Distributed Carbon Dioxide Flux Assessment in Agricultural Soils: Can Robotic Rovers Monitor the Gases While Carrying the Produce?

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Background

Goals: Building healthy soils for carbon storage, reduce greenhouse gas (GHG) emissions, while promoting food security as a part of a comprehensive climate action plan.

Focus: Examining affordable technologies for assessing soil surface CO_2 efflux in agricultural fields, emphasizing statistically significant measurements over short periods.

Factors Impacting Efflux: Soil CO_2 efflux is influenced by soil texture, moisture content, and temperature. Spatiotemporal variation is intricate, especially in fields with heterogeneous soil textures and nonuniform irrigation patterns.

Motivation

UC Merced Experimental Smart Farm: Aims to catalyze research that will inform the future of farming.

Automation in Agriculture: Addresses declining farm labor and increasing environmental constraints. Seek solutions through automation for the farm of the future.

Focus on Carbon Emissions: Recognizing the significance of carbon emissions, the farm aims to understand their dynamics comprehensively.

Methods

Approach: Combining computational modeling (Hydrus 1D) and empirical measurements at the UC Merced Experimental Smart Farm (2 ha flood-irrigated land). Simulating conditions for various soil textures, temperatures, and irrigation scenarios.

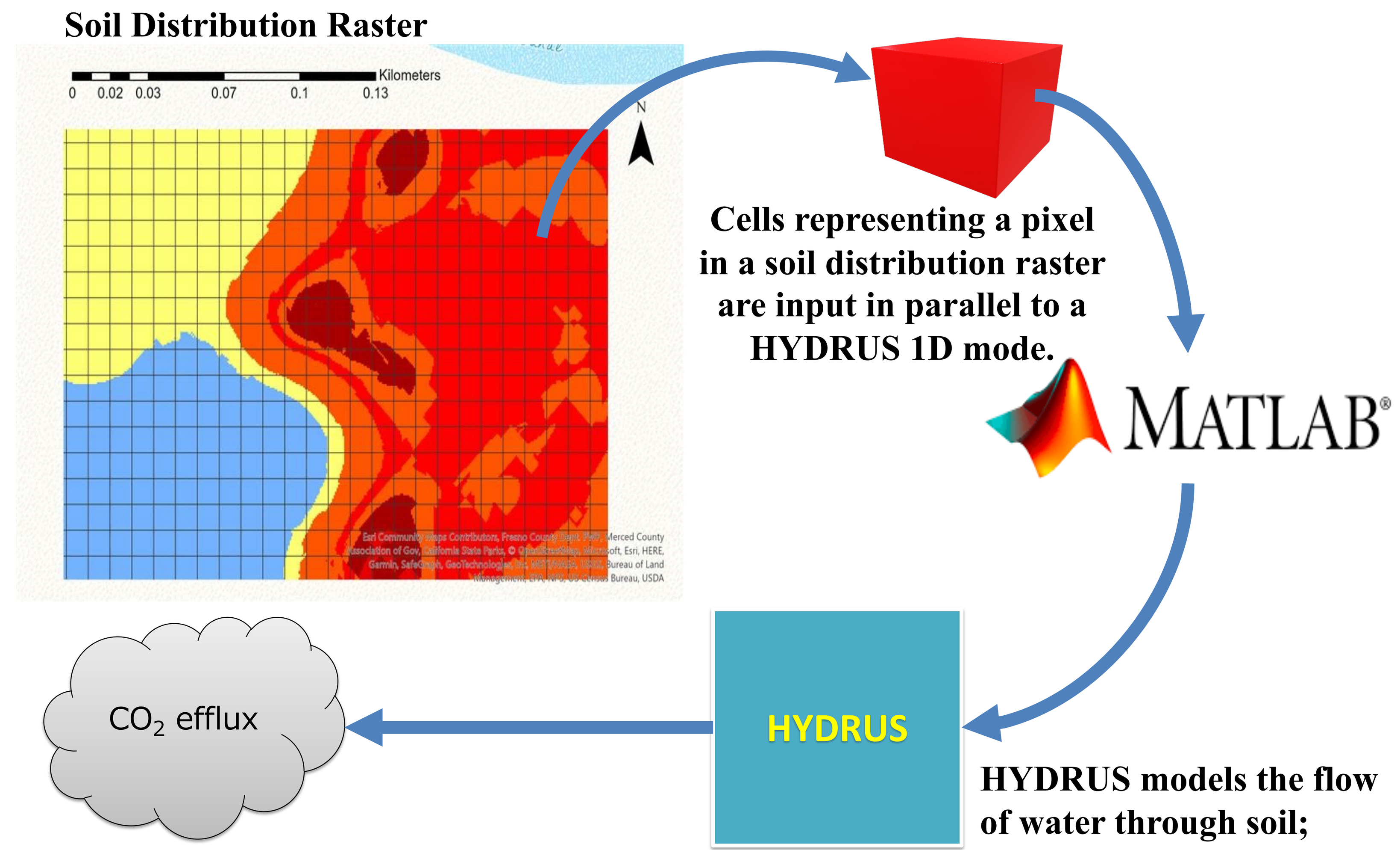
Model Inputs: A virtual representation of soil in a 2-ha field subdivided into 200 cells at 10m² resolution. Each cell was assigned soil properties through kriging geostatistical analysis.

