Simulating Nitrogen and Water Dynamics in a Rotational Production System

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INTRODUCTION

Motivation

- Section 502(14) of the US Clean Water Act defines nitrate nitrogen (NO_3-N) as a nonpoint source pollutant.

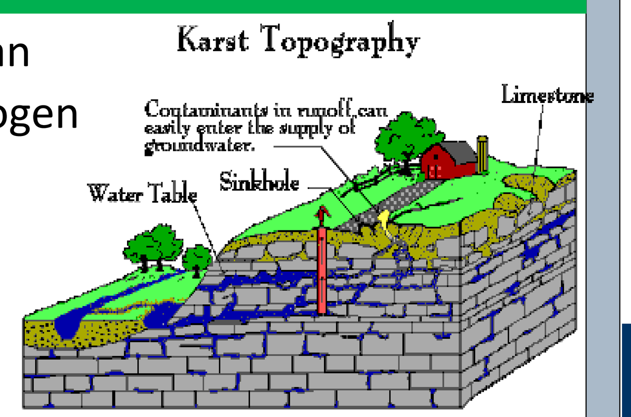

Fig 1: Unconfined and hydraulically connected karst topography. Source: Hallberg (1984)

- NO_3-N leaching is more pronounced in porous sandy soils on a karst topography as of Suwannee River Basin (SRB).

- Intensive agriculture practices intensifies NO_3-N contamination.

Fig 2: Wastewater discharged into Suwannee river [Credit WJCT News].

- More than 93 % (14 out of 15) of the springs in SRB have NO_3-N concentrations greater than the threshold of 0.35 mg/L (FDEP, 2020).

What is being done ?

- Florida Department Environment Protection (FDEP) adopts Basin Management Action Plan (BMAP) to meet Total Maximum Daily Load (TMDL).

- Florida Department of Agriculture and Consumer Services (FDACS) gets involved in developing and adopting Agriculture Best Management Practices (BMPs) via
  - Nutrient Management
  - Irrigation management
  - Buffers, setbacks and swales

Table 1: Statewide agricultural BMPs in Florida

Agriculture Acres Enrolled	4, 608, 704 (61 %)
Agriculture Irrigated acres enrolled	1, 528, 481 (82 %)

- Additionally, FDACS administers
  - Water quality policy and planning
  - BMP research and demonstration
  - Mobile Irrigation lab
  - Technical assistance

How Rotational Production qualify as BMP ?

- Use of soil moisture sensors to manage irrigation

- 4R principles of nutrient management

- demonstration to growers about farm-scale BMP

- Rotation of agronomic crops with legumes, Bahia grass and cattle grazing

Fig 3: A rotational production system of maize and peanut currently being evaluated at NFREC.

OBJECTIVES

- Assess the performance of DSSAT to simulate nitrogen and water dynamics on a peanut-maize rotational production system.

- Simulate water dynamics using HYDRUS 1D during corn growing season.

MATERIALS and METHODS

Experimental Site and Design

- Study Domain: Suwannee River Basin

- Site: Suwannee Valley Agricultural Extension Center, Live Oak, FL

- Study years: 2019-2022

- Soil type: Fine sand

- Climate: Sub-tropical Humid

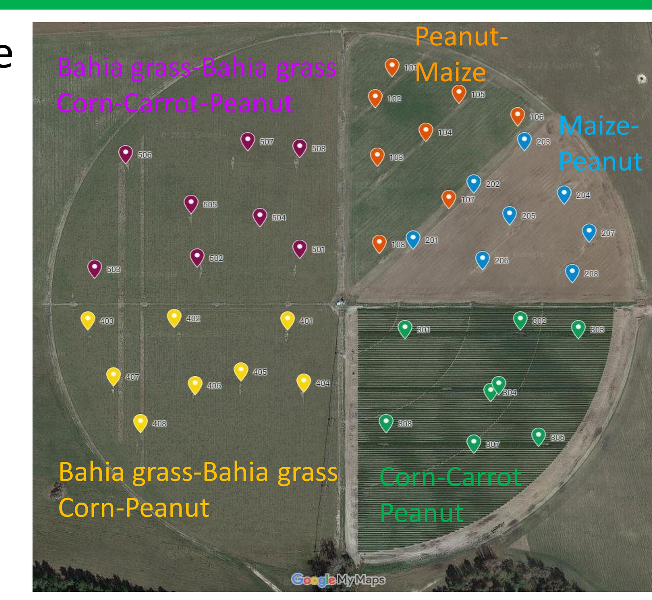

Fig 4: Aerial photograph overlooks the 40-acre center pivot irrigated field [The text in the figure represents the crop involved in the rotation and the pointers represents the 40-drain gauge lysimeters installed]. Treatments were set based on the standard grower practice around the SRB.

