INTEGRATION OF UNMANNED AERIAL SYSTEM (UAS) DATA AND PROCESS BASED SIMULATION MODELS TO FORECAST CROP GROWTH AND YIELD

J. Landivar
A. Maeda
M. Maeda
Texas A&M AgriLife Research
Weslaco, TX
J. Jung
L. Huynh
Texas A&M University
Corpus Christi, TX

Abstract

The main objective of this this study is to evaluate the feasibility and benefits of using plant growth data collected with an Unmanned Aerial System (UAS) as input for simulation models. We selected the cotton simulation model GOSSYM for the study. Our specific objectives are to (1) develop soils, weather and agronomic input databases to calibrate and evaluate the cotton simulation model GOSSYM, (2) develop an user interface to link GOSSYM with a precision agriculture database (grid) and (3) use GOSSYM to forecast growth and yield of cotton crops. GOSSYM is a cotton simulation model which simulates the main processes affecting growth and yield in the "soil-plant-atmosphere system". GOSSYM is a materials balance model which provides daily simulation based on soil's physical and chemical properties, cultural practices and weather input information (Baker et al., 1983). More recently, Landivar et al., 2010 described the physiological basis of GOSSYM. The model was linked to a rule-based expert system denominated COMAX (Lemmon, 1986) to determine optimum water and nitrogen applications under a giving set of agronomic management practices and various weather scenarios. In the Mid-1980s, the GOSSYM/COMAX system was used extensively across the US cotton belt as a management aid to cotton producers in optimizing water and nitrogen inputs. The system successfully demonstrated the potential benefit of using such tools for the management of cotton crops (Whisler et. al., 1986). However, the intensive data required for running the model, the need for extensive technical support and the inadequate computer technology of the time discouraged its use and expansion.

In this study, a soil database was collected at Corpus Christi, Texas, during the 2016 growing season. The data included residual N content, percent organic matter and water content profile for a Victoria Clay soil series. Weather data was obtained from a weather station near the field. Time course of plant weight accumulation (stem, leaves and bolls) and number of flower buds, green and open boll were collected with four replications for the cultivar PHY 499 WRF. These data sets and cultural practices were used as input for the calibration of GOSSYM for the simulation of this cultivar. Once calibrated, GOSSYM satisfactorily simulated dry weight accumulation and partitioning to stem, leaves and reproductive structures, including plant height and main-stem node development. The model also reasonably simulated the time course of number flower-bud (squares), number of green and open boll, and final lint yield. Results are shown in Figure 1.

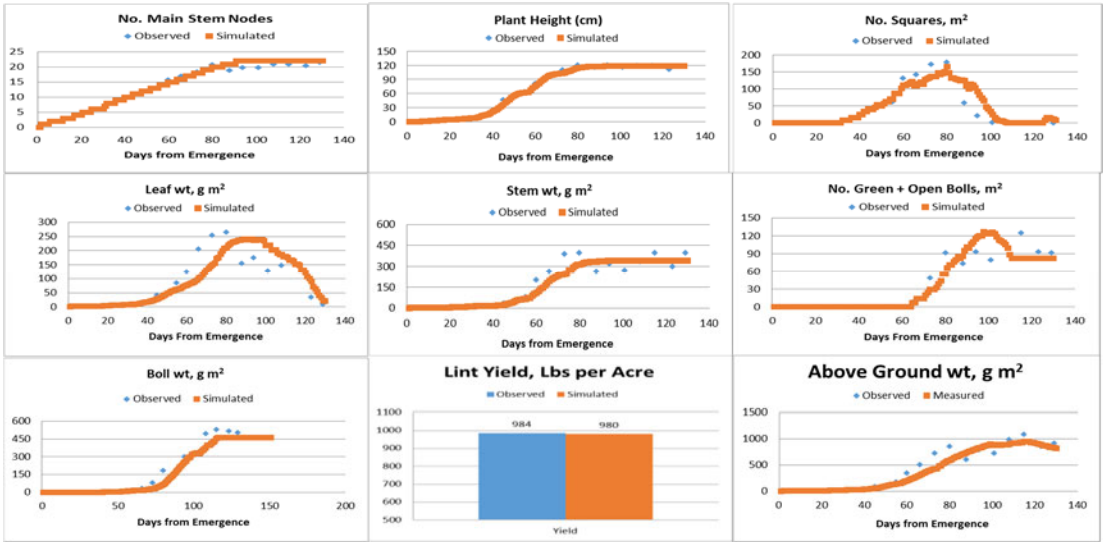

Figure 1. Comparison of field measured parameters and simulated parameters after the calibration of GOSSYM for the simulation of cultivar PHY 499 WRF at the Texas A&M AgriLife Research and Extension Center at Corpus Christi, Texas, 2016.

