CIT Update

Charles Hillyer, CSU Fresno

AMERICAN SOCIETY OF
IRRIGATION CONSULTANTS
– 2022 –
NATIONAL CONFERENCE
Hotel Monteleone
NEW ORLEANS

Research Highlights from The Center for Irrigation Technology

AMERICAN SOCIETY OF IRRIGATION CONSULTANTS

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NATIONAL CONFERENCE

Hotel Monteleone

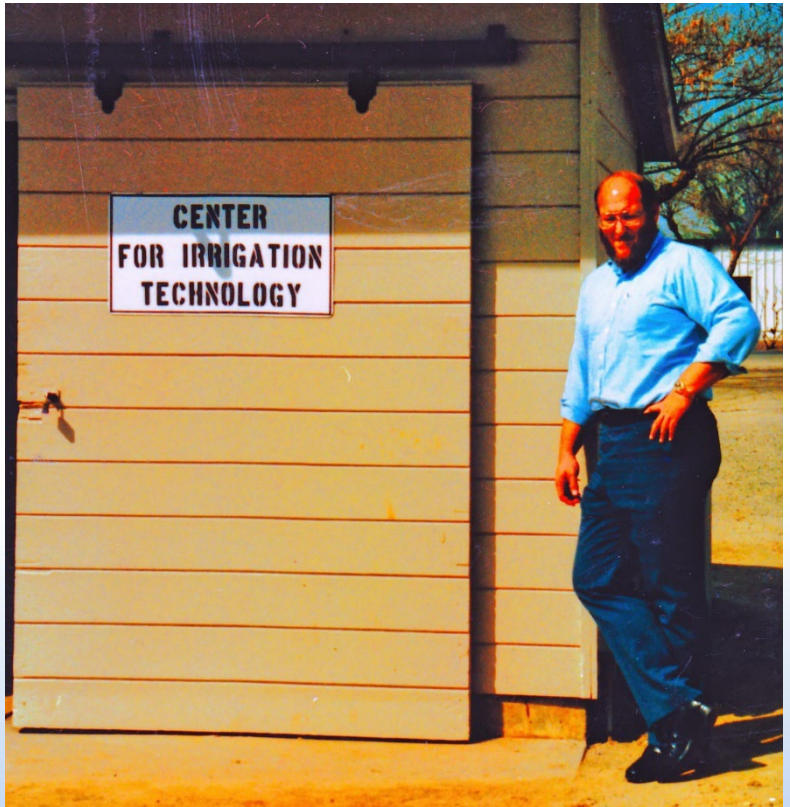
NEW ORLEANS

FRESNO STATE
Center for Irrigation Technology

The Center for Irrigation Technology

- Formally est. 1980 at California State University, Fresno
- Recognized leader in:
  - Hydraulic testing
  - Field Research
  - Analytical Studies
  - Education

➢ Testing Laboratory
➢ Research Farm
➢ Technology Incubator & Accelerator Program