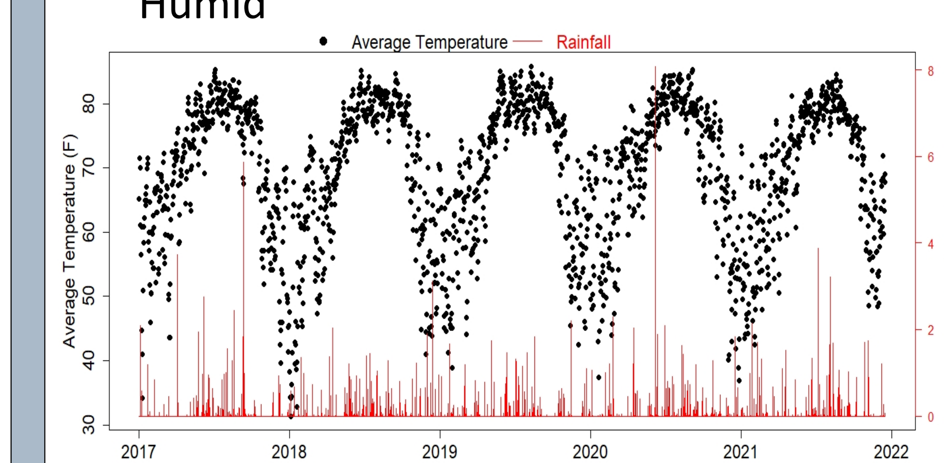

Fig 5: Daily rainfall (inch) and average temperature (Fahrenheit) for Live Oak, FL for the period of 01 September 2017 through 10 November 2021 [Average rainfall: 51 inches (2017-2021)].

Data Collection

- Water samples

- Soil samples

- Plant tissue

- Crop management data

- Yield and yield Components

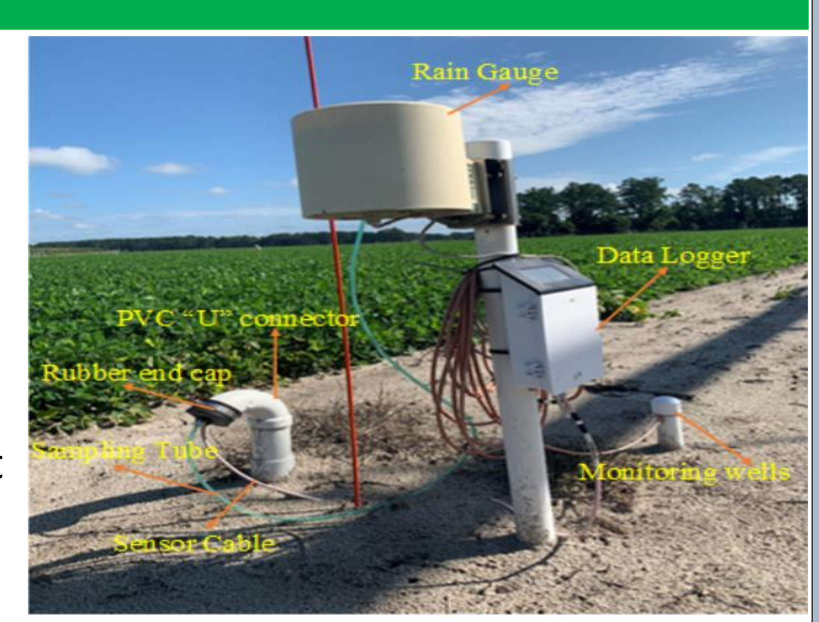

Fig 6: Drain Gauge Lysimeter installed on a peanut field at NFREC Suwanee valley, Live Oak FL [Drain Gauge helps in long term monitoring of vertical soil water and chemical flux].

Simulation Models

- Facilitates long-term study after successful model calibration, validation and Evaluation.

- Allows to test the effectiveness of BMPs without having to deal with rigorous and long-term field trials on different soil and climatic conditions.

DSSAT

- Simulation models for 42 different crops.

- CERES-Maize and CROPGRO models for maize and peanut, respectively.

