Forecast-Based Framework for Streamflow and Soil Moisture Modeling to Support Agricultural Water Management.

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Digital Infrastructure for Research and Extension on Crops and Technology for Agriculture

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AI for Future Agricultural Resilience, Management, and Sustainability

Introduction

- Understanding the spatiotemporal dynamics of water availability is essential
- Conventional soil moisture monitoring is costly and spatially limited
- Forecast models like GEFS and NWM are underutilized for agricultural needs

Goal: Combine forecasts and agricultural data to anticipate water risk and guide irrigation

Can forecast data feed farms before it's too late?

Figure 1: Flood damaged soybeans on a farm in Cedar Rapids, Iowa (https://civileats.com/)

Figure 2: U.S. crops losses due to drought and flooding more than tripled from 1995 to 2020 (Yale Environment 360, 2024)

Figure 3: NWM by NOAA Streamflow simulations (https://water.noaa.gov/map)

Our Tools: Soil-MIIST and AWRI

IN-SITU SOIL SENSORS (Ground truth)

SATELLITE MOISTURE INDICES ANALYSIS (MSI, NDMI)

GEFS SOIL MOISTURE FORECASTS (MACHINE LEARNING)

CROP WATER REQUIREMENT FRAMEWORK
Root Depth Classification (Shallow, Deep)

SOIL MOISTURE INSIGHT AND IRRIGATION SCHEDULING TOOL (Soil-MIIST)

NWM STREAMFLOW FORECASTS
(Exposure to Hazard, Crop Sensitivity, Adaptive Capacity)

AGRICULTURAL WATER RISK INDICATOR (AWRI)

IRRIGATION & WATER USE MANAGEMENT DASHBOARD

- AWRI (Water Excess, Scarcity)
- Soil-MIST (Water Deficit Calculation, Sufficiency Ratio)
- Irrigation Trigger

Figure 4: Study Area showing installed sensors in Alabama Black Belt Region (ABBR)

AWRI: Uses NWM streamflow to assess hydrologic threat
Soil-MIIST: Predicts soil moisture at 15-30 cm using GEFS, satellite-derived indices (NDMI/MSI), and sensors
Unified approach: Evaluate water risk + Predict soil moisture

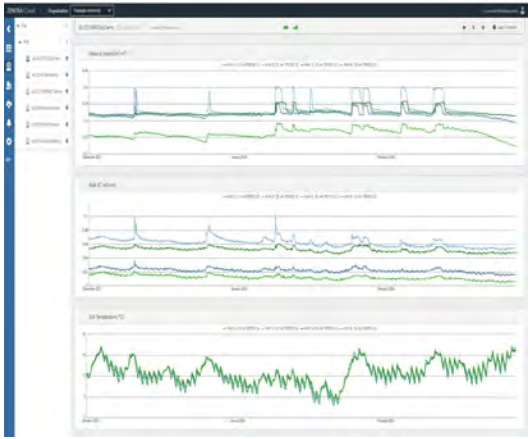
NWM predicts up to 30days
GEFS predicts up to 16 days

Computational Ecosystem – Data, ML & Cloud

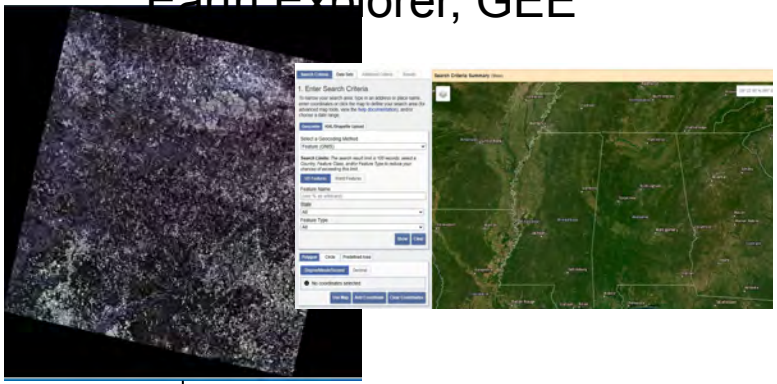
Developed tools (Soil-MIIST & AWRI) rely on national-scale, cloud-based, and computational systems.