Model Specifics: Calibrating biokinetic parameters using low-cost CO_2 efflux chambers during multiple sampling campaigns. 1455 hours (60 days) simulation considering ten irrigation management practices. Focused analysis on the 2-week 3-inch irrigation scenario as the most representative of field conditions.

Distribution Analysis: Studied the distribution of CO2 efflux at various sampling intervals. Aids in determining the minimum sampling frequency to capture a representative sample of the field.

Graphical Abstract

Students collecting CO_2 efflux manually using low-cost flux chamber



Cells representing a pixel in a soil distribution raster are input in parallel to a HYDRUS 1D mode.

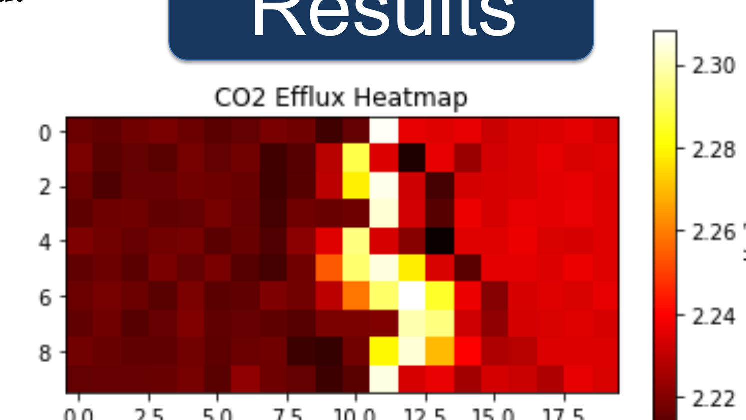
HYDRUS models the flow of water through soil; accounting for biogeophysical processes.

Model results give us an understanding of the spatiotemporal distributions of CO_2 efflux in our field.

Field site during flood irrigation

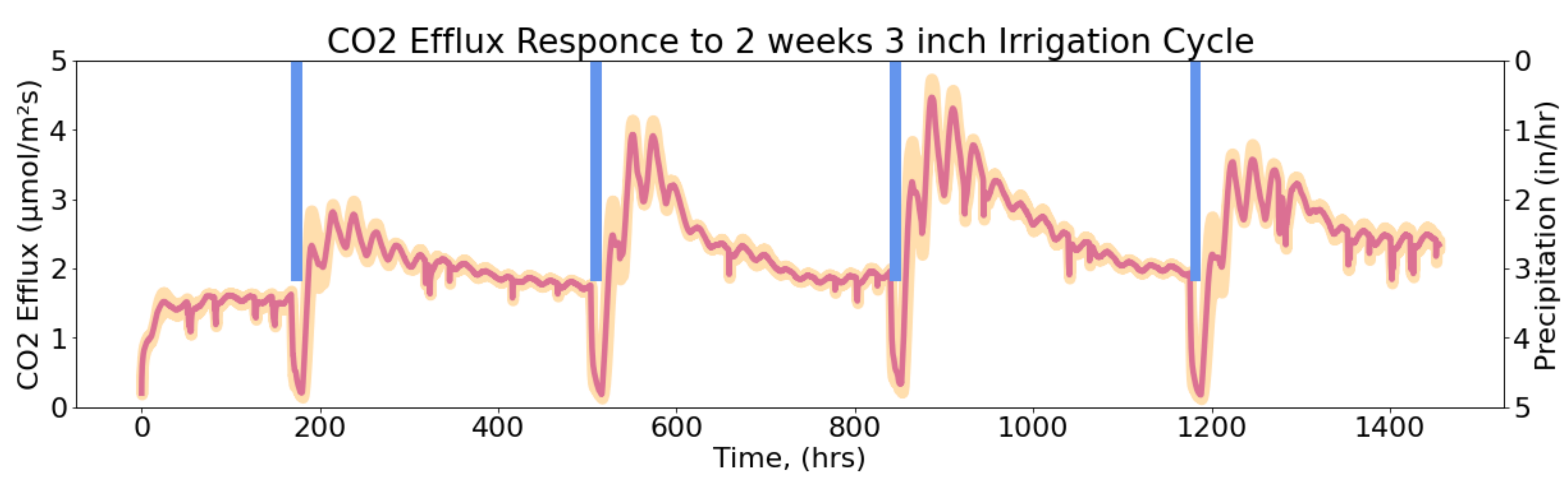
Validating our model requires repeated manual measurements with our CO2bie devices, depicted here. There are current efforts with other LACA collaborators to automate this process.