- Ritchie water balance (tipping bucket) for hydrological process.

$$\frac{d\theta}{dt} = -\alpha\,(\Theta - FC)$$

Θ = volumetric water content
t = time
FC = field capacity
α = drainage coefficient

HYDRUS-1D

- Solute transport: Advective-Dispersion equation

- Water flow: Richard's equation

$$\frac{d\theta}{dt} = \frac{d}{dz}\left[k(\Theta)\left(\frac{dh}{dz} + 1\right)\right]$$

k = hydraulic conductivity
z = elevation head
h = pressure head

RESULTS and DISCUSSION

Soil NO_3-N

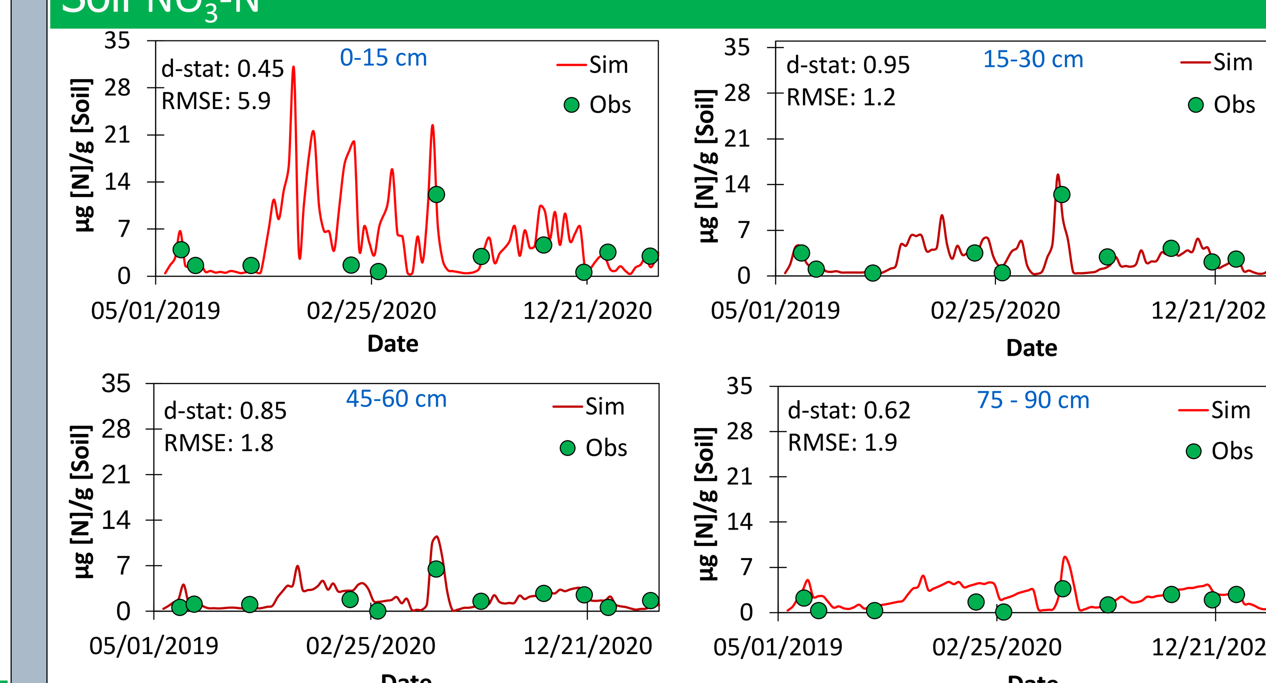

Fig 7: Observed (Obs) vs Simulated ([Sim] DSSAT) soil NO_3-N (µg [N]/g [soil]) on a peanut-maize rotational production during 2019-2021 growing season.