aws

In-Situ Soil Sensor Readings
Zentra Cloud (API)



Satellite Imagery (Landsat 8/9, Sentinel 2) – USGS Earth Explorer, GEE



NOAA AWS Cloud (GEFS, NWM)

Streamflow and soil moisture from AWS S3 buckets

Machine Learning (XGBoost) Models

Data Processing & Modeling
Python pipelines , Google Earth Engine, Erdas Imagine, ArcGIS Pro

Biophysical Modeling

Difference Moisture Index

Moisture Stress Index (MSI)

Insights

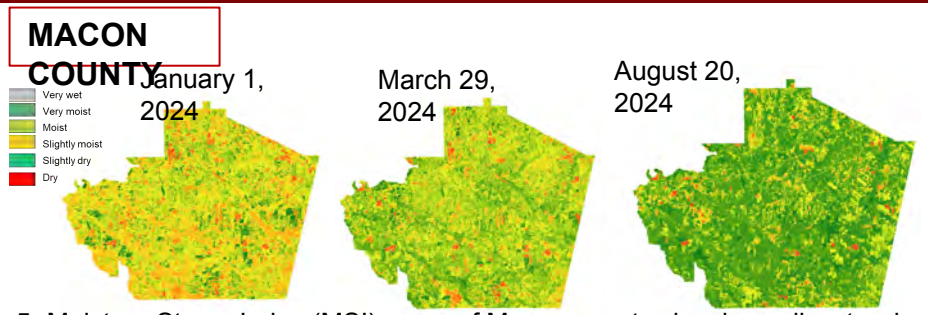


Figure 5: Moisture Stress Index (MSI) maps of Macon county showing soil water dynamics and trends

High MSI Value = Low NDMI value = Low Soil Water Content

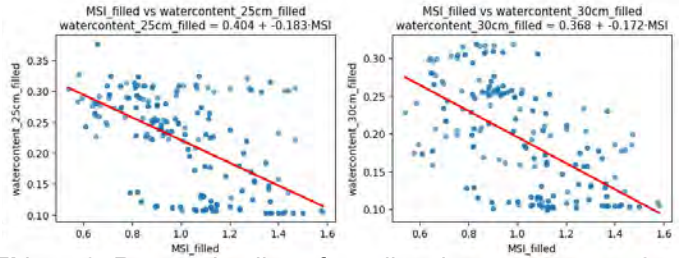


Figure 6: Regression lines for soil moisture content at 25cm, 30cm depths against MSI

Period / Crop	Week1 NS	Week1 NE	Week 2 E	Week 3 E	Week 4 E	Resilience measures
Dry bean	WN-0	WN-0	WE-2	WE-2	WE-2	No measure
	WN-0	WN-0	WE-1	WE-1	WE-1	Measures
Green beans	WN-0	WN-0	WE-2	WE-2	WE-2	No measure
	WN-0	WN-0	WE-1	WE-1	WE-1	Measures
Watermelon	Out of season		WE-2	WE-1	WE-1	No measure
			WE-1	WN-0	WN-0	Measures
Sunflower	Out of season		WE-2	WE-2	WE-1	No measure
			WE-1	WE-1	WN-0	Measures
Peanut	WN-0	WN-0	WE-2	WE-2	WE-2	No measure
	WN-0	WN-0	WE-1	WE-1	WE-1	Measures
Spring wheat	WN-0	WN-0	WE-1	WE-1	WE-1	No measure
	WN-0	WN-0	WN-0	WN-0	WN-0	Measures
Winter wheat	WN-0	WN-0	WE-1	WE-1	WE-1	No measure
	WN-0	WN-0	WN-0	WN-0	WN-0	Measures
Corn	WS-1	WN-0	WE-1	WE-1	WE-1	No measure
	WN-0	WN-0	WN-0	WN-0	WN-0	Measures
Soybean	WN-0	WN-0	WE-1	WE-1	WE-1	No measure
	WN-0	WN-0	WN-0	WN-0	WN-0	Measures
Cotton	WN-0	WN-0	WE-2	WE-2	WE-2	No measure
	WN-0	WN-0	WE-1	WE-1	WE-1	Measures
Sorghum	WN-0	WN-0	WE-1	WE-1	WE-1	No measure
	WN-0	WN-0	WN-0	WN-0	WN-0	Measures

