# CPS: Medium: A scalable real-time sensing and decision-making system for field-level row-crop irrigation management

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## Introduction

- **Background**: > 75% irrigation decisions based on rule-of-thumb methods
- **Four challenges**: (1) data availability and scalability, (2) quantification of plant water stress, (3) model uncertainties and constraints, and (4) producers' participation and motivation
- **Solutions**: (1) high spatial-temporal-resolution satellite fusion products and inexpensive sensor networks; (2) mechanistic quantification of "plant water stress" as triggers to improve irrigation decision; (3) constrain the process-based and statistical/machine learning models at each individual field; and (4) develop easy-to-use tools with flexibility, and increase governments' financial incentives and support
- **Three key components: Data Acquisition – Modeling & Analytics – Decision making Support** (Fig 1)

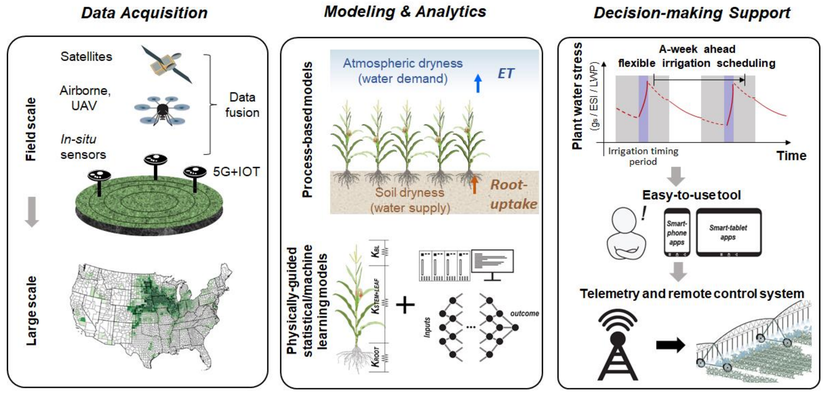


**Fig 1. Proposed systematic framework of precision irrigation decision-support system for center pivots** (Zhang et al., 2021).

## Data Acquisition

- **STAIR (SaTallite dAta IntegRation)**: a generic and fully automated fusion algorithm
- **BESS-STAIR ET**: high spatial-temporal resolution dataset (30 m, daily) with high accuracy ($R^2$=0.75) (Fig 2)

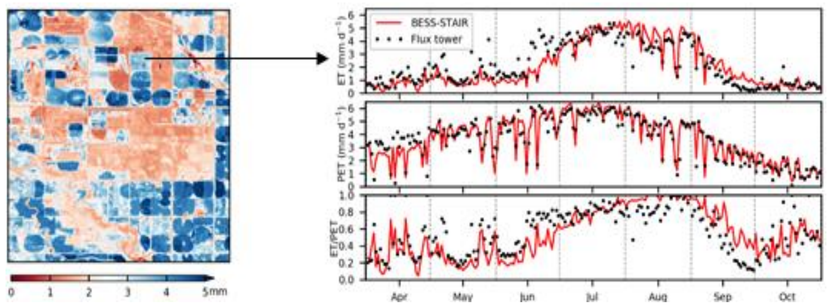


**Fig 2. BESS-STAIR ET performance**. Left: a daily ET map in eastern Nebraska. Right: time series comparison of ET, potential evapotranspiration (PET), and ET/PET between BESS-STAIR daily estimations and flux tower measurements in 2012 (Jiang et al., 2020).

## Modeling & Analytics

- **Various definitions of plant water stress**: plant hydraulics (water potential), stomatal conductance, canopy temperature (crop water stress index, CWSI), transpiration/evapotranspiration (ET), soil moisture (Fig 3)
- **Supply-Demand Dynamics (SDD) irrigation scheme**: a novel irrigation scheme based on co-regulation of soil moisture and VPD on stomatal conductance (Fig 4)
- **Process-based modeling**: *ecosys* and Noah-MP model, rigorously constrained with high spatial-temporal resolution dataset (ET, LAI, and GPP)

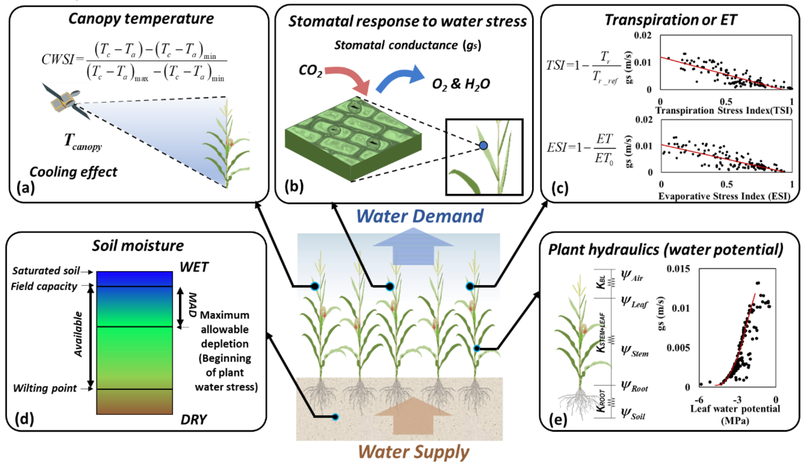


**Fig 3. Conceptual scheme of five possible aspects to define plant water stress**. (a), Crop Water Stress Index (CWSI) based on canopy temperature. (b), Stomatal conductance considering stomatal response to water stress. (c), Transpiration stress index (TSI) or evaporative stress index (ESI) based on transpiration or ET. (d), Soil moisture-based metric: maximum allowable depletion (MAD). (e), Leaf water potential based on plant hydraulics.