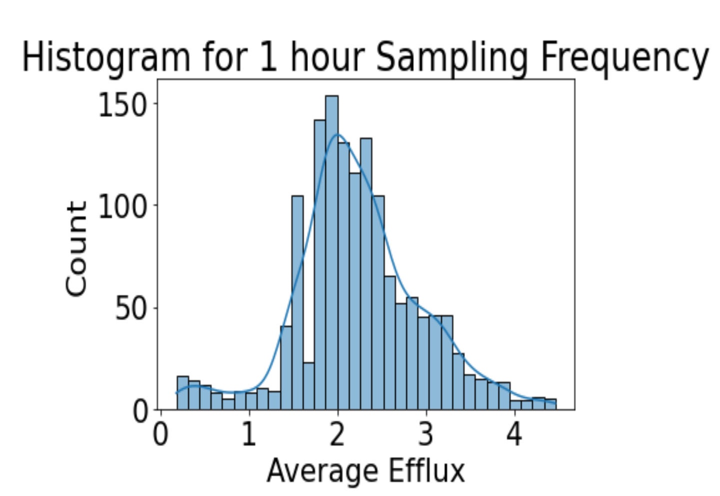
Results

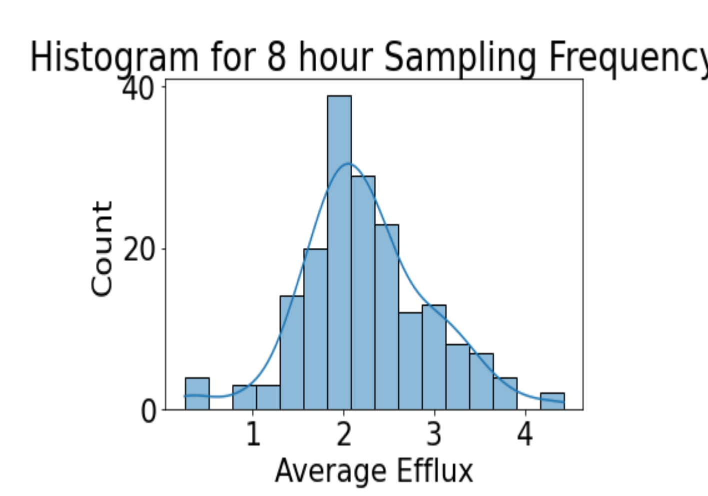


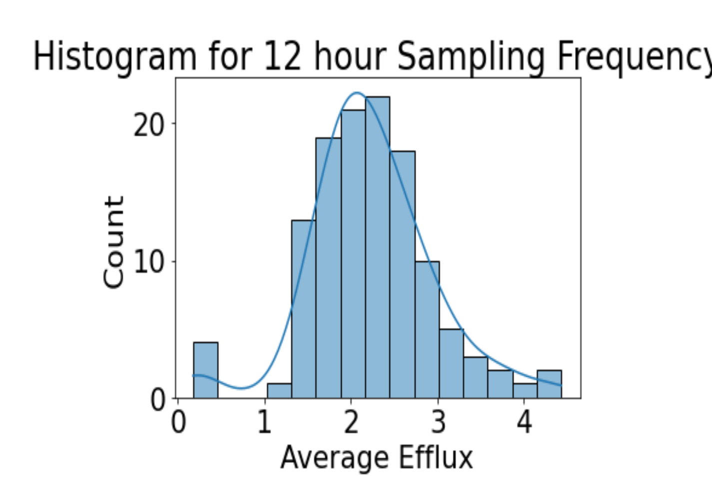
Spatial distribution of CO_2 efflux

CO2bie Rover developed in collaboration with Dr. Carpin's Lab









Discussion

Future Implementations: Transitioning from researcher-led campaigns to employing robotic micro-tractors equipped with CO2 chambers. These tractors will utilize path planning algorithms to characterize field-scale CO2 efflux while performing primary agricultural functions.

Farmers' Future Role: Enabling farmers to monitor and achieve GHG emission goals with minimal time investment through the integration of robotic micro-tractors in future campaigns.

Conclusions

This Study

- Manual sampling (results not shown) necessitates multiple workers within a limited time window (approximately 2 hours).
- Consistent sampling with multiple workers requires training and practice.

Greater Context

- Fluxes exhibit significant variations over time (attributed to temperature and moisture) and space (attributed to texture).
- Empirical field-scale efflux is yet to be determined, but simulated distributions provide insights into the required sample size.
- Connections between point-scale measurements and eddy covariance measurements also needs investigation.
- As we strive for sustainable food production, integrating environmental sensing systems into existing mobile platforms (e.g., tractors, robotic carts, etc.) can help to automate environmental compliance while saving time for farmers.

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