Adaptive and Predictive Decision Support System for Irrigation Scheduling: An Approach Integrating Humans in the Control Loop

Gregory Conde
Postdoctoral Associate
Smart Irrigation and Hydrology
Agricultural and Biological Engineering Department
Indian River Research and Education Center
Fort Pierce, FL
gregory.condemen@ufl.edu

Sandra M. Guzmán
Assistant Professor
Smart Irrigation and Hydrology
Agricultural and Biological Engineering Department
Indian River Research and Education Center
Fort Pierce, FL
sandra.guzmangut@ufl.edu

Enhancing the irrigation management in vegetable farms in southeast US by developing root zone soil moisture maps in both high spatial and high temporal resolutions
Conservation Innovation Grants (CIG)

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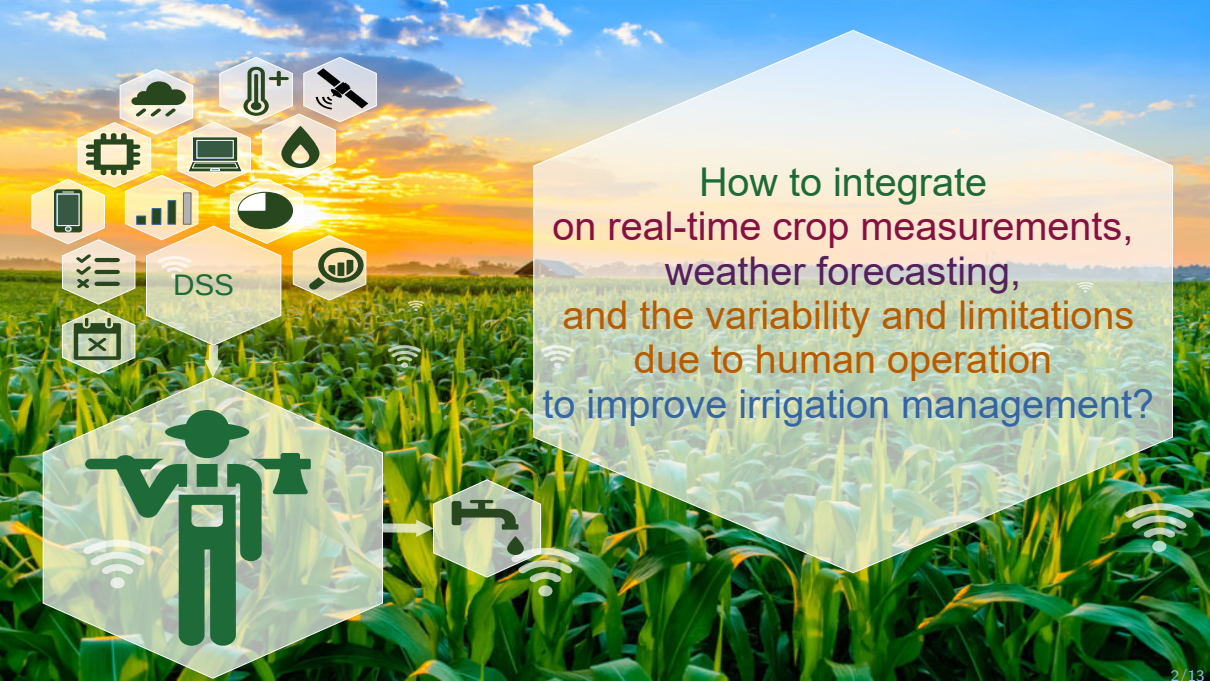
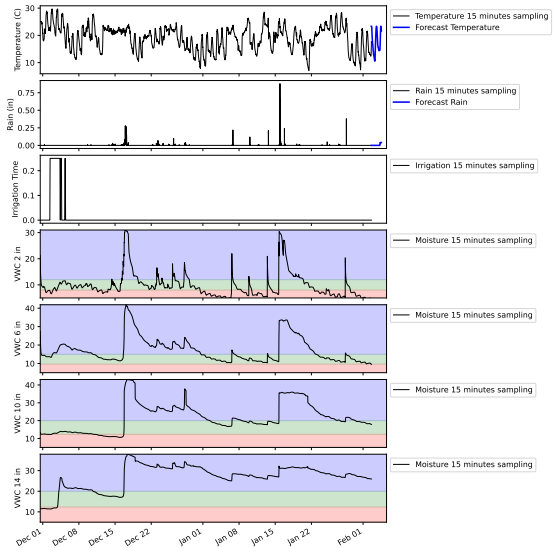


How to integrate
on real-time crop measurements,
weather forecasting,
and the variability and limitations
due to human operation
to improve irrigation management?

Problem Overview (How Much to Irrigate?)