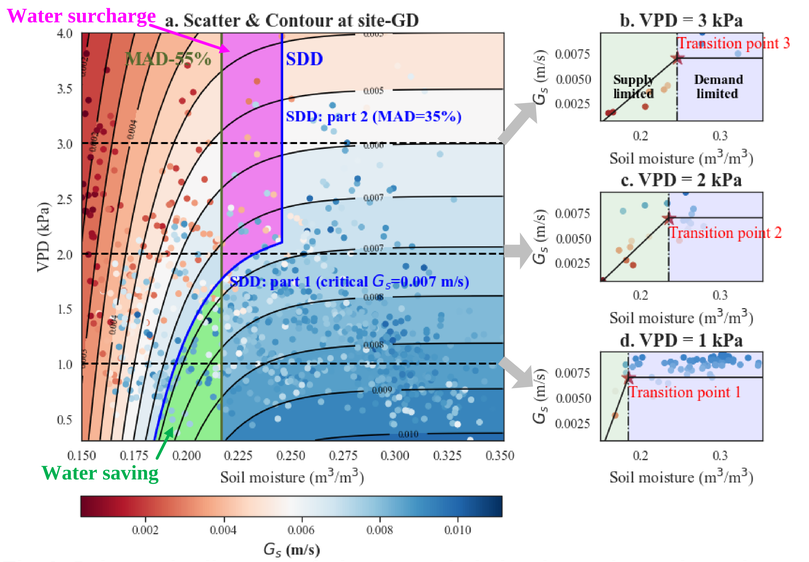


**Fig 4. Schematic diagram of plant-centric irrigation scheme based on water supply-demand dynamics (SDD) at an example site-GD.**

## Decision-making Support

- **Performances**: the plant-centric SDD irrigation scheme could significantly reduce irrigation water use (-24.0%, -58.6 mm) while maintaining crop yields, and thus increase economic profits (+11.2%, +$13.8/ha) and irrigation water productivity (+25.2%, +1.4 kg/m$^3$) compared with MAD (Fig 5)

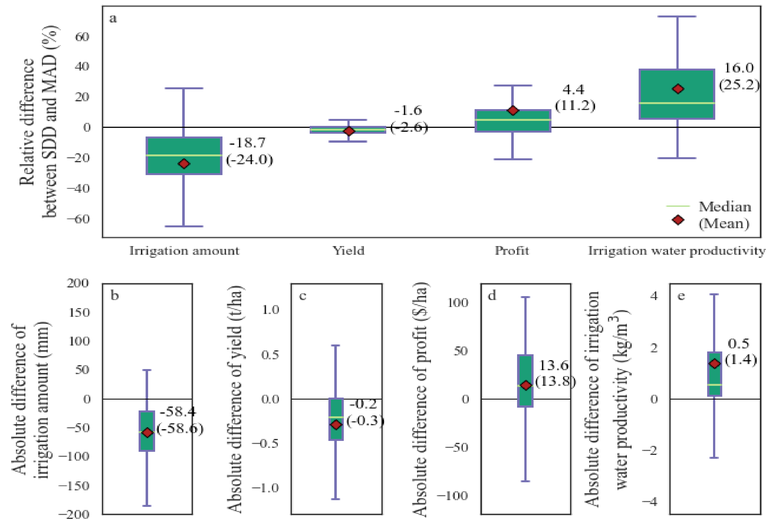


**Fig 5. Performances of plant-centric SDD and soil-moisture-based MAD irrigation schemes across 12 sites in Nebraska under current climate (2001-2019).**

## Summary

- **Data Acquisition:** BESS-STAIR ET (30 m, daily)
- **Modeling & Analytics:** five possible aspects to define plant water stress based on hydraulically-driven ecosystem model (*ecosys*), propose a novel Supply-Demand Dynamics (SDD) irrigation scheme
- **Decision-making Support**: the plant-centric SDD irrigation scheme, combining soil water supply and atmospheric evaporative demand, could significantly contribute to water sustainability

## References

- Zhang, J., Guan, K., et al. (2021), Challenges and opportunities in precision irrigation decision-support systems for center pivots, Environmental Research Letter. DOI: 10.1088/1748-9326/abe436.
- Jiang, C., Guan, K., et al. (2020), BESS-STAIR: a framework to estimate daily, 30 m, and all-weather crop evapotranspiration using multi-source satellite data for the US Corn Belt, Hydrol. Earth Syst. Sci.
- Yang, Y., Guan, K., et al. (2020). High-resolution spatially explicit land surface model calibration using field-scale satellite-based daily evapotranspiration product. Journal of Hydrology, 125730.

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