AWRI classes	Impact Description
Critical water scarcity [WS-4]	Major crop/pasture losses, and widespread water shortages or restrictions
Severe water scarcity [WS-3]	Crop and pasture losses likely
Moderate water scarcity [WS-2]	Some damage to crops
Abnormally dry [WS-1]	Some yield reduction and longer duration in growth stage
Normal: [WN-0]	Normal crop development
Moderate water excess: [WE-1]	Some crops will have waterlogging issues or reduction in yield production
Severe water excess: [WE-2]	Likely crops will be loss for waterlogging, etc.
Critical water excess: [WE-3]	Widespread crop losses, move animal to high land, some damage in infrastructure

Figure 7: AWRI Long Range Forecast Assessment Near Tu Organic Farm, Reach Id: 21717804

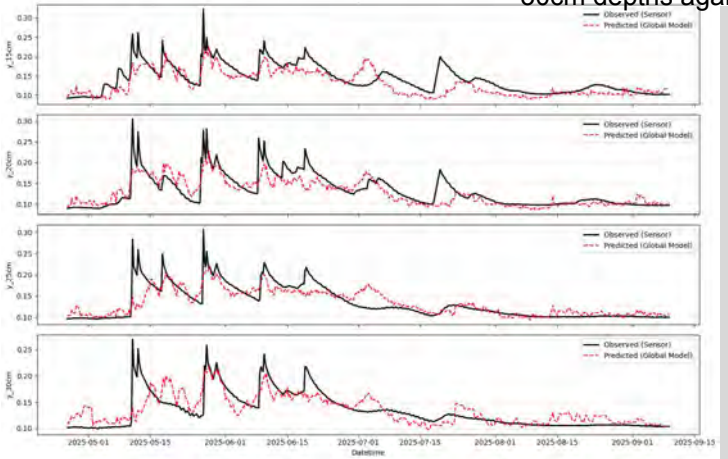
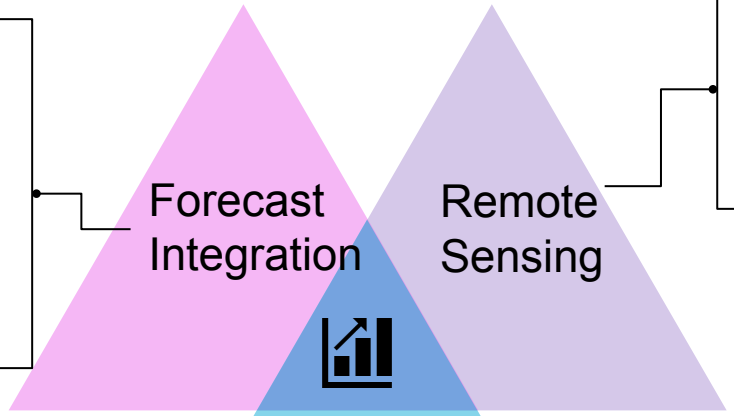


Figure 8: Machine learning model test on a pilot site for soil moisture

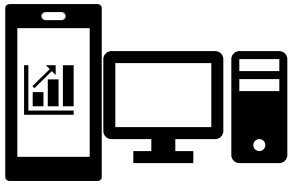
- Satellite indices track moisture trends
- NDMI & MSI correlated strongest at deeper depths
- Machine-learning models improve forecast across multiple depths
- AWRI translates streamflow forecasts into actionable water risk

advisory system

- Forecasts future water availability and drought risk
- Enables forward-looking irrigation scheduling



- Scales moisture monitoring and visualization across entire field
- Tracks surface and sub-surface wetness using satellite or drone imagery



- Defines water need by crop, stage, and rooting depth
- Links moisture status to actual crop demand and sets thresholds for irrigatio

- Unified advisory platform integrates all components into actionable guidance.
- Enables smarter water use and climate-resilient agriculture
- Real-time and forecasted guidance in one place
- Accessible via user-friendly dashboard

END GOAL: An Interactive Dashboard for Agricultural Water Management

THANK YOU!!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