FRESNO STATE
Center for Irrigation Technology

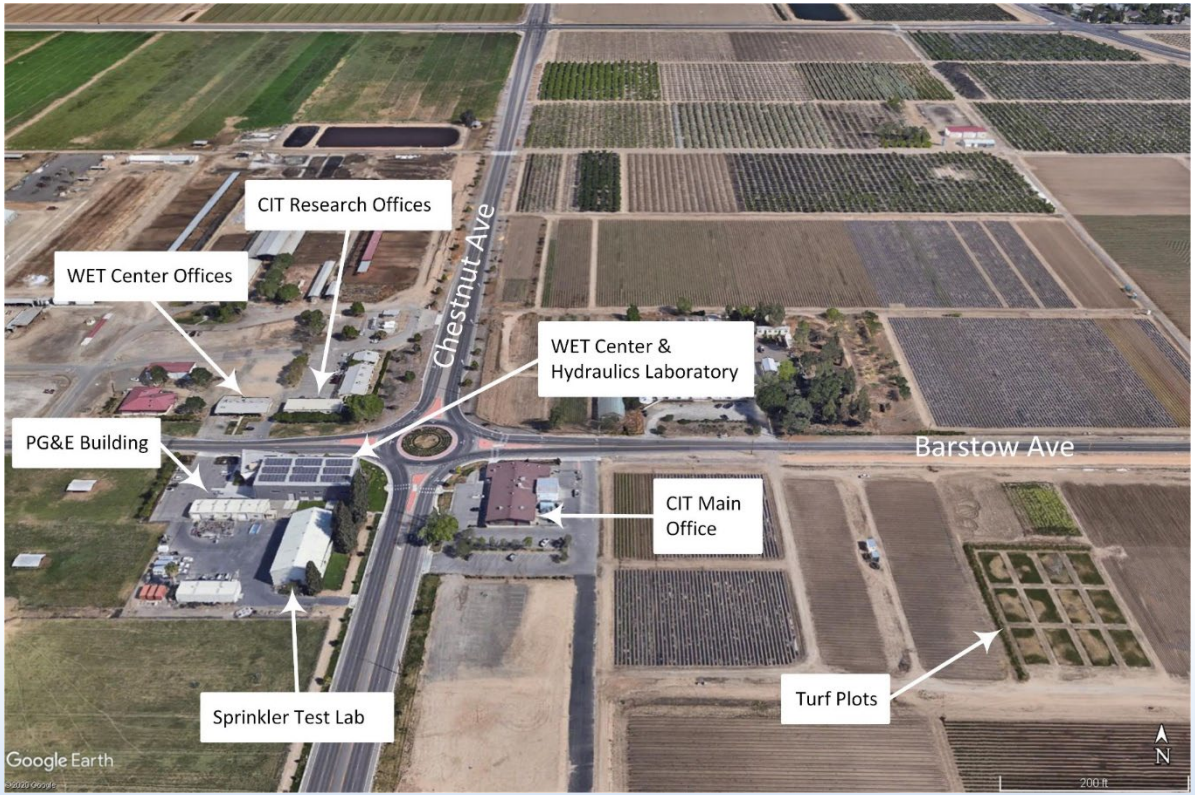
CIT Today

Mission

Bringing the world the most innovative products and resource management tools

Core Activities

- Education
- Applied Research
- 3rd Party Testing
- Technology Transfer
- Entrepreneurship



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CIT HYDRAULICS LAB

Facility Size……13,000 ft^2

Test Lab Size ……8,000 ft^2

Year Opened……2007

Test Pit Depth……22 ft

Test Pit Volume…….53,000 Gallons

HP Capacity……300 HP

Flow Capacity……0 to 6000 gpm

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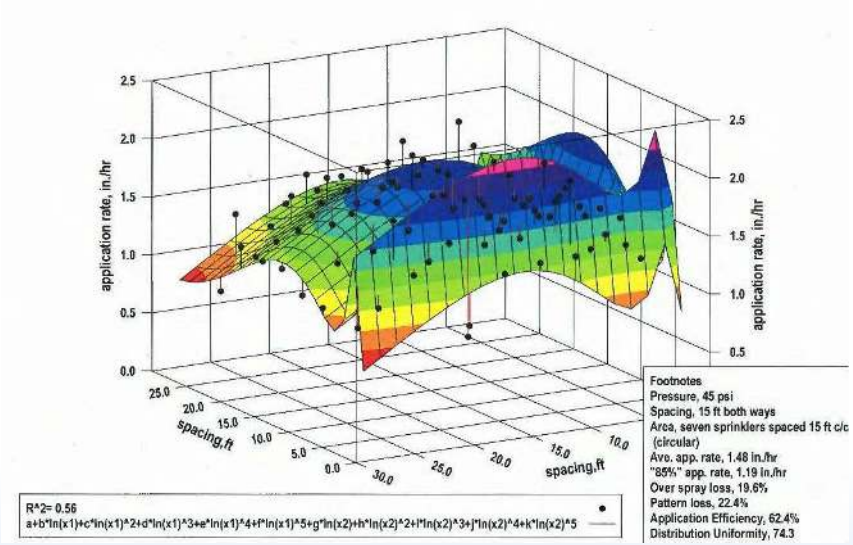
Sprinkler Testing Laboratory



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Standard Tests Available

Test #	Description
1	Sprinkler radial distribution pattern (indoor to a maximum radius of 100 ft.).
2	Sprinkler full grid distribution pattern per ASABE S330.
3	Micro-sprinkler or spray head radial distribution pattern (determined for 4 radial directions space 90° (degrees).
4	Computerized analysis a sprinkler overlapped distribution patterns
5	Valve closing speed determination (maximum flow rate 600 gpm).
6	Determine valve head loss as a function of flow rate
7	Determine drip emitter manufacturing variability (100 emitters required)
8	Determine a drip emitter discharge as a function of pressure (25 emitters required)
9	Determine drip emitter discharge as a function of temperature (25 emitters required)

