Examining the Influence of Shallow Groundwater on Net Primary Productivity and Evapotranspiration in Managed Ecosystems

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Introduction

WATER BALANCE

- Evapotranspiration
- Precipitation
- Runoff
- Infiltration

GROUNDWATER

ENERGY BALANCE

- Sensible Heat Flux
- Latent Heat Flux
- Incoming Radiation
- Ground Heat Flux
Introduction

- Global scale observational studies showed that spring has advanced about a rate of 2.3 days per decade (Parmesan and Yohe, 2003).

- However, phenology of agricultural species are changing less than those in the wild (Menzel et al., 2006). Mainly because of
  - Farmers decisions
  - Developments in biotechnology and equipment
  - Irrigation or existence of shallow groundwater
Modeling the Impacts of GW on Plants

**Land Surface Models**
- simulate water and energy fluxes among soil-vegetation-atmosphere systems in a process-based way
- lack a detailed simulation of soil water movement in the unsaturated zone, particularly when groundwater is present
- only a few models are available to simulate agroecosystems

**Variably Saturated Soil Water Flux Models**
- simulate water movement in the unsaturated zone with high accuracy
- often lack a detailed plant physiology component
Objectives

- To develop a dynamic modeling approach that is capable of simulating interactions of groundwater and plant/crop system in a fully coupled, physically-based fashion

- How do net primary productivity, evapotranspiration and leaf level micro-scale environmental conditions respond to varying water table depths?

- What is the influence of groundwater-induced soil temperature changes on plant phenology?
Incorporation of Hydrus-1D into Agro-IBIS

LAND SURFACE MODULE

- LAI
- PAR, g_s, c_r, A_n
- T_airr, T_leafr, q_airr, c_s
- T_soil, \( \theta, \theta_f \)

ATMOSPHERE
- prescribed climate forcing
- radiation, precipitation, temperature, wind speed, humidity

HYDRUS-1D soil physics
- energy balance
- water balance
- soil water movement

plant physiology
- photosynthesis
- leaf respiration
- LAI & stomatal C.

SOLUTE TRANSPORT MODULE

BELOWGROUND CARBON & NITROGEN CYCLING MODULE

NATURAL VEGETATION & CROP PHENOLOGY MODULE

VEGETATION DYNAMICS MODULE
Model Evaluation

Data obtained from 3 replicated maize plots at Arlington, Wisconsin

- Nash Sutcliffe = 0.84
- $R^2 = 0.93$

- Nash Sutcliffe = 0.67
- $R^2 = 0.69$
Model Sensitivity Experiments

ET relative to deep GW (mm)

Transpiration (mm)

Evaporation (mm)
Groundwater subsidy: The additional water available for transpiration resulting from shallow groundwater.

Groundwater Subsidy

Groundwater Subsidy Precipitation

Growing Season Precipitation (mm)

Groundwater Subsidy (mm)

Change in NPP (%)

Lowry & Loheide, 2010
**Current understanding of GW-Plant relationships**

- **Water table is too shallow** = Anoxic conditions

- **Water table depth is just right** = GW helps plant escape water stress during dry summer

- **Water table is too deep** = No impact on plants

Feddes et al., 1978
No oxygen stress experiments
• Cooler early season soil temperatures delays leaf emergence

• The delay impacts both annual carbon uptake and transpiration
Groundwater could play a critical role in plant phenology, which might be necessary to take it into account in agricultural management decisions in a changing climate.
Questions

http://wsc.limnology.wisc.edu/