Mathematical modeling of Miscathus x giganteus

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Introduction

•Dedicated biomass energy crops will be needed to meet the goals of the billion ton report.
•Miscanthus x giganteus is one of the most productive crops at higher latitudes (40 degrees and above).
•Cellulosic ethanol is one of the most exciting and challenging technologies needed to supply enough fuel to meet the nations' needs and Miscanthus x giganteus can play an important role in feedstock supply.

Objective

▪ To parameterize a mathematical model for simulating Miscanthus x giganteus.
▪To validate model simulations with independent data sets.

Materials and Methods

The model used was WIMOVAC (Windows Intuitive Model of Vegetation response to Atmospheric and Climate Change).
http://www.life.uiuc.edu/plantbio/wimovac/

Briefly, WIMOVAC uses mechanistic sub-models for phtotosynthesis, transpiration, light interception and canopy microclimate, to predict carbon uptake, water balance and microclimate. Growth is predicted by partitioning net carbon uptake among the organs of the plant. Partitioning is governed by a table which accounts for the thermal periods devoted to phenological stages typical of grasses (i.e. Emergence, Juvenile, Induction, Post-induction, Flowering and post-Flowering). Developmental stage is predicted by thermal time, i.e. the accumulated temperature above a threshold during the growing season.

C4 photosynthesis was modeled after the Collatz et al. (1992) model and the default parameters were used. Validation of Miscanthus canopy photosynthesis was conducted using data from Beale, Bint and Long (1996) shown in Fig. 2.

Weather data, dry biomass production and leaf area index was obtained from several field trials conducted in Europe (Foti 1996; Clifton Brown et al. 2000; Danalatos, 1996, 1998; Schwarz, 1994; Jorgensen, 1996; van der Werf, 1992).

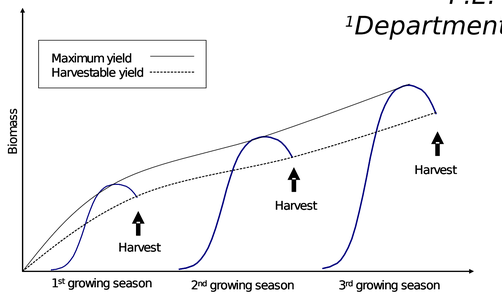

Fig. 1 Schematic representation of M. x giganteus growth for the first three growing seasons.

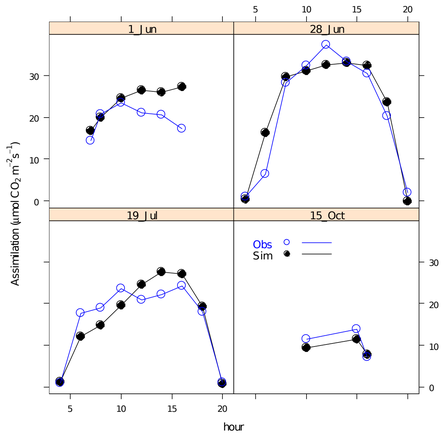

Fig. 2 Validation of carbon dioxide assimilation for four diurnal measurements in England. The model is based on Collatz et al. (1992) and the data is from Beale, Bint and Long (1996).