Test #	Description
10	Combined test for drip emitters
11	Environmental stress crack resistance test
12	Chemigation valve standard test
13	Determine hydrostatic burst pressure (to 3,000 psi)
14	Testing to characterize emitter plugging susceptibility (range of grit sizes 0.0029 to 0.0165 in./control sieve)
15	Testing to determine separator effectiveness. Applicable to hydrocyclones and ring and screen filters.
16	Determine the vacuum relief capacity of vacuum relief valves
17	Determine the air venting capacity of air release valves plus the cost of renting an air compressor
18	Determine the friction loss characteristics of drip tape and collapsible tubing to sizes 1.0 in.
19	Drop spectrum studies on sprinkler jets
20	Testing to Irrigation Association SWAT Testing Protocols (Climatologically Based Controllers, Soil Moisture Sensor Based Controllers)

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CIT Research Plots

- 6.5 acres
- Dedicated turf plots
- Multiple research projects each year
- Public and private funded research

➢ Focus on Applied Research

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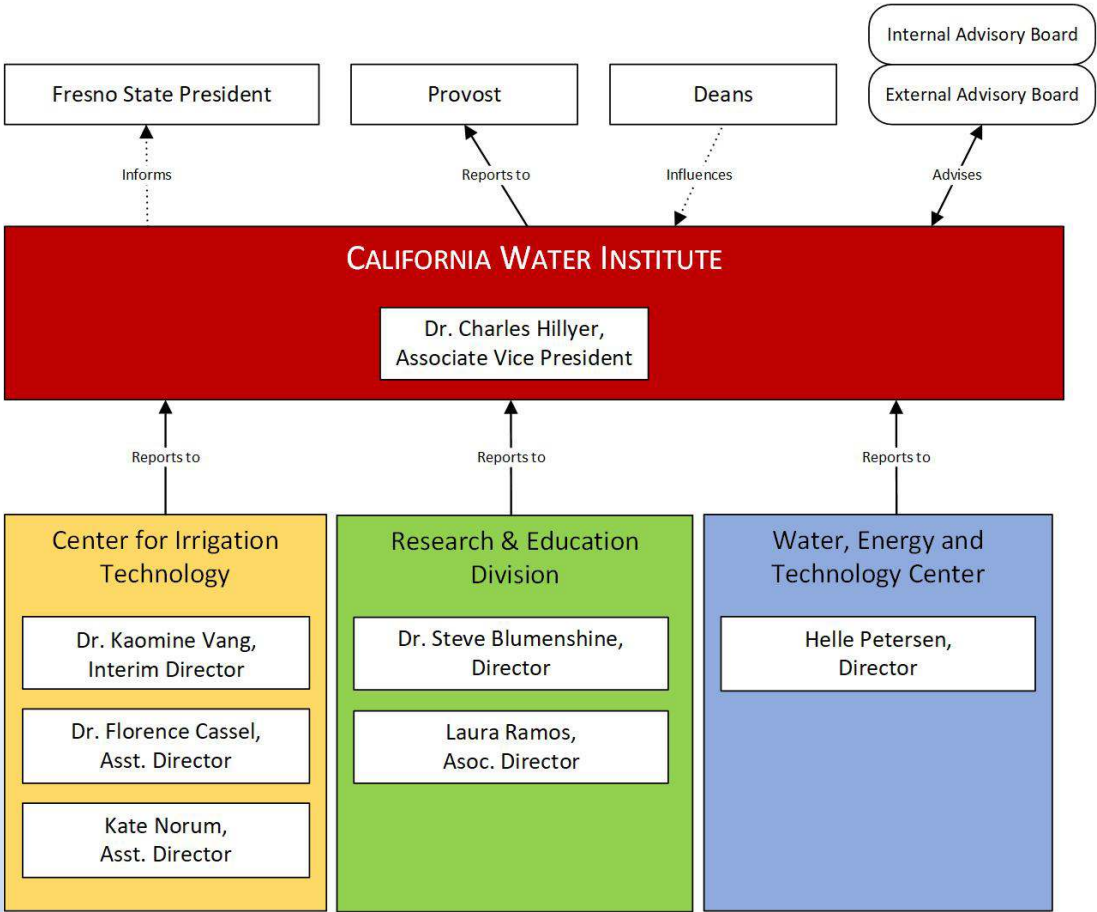
The California Water Institute was founded to be a forum for unbiased, open, collaborative discussion, research and education on water-related issues benefiting the entire state and beyond. Today CWI's mission is to engage the San Joaquin Valley, California, and the world with Fresno State's Faculty, Staff, and Students to pursue sustainable water resource management solutions through outreach, research, and education.

