Use of a Computer Model to Simulate Soil Moisture Content in Irrigated Fields

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Outline

✓ Introduction
✓ Objectives
✓ Materials and Methods
✓ Results
✓ Conclusions
✓ Acknowledgement
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Introduction

• Why use model?

✓ To implement an efficient water management strategy in irrigated fields, soil moisture status must be carefully monitored throughout the growing season.

✓ However, obtaining information about soil moisture can be expensive, time-consuming and labor-intensive

✓ Models, if validated, can be used to simulate the fluctuations in soil moisture under variable field conditions

https://www.foodinsight.org/conserving-water-home-farm-agriculture-sustainability-footprint
Objectives

✓ To measure soil moisture dynamics at four soil depths in irrigated fields located in central Oklahoma, using a previously tested soil moisture sensor.

✓ To evaluate the performance of HYDRUS model by comparing the simulated soil water content with sensor readings in the same fields and depths.
Materials and Methods

- **Study Area**
  - Fort Cobb Reservoir Experimental Watershed, Caddo county, Central Oklahoma
  - 5 irrigated fields
  - 3 crops: peanut (PT), Soybean (SB), and Cotton (CN)
  - Irrigation system: Center Pivot
  - Climate: Semi-arid with annual rainfall of 752 mm (1997-2016).
  - June to October 2018 (Precipitation = 520 mm)
Materials and Methods

• Step 1. Field Measurements
  ✓ Hourly based soil moisture data were collected at 10, 30, 51, and 71 cm depths using Acclima TDR 315 sensors (tested previously).
  ✓ Soil samples for textural analysis: 0-10, 10-20, 20-30, 30-41, 41-51, and 51-71 cm
  ✓ Rainfall and irrigation amounts were measured by rain gauges.

• Step 2. Reference Evapotranspiration (ET₀) Calculation
  ✓ FAO-56 Penman-Monteith (PM) ET₀ equation (R. G. Allen et al., 1998; Suleiman & Hoogenboom, 2009; Walter et al., 2000)
  ✓ Hourly ET₀ was calculated by REF-ET software (R. Allen, 2000)
Materials and Methods

• Step 3. Estimating crop evapotranspiration (ETc)
  ✓ FAO-56 single crop coefficient (Kc) approach was used to estimate ETc based on ET₀ by applying crop-specific Kc values adjusted based on local climatic condition.

\[
ET_c = K_c \times ET_0
\]

• Step 4. Partitioning ETc to Evaporation (Ep) and Transpiration (Tp)

\[
E_p = ET_c \times e^{-k.LAI}
\]

\[
T_p = ET_c - E_p
\]

✓ LAI = leaf area index; K = radiation extinction coefficient
✓ Values of these variables were obtained for peanut from Singh (2004), for soybean from Setiyono et al. (2008), and for cotton from Aggarwal et al. (2017).
Materials and Methods

- Step 5. Hydrus-1D Simulation for Root Water Uptake (RWU)
  
  ✓ Hydrus-1D v4.0 was developed by Šimůnek et al. (2008).
  
  ✓ Numerically solves Richards’ equation

- Assign number of materials & depth of the soil profile
- Input number of time-variable boundary records
Materials and Methods

- Other inputs to HYDRUS model
  - Single porosity models: Van Genuchten (1980)’s closed form model
  - Water flow boundary condition: Atmospheric BC with surface runoff for upper BC and free drainage for lower BC
  - Root water uptake model: Used Feddes (1982) parameters
  - Root distribution from Fan, McConkey, Wang, and Janzen (2016)
Materials and Methods

• Statistical Indicators for Model Performance

- Root mean square error (RMSE)
- Mean bias error (MBE)
- Nash–Sutcliffe model efficiency (NSE)
- Coefficient of determination ($R^2$)
- Correlation coefficient ($r$)

Statistical Indicators
# Results: PT

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>RMSE</th>
<th>MBE</th>
<th>$R^2$</th>
<th>$r$</th>
<th>NSE</th>
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<tr>
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<tr>
<td>71</td>
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<td>-0.07</td>
<td>0.53</td>
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Results: SB-1

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Results: SB-2

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Results: CN-1

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Results: CN-2

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<th>MBE</th>
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<th>NSE</th>
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</thead>
<tbody>
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<td>0.02</td>
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<td>-1.24</td>
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Conclusions

✓ The study compared simulated water content ($\Theta_v$) with sensor readings at high temporal resolution.

✓ The statistical indicators showed the performance of the model at top soil layer was reasonably good.

✓ The simulations from deeper soil layers did not produce satisfactory results except one field.

✓ Some differences between simulated and measured may be due to high level of heterogeneity in agricultural fields that can not be captured in input data, and thus cannot be blames on poor model performance

✓ HYDRUS can be considered as a useful tool for estimating top soil layer $\Theta_v$. 
Acknowledgement

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Thank You