We modified the code of GOSSYM to use temporal % canopy cover measured with an Unmanned Aerial System (Maeda et. al., 2017) as input, replacing the % canopy cover values estimated by the model. GOSSYM uses % canopy cover to estimate photosynthesis per unit of area and to partition water losses into soil evaporation and plant transpiration, making this variable a key parameter for the simulation of plant stresses, growth and yield. Temporal canopy cover data collected by the UAS for experimental cultivars 5421 (high canopy cover), CA 4003 (low canopy cover), and PHY 499 WRF (mid- canopy cover) were used to evaluate the results of the simulation in response to these various patterns of canopy development, under dry-land production conditions (Figure 2, Top). Under the water stress conditions simulated for the study (Figure 2, Middle), the model predicted that high canopy cover (cultivar 5421) would result in reduced lint yield as compared to a mid-size canopy produced by PHY 499 WRF, because of higher water use. However, under a low canopy cover pattern such as CA 4003, lint yield would be limited by reduced canopy sunlight interception (Figure 2, Bottom). The model suggest that optimum canopy size for a giving environment is the result of an active balance between water use efficiency and canopy sunlight capture for photosynthesis.

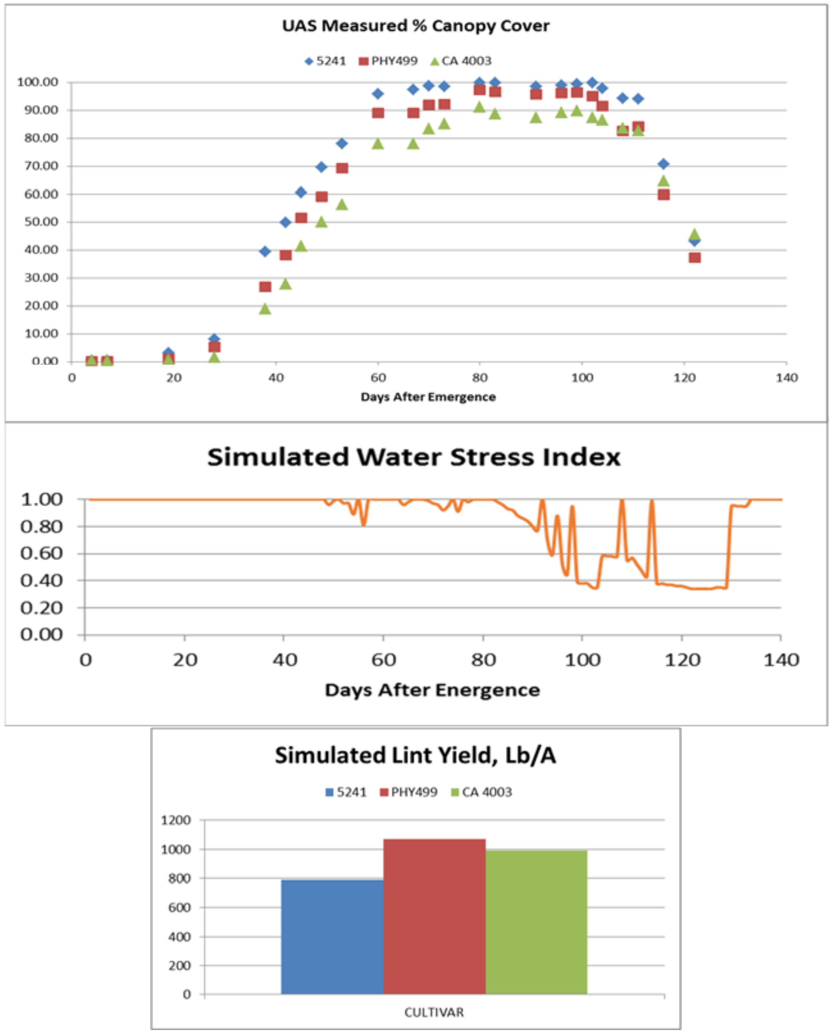

Figure 2. Top: % canopy cover measured with an UAS-platform for two experimental genotypes (5421 and CA 4003) and cultivar PHY 499 WRF. Middle: GOSSYM Simulate temporal water stress index and Bottom: Simulated yields resulting from the patters of canopy cover for the 5421, PHY 499 WRF and CA 4003.

This preliminary study showed that simulation models like GOSSYM provide stimulating “food for thought” about the interaction between canopy characteristics and water inputs. We plan to use physiological models such as GOSSYM as analytical tools to enhance our understanding of how plant parameters measured with our UAS-platform influence the performance of a genotype under various environmental scenarios.

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