Cumulative NO_3-N leached

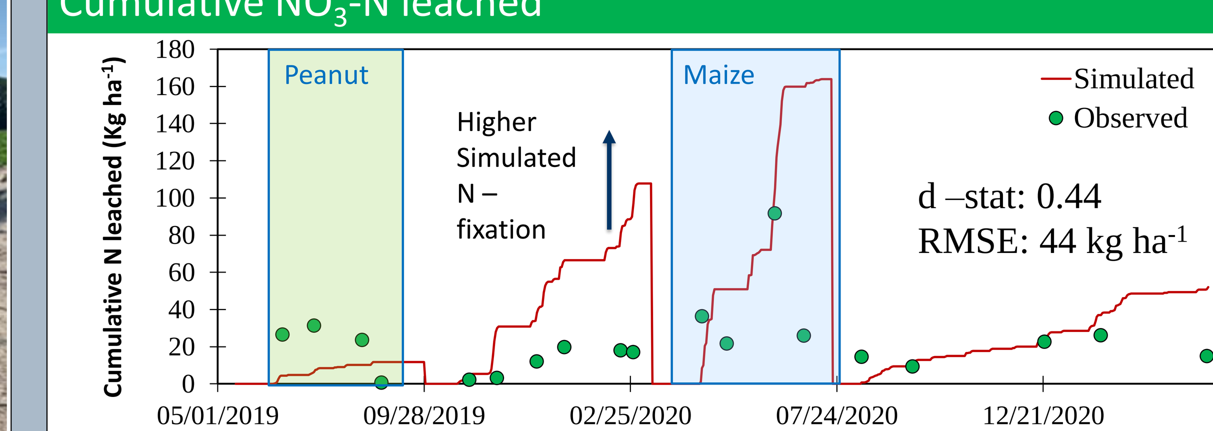

Fig 8: Observed vs Simulated (DSSAT) cumulative N leached (kg ha^{-1}) on a peanut-maize rotational production during 2019-2021 growing season.

Nitrogen Dynamics

Table 2: Nitrogen dynamics (kg ha^{-1}) on a peanut-maize rotational production during 2019-2021 growing season [Obs: Observed; Sim: Simulated].

Crop	Year	Obs-N leached	Sim-N leached	Sim-N mineralized	Sim N-uptake	Sim N-fixation	N Fertilizer Input
Peanut	2019	82	80	111	30	349	0
Fallow	2019/20	72	108	130	0	0	0
Maize	2020	175	182	49	305	0	338
Fallow	2020/21	87	55	66	0	0	0

Volumetric water content (15 cm)

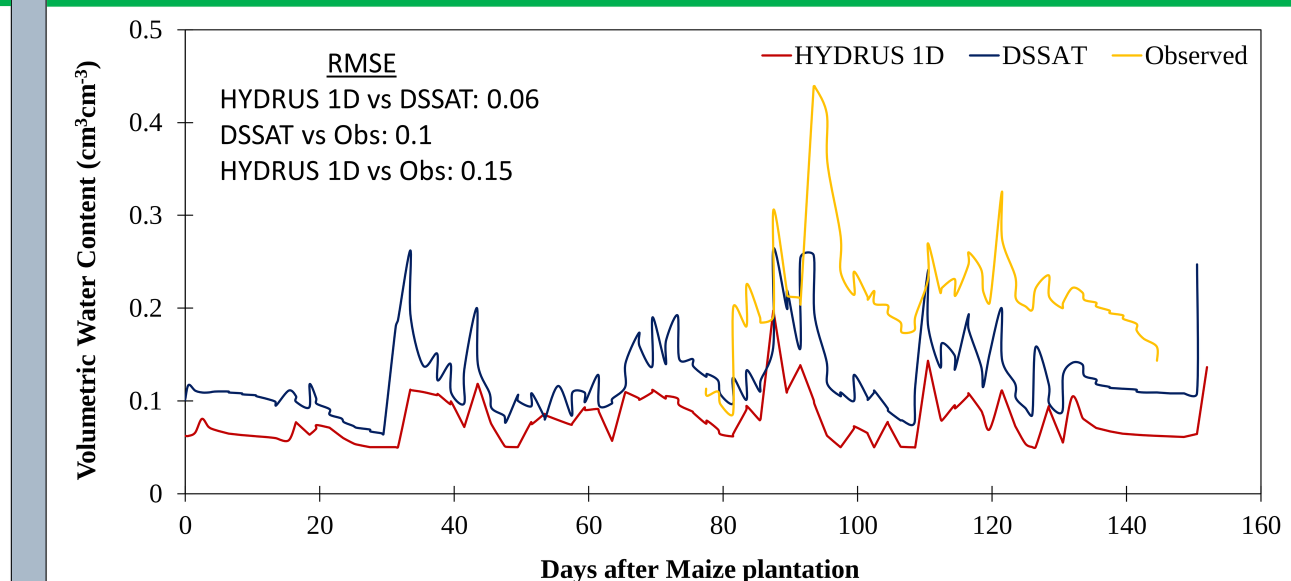

Fig 9: Comparison of observed (Obs) and simulated volumetric water content at 15 cm during 2020 maize growing season.

Actual root water uptake (cm)