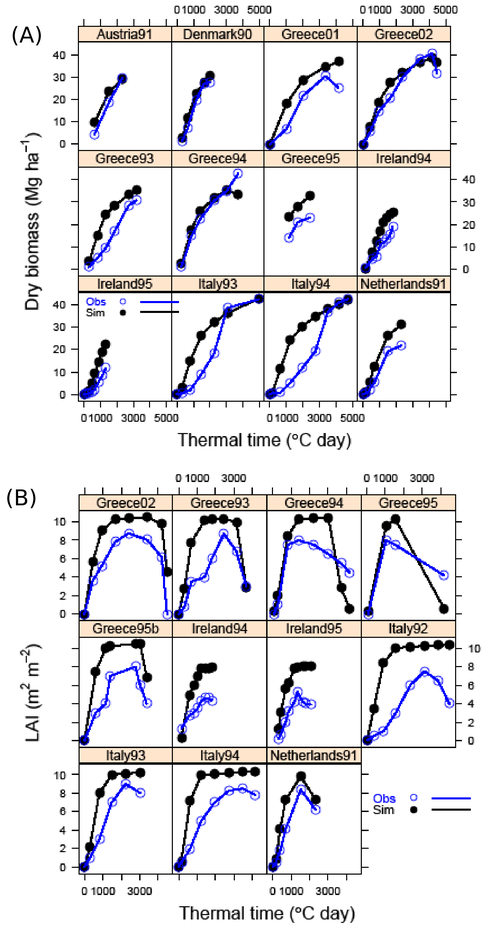

Fig. 3 Validation Of WIMOVAC with independent data from experiments conducted in research stations. Each panel is a country/year combination. (A) Observed and simulated dry biomass (Mg ha-1). Prediction is very good (R2 = 0.92) for all countries. Phenology in Italy was not predicted as well as other countries possibly due to water stress effects on delayed development at this location. (B) Observed and simulated leaf area index (LAI). The model tends to overpredict as it does not account for agronomic limitations (e.g. water stress, poor nutrient supply, weed control or less than optimal management).

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▪WIMOVAC successfully modeled Miscanthus x giganteus dry biomass and leaf area index (LAI) in several agricultural experiments conducted at research stations. The model tends to predict potential dry biomass and LAI as it does not account for limitations such as severe water stress, poor fertility, or less than optimal management). Although the model does not account for severe water stress it does model the effect of low relative humidity on stomatal conductance and thus the reduction in dry biomass production in dryer regions.

▪Several improvements to the model are being currently develop. Parameter estimation methods and global optimization are being developed. Additionally, the model will be used to predict dry biomass production in Illinois and the Midwest at the regional scale.

References

•S. Foti, S. L. Cosentino, C. Patane, P. Guarnaccia, Growth and yield of c4 species for biomass production in the mediterranean environment, in: Biomass for Energy and the Environment, Proceedings of the 9th European Bioenergy Conference, Pergamon/ Elsevier, Copenhagen, Denmark, 1996, pp. 616–621.
•N. G. Danalatos, S. V. Archontoulis, I. Mitsios, Potential growth and biomass productivity of Miscanthus Ogiganteus as affected by plant density and n-fertilization in central greece, Biomass and Bioenergy (2007) 145–152..
• U. Jorgensen, Miscanthus yields in denmark, in: Biomass for Energy and the Environment, Proceedings of the 9th European Bioenergy Conference, Pergamon/Elsevier, Copenhagen, Denmark, 1996, pp. 48–53.
•H. M. G. van der Werf, W. J. M. Meijer, E. W. J. M. Mathijssen, A. Darwinkel,Potential dry matter production of miscanthus sinensis in the netherlands, Industrial Crops and Products 1 (2-4) (1992) 203–210.
•J. C. Clifton-Brown, B. Neilson, I. Lewandowski, M. B. Jones, The modelled productivity of miscanthus x giganteus (greef et deu) in ireland, Industrial Crops and Products 12 (2) (2000) 97–109.
•H. Schwarz, P. Liebhard, K. Ehrendorfer, P. Ruckenbauer, The effect of fertilizationon yield and quality of miscanthus sinensis 'giganteus', Industrial Crops and Products 2 (3) (1994) 153–159.
•N. Danalatos, C. Dalianis, S. Kyristis, Influence of fertilisation and irrigation on the growth and biomass productivity of miscanthus sinensis x giganteus under greek conditions,
in: Sustainable Agriculture for Food Energy and Industry, Vol. 1, James & James (Science Publishers), Braunschweig, Germany, 1998, pp. 319–323.
•C. V. Beale, D. A. Bint, S. P. Long, Leaf photosynthesis in the c4-grass miscanthus x giganteus, growing in the cool temperate climate of southern england, J. Exp. Bot. 47 (2) (1996) 267–273.
• C. V. Beale, S. P. Long, Seasonal dynamics of nutrient accumulation and partitioning
in the perennial c4-grasses miscanthus x giganteus and spartina cynosuroides, Biomass and Bioenergy 12 (6) (1997) 419–428.

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