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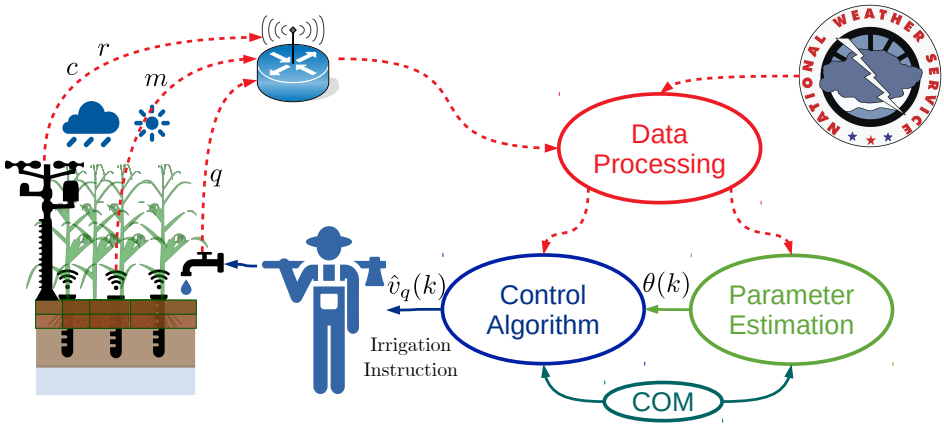
Adaptive and Predictive DSS for Irrigation Scheduling



$m \rightarrow$ Soil moisture $\quad c \rightarrow$ Temperature $\quad$ Control Oriented Model (COM)

$r \rightarrow$ Rain $\quad q \rightarrow$ Irrigation $\quad \theta(k) \rightarrow$ Model Parameters

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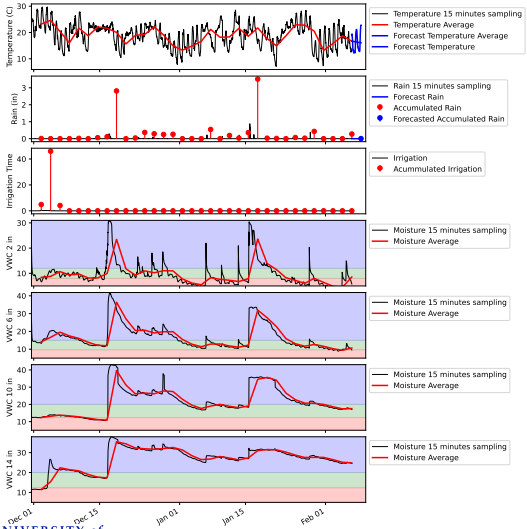
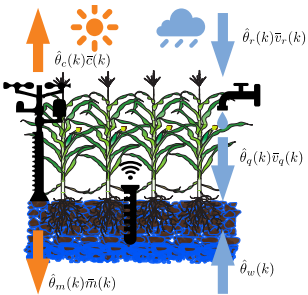
Data Processing Stage



Data processed

- $\bar{c}(k)$ average temperature
- $\hat{\bar{c}}(k)$ average temperature (forecast)
- $\bar{v}_r(k)$ accumulated rainfall
- $\hat{\bar{v}}_r(k)$ accumulated rainfall (forecast)
- $\bar{v}_q(k)$ accumulated irrigation
- $\bar{m}(k)$ moisture average

Control Oriented Model (COM)



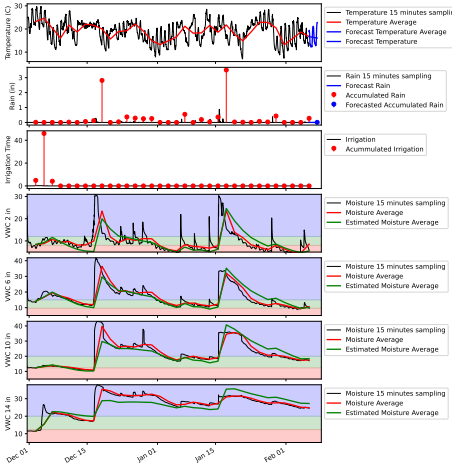
Rates of change during a time period

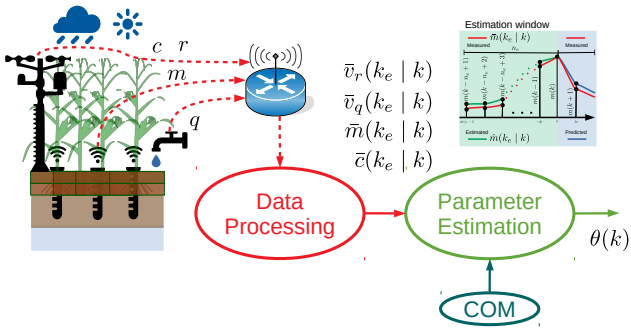
- $\hat{\theta}_m(k)$ moisture variation and moisture average
- $\hat{\theta}_r(k)$ moisture variation and accumulated rain
- $\hat{\theta}_c(k)$ moisture variation and temperature average
- $\hat{\theta}_q(k)$ moisture variation and accumulated irrigation
- $\hat{\theta}_w(k)$ moisture variation and upward capillarity flow

$$\bar{m}(k+1) - \bar{m}(k) = -\hat{\theta}_m(k)\bar{m}(k) + \hat{\theta}_r(k)\bar{v}_r(k) - \hat{\theta}_c(k)\bar{c}(k) + \hat{\theta}_q(k)\bar{v}_q(k) + \hat{\theta}_w(k)$$

