International Congress on Environmental Modelling and Software

9th International Congress on Environmental Modelling and Software - Ft. Collins, Colorado, USA - June 2018

Jun 25th, 9:00 AM - 10:20 AM

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iEMSs International Congress on Environmental Modelling and Software

9th International Congress on Environmental Modelling and Software
Fort Collins, Colorado, USA, Mazdak Arabi, Olaf David, Jack Carlson, Daniel P. Ames (Eds.)
https://scholarsarchive.byu.edu/iemssconference/2018/

Unified Plant Growth Model (UPGM): 2. Component development and integration with agroecosystem models

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Abstract: The goals of the Unified Plant Growth Model (UPGM) project are: 1) integrating into one platform the enhancements from the multiple EPIC-based plant growth models, 2) further enhance the integrated UPGM model, and 3) develop a component that can be more easily linked into other agroecosystem models such as the Wind Erosion Prediction System (WEPS) and Agricultural Ecosystem Services Model (AgES). Objectives 1 and 2 are presented in part one, and this presentation discusses the development of a prototype for Objective 3. The overall design of the integrated UPGM component is presented, focusing on the need to adequately represent the plant "phases" and growth "stages" inherent within the original models with a data-driven representation. The modules developed are being built following object-oriented constructs. This is to allow the UPGM component to be more modular for facilitating easier integration into other models and allowing for future migration of the code to other languages. Discussion of the actual integration process of the integrated UPGM component into WEPS will be provided. A definition and graphical depiction of phases and stages of a generic crop is presented with example corresponding physical processes. The general coding structure is also diagrammed. The incorporation of UPGM into WEPS and AgES is expected to provide more accurate plant growth simulations and thereby better predict wind erosion and hydrology. Development of the standalone UPGM component prototype shows promise for incorporation into other agroecosystem models, and provides greater opportunity for scientists to improve or add specific algorithms in their areas of interest.

***Keywords**:* plant growth model; phenology; seedling emergence; water management; wind erosion

1 INTRODUCTION

Since the development of the Environmental Policy Integrated Climate (EPIC) model (Williams, et al, 1983 and Williams, 1990) in 1985, the EPIC-based plant growth code (Williams, et al , 1989) has been incorporated and modified into many agro-ecosystem models. The goals of the Unified Plant Growth Model (UPGM) (McMaster, et al, 2014) project are: 1) integrating into one platform the enhancements from the multiple EPIC-based plant growth models, 2) further enhance the integrated UPGM model, and 3) develop a component that can be more easily linked into other agroecosystem models such as the Wind Erosion Prediction System (WEPS) (Hagen, 1991; Wagner, 1996; 2013) and Agricultural Ecosystem Services Model (AgES). We discuss Objective 3 here; Objectives 1 and 2 were covered in Part 1.

The Wind Erosion Prediction System (WEPS) model was originally chosen as the base platform for UPGM development for many reasons, but primarily because it was the most extensively modified of the EPIC-based plant growth code (Retta and Armbrust, 1995). The initial step was to construct a rudimentary standalone UPGM component, created in Fortran 90/95, which combined the UPGM phenology, seedling emergence, and plant height algorithms from the Phenology Modular Modeling System (PhenologyMMS) (McMaster, et al 2013) into the WEPS plant growth submodel. These routines were added and tested for unstressed conditions. This UPGM component was also incorporated into the Java-based AgES model and has been tested under a range of environments. A number of issues were identified including: 1) much better linkage between the PhenologyMMS and WEPS algorithms (e.g., improving the partitioning among plant fractions) was needed, and 2) a redesign of the UPGM component was needed for easier incorporation into other agro-ecosystem models.

In UPGM, plant growth "stages" are considered to be discrete sequential time intervals of plant growth, within which plant growth “phases" are occurring. The time interval for each stage is dependent upon the external conditions affecting the growth of the plant during that stage, such as specific climatic effects, including temperature and water stress. Each plant stage can initiate, continue or end one or more physical plant processes being simulated.

Plant growth stages are represented as linked lists, e.g. one discrete stage can only follow the termination or end of the previous stage. Thus, the sequence and duration of each stage, beginning with planting (seeding) and continuing through maturity represents the entire life cycle of the plant.

A plant growth “phase” is considered to be a somewhat arbitrary collection of one or more specific plant growth processes, where the dominate process occurring is typically the plant growth phase label. Multiple growth phases can occur simultaneously and overlap other plant phase periods.

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