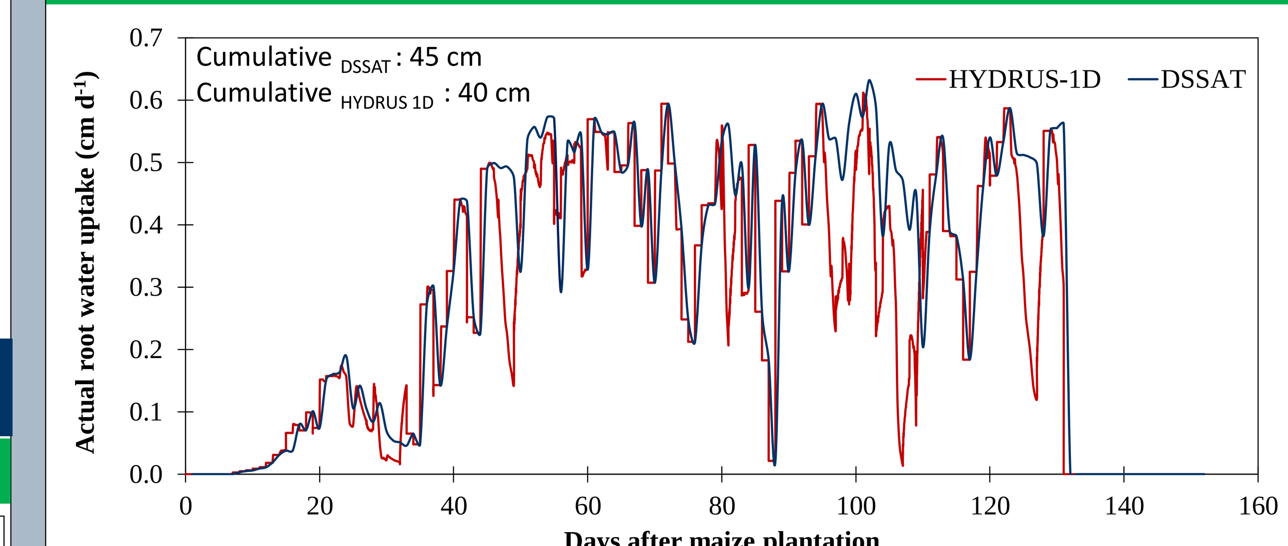

Fig 10: Comparison of DSSAT and HYDRUS-1D simulated actual root water uptake (cm d^{-1}) during 2020 maize growing season.

Total water in soil profile

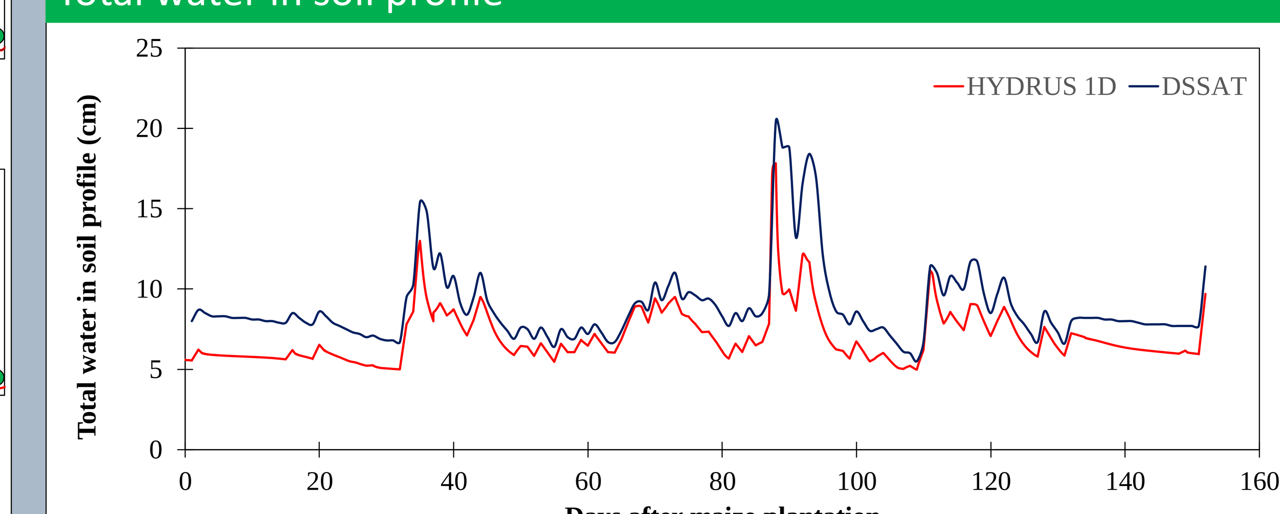

Fig 11: Comparison of DSSAT and HYDRUS-1D simulated total water in soil profile (cm) during 2020 maize growing season.

CONCLUSION and Future work

- Leaching event was triggered by fertilization as well as precipitation and irrigation.

- DSSAT simulated soil nitrate nitrogen with greater precision as compared to nitrate leaching.

- DSSAT and HYDRUS 1D produced similar results on soil water dynamics.

- This is an ongoing study and future work will include simulating nitrogen and water dynamics using DSSAT, HYDRUS-1D, SWAT as well as machine learning models.

Acknowledgement

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