Parameter Estimation Stage

The objective is to estimate the parameters $\theta(k)$ that minimize the error between measured moisture and estimated moisture.





$$\overline{m}(k+1) - \overline{m}(k) = -\theta_m \overline{m}(k) + \theta_r v_r(k) - \theta_c \overline{c}(k) + \theta_q v_q(k) + \theta_w$$

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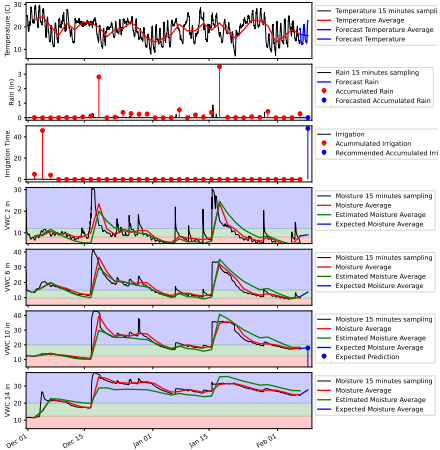
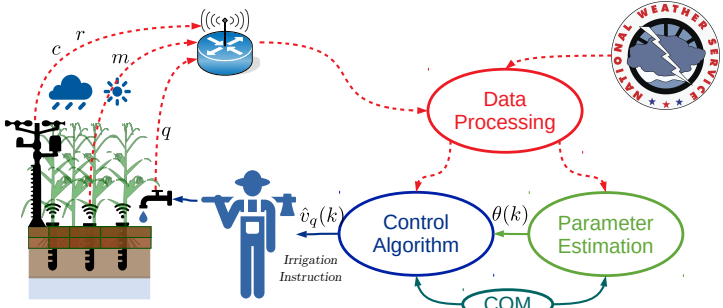
Control Stage





$m_r \longrightarrow$ Desired moisture $\qquad \bar{m}(k+2) = m_r$

$$\hat{\bar{v}}_q(k+1) = \frac{1}{\hat{\theta}_q(k)} m_r - \frac{1-\hat{\theta}_m(k)}{\hat{\theta}_q(k)} \hat{\bar{m}}(k+1) - \frac{\hat{\theta}_r(k)}{\hat{\theta}_q(k)} \hat{\bar{v}}_r(k+1) + \frac{\hat{\theta}_c(k)}{\hat{\theta}_q(k)} \hat{\bar{c}}(k+1) - \frac{\hat{\theta}_w(k)}{\hat{\theta}_q(k)}$$

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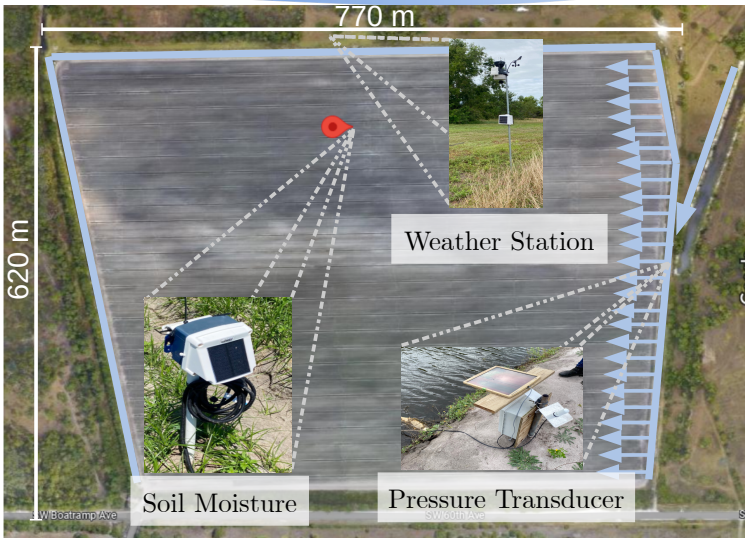
Study Case in South Florida; Seepage Irrigation



Preliminary Results

Click here to play the video

Concluding Remarks and Future Work

- **Integrated DSS:** Sensor data + weather forecasts + human limitations.
- **Water Savings:** Up to 30% for sandy soil crops **(450 m^3/ha/season)**.
- **Model accuracy:** Soil moisture $R^2 > 0.84$.
- **Control Systems:** Feedback and feedforward for moisture management.
- **Expansion Plans:** Wider crop and irrigation system applicability, algorithm enhancement.

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Acknowledgements

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Thank You!

Questions?