

## SUPPORTING INFORMATION

Title:

Modeling Miscanthus in SWAT to Simulate its Water Quality Effects as a Bioenergy Crop

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## 1. BACKGROUND INFORMATION ON MODELING MISCANTHUS GROWTH

There are several studies that have successfully developed and validated mathematical models of miscanthus growth to predict its productivity under various climate and soil conditions. Central to many of these studies are (1) suppositions that the growth of a plant is a function of the amount of solar radiation intercepted during its growing season and the efficiency by which that radiation is converted to biomass. In turn, the plant's radiation interception efficiency depends on its leaf area which varies with temperature and soil water availability.

A simple mathematical expression of these principles, as given by (2), is as follows.

$$Y = Se_i e_c \eta / E = Se_i \eta R \quad (1)$$

where  $Y$  is the amount of dry biomass at harvest,  $S$  is the total photosynthetically active incident solar radiation received throughout the growing season,  $e_i$  is the light interception efficiency of the plant,  $e_c$  is the radiation-to-biomass conversion efficiency of the plant,  $\eta$  is the fraction of total biomass that is harvestable and  $E$  is the energy content of the biomass. The  $e_c$  and  $E$  terms can be combined to give the overall radiation use efficiency (RUE) of the plant,  $R$ .

(2) were able to fit equation (1) to miscanthus field data using linear regression by setting  $e_i$  as a constant (which the authors approximated from field measurements) and  $R$  as the gradient of the best fit line. In another study, (3) were also able to fit equation (1) to miscanthus field data. Unlike (2) though, (3) did not assume  $e_i$  to be constant throughout the growing season, but allowed it to vary day-to-day as a function of leaf area index (LAI) and the radiation extinction coefficient. The latter is a constant while the former was assumed to increase linearly with growing degree days (GDD) with a pre-defined maximum limit. Using the fitted equation and a geographic information system (GIS), (3) mapped out the potential yields of miscanthus for England and Wales. By setting the potential yields as an upper limit and adjusting them according to the ratio of actual evapotranspiration to potential evapotranspiration, the authors were also able to estimate the yields that can be expected when water is limited.

(4) and (5) carried out similar studies, also based on equation (1) and applying GIS methods, for miscanthus grown in Ireland and in the European Union respectively. The authors have named the model they have developed as MISCANMOD, which has since been applied by

others such as (6) and (7) to assess the yield potential and economic feasibility of adopting miscanthus on a large scale. A more recent miscanthus model is MISCANFOR (8), which is adapted from MISCANMOD. Compared to MISCANMOD, MISCANFOR has improved and new procedures for estimating light interception, temperature and water stress impacts, photo-period sensitivity, drought and frost kill predictions, thermal time and nutrient repartition to the rhizome.

However, as noted by (9), a disadvantage of equation (1) and consequently, the models based on it, is its empirical nature and over-reliance on  $R$ . The common approach is to assume  $R$  constant and to estimate its value by fitting simulated data to field data. The results obtainable using this approach are thus case specific and may not be suitable for extrapolation to other cases where conditions are very different. A more robust approach would be to model  $R$  in a more mechanistic manner. To achieve this, (9) parameterized the Windows Intuitive Model of Vegetation Response to Atmospheric and Climate Change (WIMOVAC) (10) for miscanthus.

WIMOVAC is a generic crop growth model. In WIMOVAC the main driver of biomass growth is the calculation of leaf-level photosynthesis based on the coupled  $\text{CO}_2$  uptake-stomatal conductance model of (11). Canopy-level photosynthesis is aggregated by dynamically calculating the extinction of light in the profile of the canopy, the distribution of light into sunlit and shaded leaves (12) and by summing up leaf-level assimilation by the contribution of leaf area by the entire canopy. The assimilated carbon is then partitioned according to a thermal time calendar and fixed carbon allocation coefficients into the main plant components (i.e. leaf, stem, rhizome and root). The leaf area index is calculated using a specific leaf area ( $\text{m}^2$  leaf per kg of leaf) multiplied by the accumulated leaf biomass.

