been studied extensively. Miscanthus in its range of varieties differs in growth pattern and composition; it is still not clear which parameters have the greatest impact on yield formation and whether production is more source or sink-limited. Using a process-based growth model we rank morpho-and physiological parameters according to their "Morris Sensitivity". We present here results for the most popular C4-grass *Miscanthus X giganteus* and discuss the opportunities for its improvement.

Model and Sensitivity Analysis

BEGraS Model & Calibration

The BEGraS (Bio Energy Grass Species) model balances sink (tillers, plant extension) with resource (photosynthate) availability and includes a dynamic rhizome/reserve compartment (Fig. 1). Growth and carbon partitioning into above-/belowground plant compartments were calibrated and evaluated using the detailed measurements collected in a Miscanthus field trial established at Rothamsted in 1993.

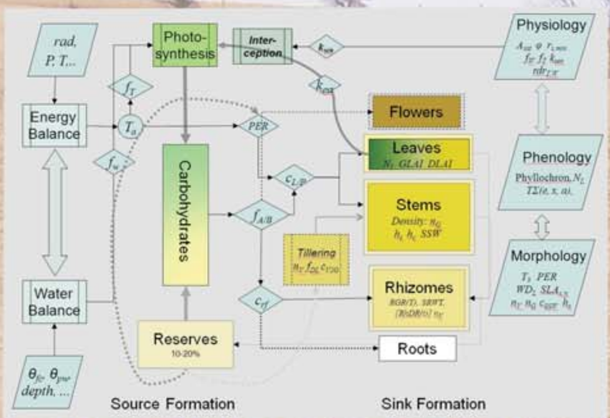


Figure 1: Diagram of the Bio Energy Grass Species model, BEGraS

Morris Sensitivity Analysis (MSA)

The MSA changes one-parameter-at-a-time using randomized sampling matrices of the parameter space, defined by trajectories and levels; normally distributed parameters are defined by mean and standard deviation (CV 10%).

Sensitivity estimates are mean (μ*; strength) and standard deviation (σ; spread) of modelled yield change due to parameter changes. μ* indicates the overall influence (total effect), σ, indicates non-linear or second-order effects.

Elementary effects of principal parameter groups (phenology, morphology, physiology) and initial conditions were tested for 4[th]-year potential and water-limited *Miscanthus* productivity. Key parameters tested are given in the table below.

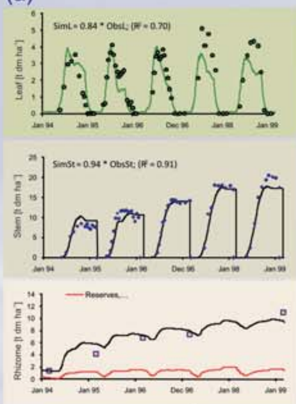
Table: Selected parameters included in the sensitivity analysis

Parameters		Sink, Source
Initial conditions (planting material)		
DM_{rhz}	Dry matter of rhizome,	So
Phenology (transformation of vegetative to generative tiller)		
c_{v2g}	Conversion coefficient	Si
$Topt_{v2g}$	Optimum temperature	Si
f_{DL}	Daylength factor	Si
Morphology		
f_{sht}, $f_{A/B}$	Fraction of shoot, above/belowground	Si
T_b	Aerial base temperature	Si
$c_{L/P}$	Coefficient of leaf to plant extension ratio	Si, So
WD_L	Leaf width	Si, So
N_L	Number of simultaneously extending leaves	Si
$SLA_{x,n}$	max/min specific leaf area	Si, So
k_{ext}	Extinction coefficient	So
h_x	Maximum stem height	Si
h_C	Crown height	So
c_{SSW}	Increase rate coefficient of specific stem weight	Si
Physiology (photosynthesis, stress, senescence		
φ	Quantum efficiency of photosynthesis	So
A_{sat}	Photosynthesis rate at light saturation	So
E_x	Efficiency of conversion	So
f_T, $T_{b,n,x}(A)$	Parameters of temperature function for photosynthesis	So
$r_{s,min}$	Stomatal resistance	So
f_w	Water stress response function	So
$rdr_{W,T}$	Relative death rates (water stress, temperature)	So

Results and discussion

Growth and carbon partitioning into above-/belowground compartments was calibrated using the 5-year establishment phase (Fig. 2a; r^2 = 0.93, RMSE = 1.6 t ha^{-1}) and evaluated for a 12-year period (Fig. 2b; r^2 = 0.82, MD = 0.5 t ha^{-1}, RMSE = 1.2 t ha^{-1}). The last two years of yield discrepancy were excluded from the evaluation.

(a)



(b)

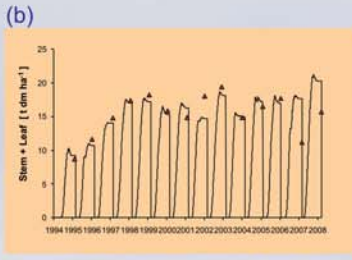


Figure 2: Observed (symbols) and simulated (_) dry matter partitioning of *Miscanthus X giganteus* (a) during calibration (1994-98) and (b) evaluation of yield (14 years).

The MSA shows the relative importance of different parameter domains, allowing association with source/sink availability. For potential growth (Fig. 3a) the strongest response of the model comes from the quantum efficiency, stronger than A_{sat} or its temperature function parameters. Morphological parameters rank next highest and relate to either light interception (k_{ext}, WD_L) or aboveground sink size ($c_{L/P}$, c_{SSW}, f_{sht}). Applied to water-limited growth (Fig. 3b) the MSA highlights the importance of the parameters related to water stress, directly or indirectly through the response function, f_w, the stomatal resistance, $r_{s,min}$, or relative death rates, $rdr_{W,T}$.

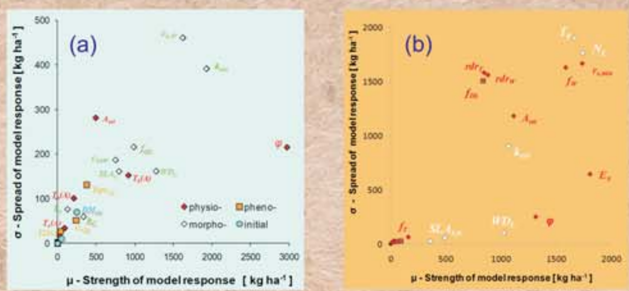


Figure 3: Ranking of parameters acc to strength of response, μ [kg/ha], applied to (a) potential and (b) water-limited production for different model domains

Conclusions & future work

- The relatively simple model for the carbon partitioning describes the growth pattern and yield very well.
- Few parameters have a major direct effect on yield; their ranking may change with the introduction of water-limitation.
- Morphological and physiological parameters have a strong effect on yield, which reflects sink - source interaction.
- Ongoing work extends the model to varieties whose parameters vary by more than 10%.

Acknowledgements: Work was funded by the UK Research Councils under the interdisciplinary initiative "Towards a Sustainable Energy Economy" (TSEC-Biosys; http://www.tsec-biosys.ac.uk/); Rothamsted Research is an institute of the BBSRC