By applying C4 photosynthesis parameters reported in the literature and dry biomass partitioning coefficients estimated from field data from a single site, (9) were able to reproduce yield and leaf area data for a number of sites across Europe.

While the abovementioned models have been shown to perform well within each model's own assumptions and limits, they are all standalone models that are not linked to a hydrologic model. On the other hand, the SWAT crop growth model is embedded within a larger hydrologic model, enabling the modeling of the surrounding water quality and quantity in response to crop choices. This crop growth model originated from the Erosion Productivity Impact Calculator

(EPIC) model by (13) and is based on equation (1) with additional algorithms for estimating the effects of limited water and nutrients and non-optimal temperature on crop growth.

## 2. ADDITIONAL FIGURES

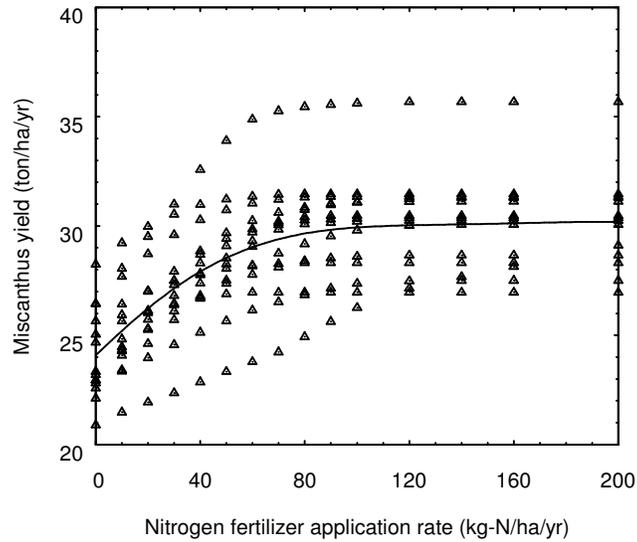


Figure S1: Points estimated by SWAT ( $\Delta$ ) representing most likely miscanthus yield for each of the years 1995-2008, and the corresponding best-fit line (—) for various nitrogen fertilization rates

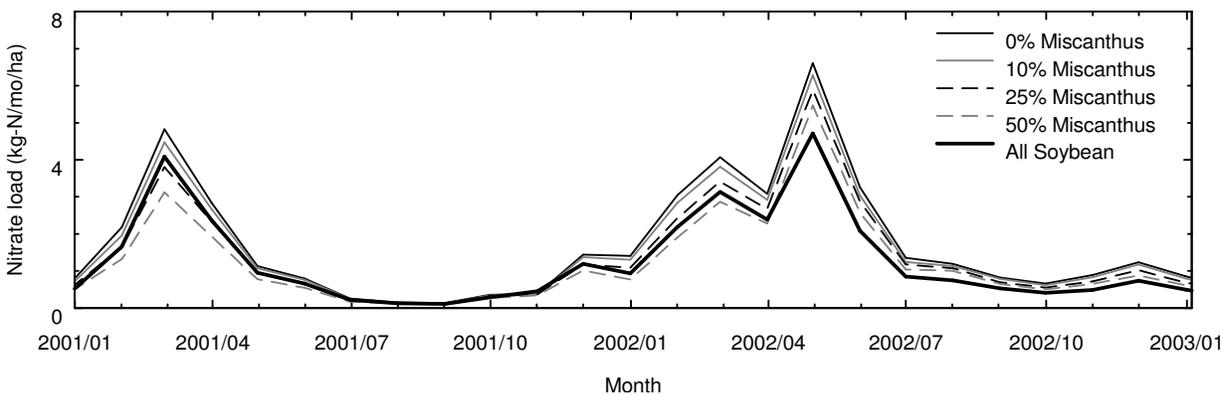


Figure S2: Expected monthly nitrate load at the watershed outlet under various scenarios of percent land use change to miscanthus (the remainder in corn and soybean in 1:1 rotation) and an all soybean scenario for years 2001 and 2002, assuming a nitrogen fertilizer application rate of 90 kg-N/ha for miscanthus

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