FRESNO STATE
California Water Institute



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Research Highlights from 2021

- Shawn Ashkan
- Dr. Dilruba Yeasmin
- Dr. Florence Cassel
- Dr. Dave Goorahoo

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SHAWN ASHKAN

Project: Groundwater Sustainability Agency (GSA) Irrigation Scheduling Toolkit

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Charles Hillyer
Shawn Ashkan
Sarge Green
Xiaoming Yang
Athanasios Aris Panagopoulos

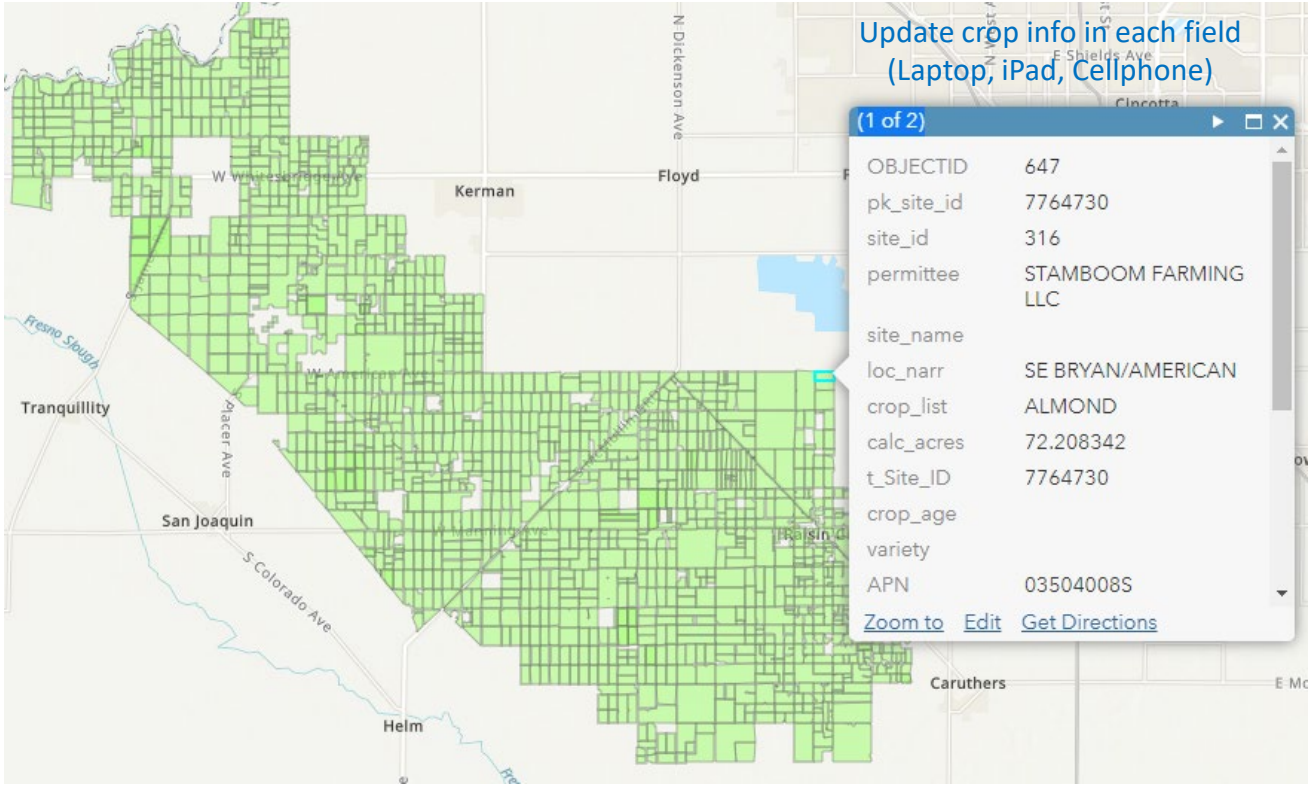
Problem/Issue

- Recently California passed a law regulating the use of groundwater.
- The law represents a historic transition to groundwater pumping and will significantly impact the agricultural industry.
- The proposed 'Tool' is designed to help with this transition.

Groundwater Sustainability Agency (GSA)

- Groundwater levels have dropped continuously over the past several decades.
- In 2014, California enacted Sustainable Groundwater Management Act (SGMA), requiring a long-term balanced groundwater budget.
- SGMA established a new structure for managing groundwater resources at the local level by local agencies, called the Groundwater Sustainability Agency (GSA).
- GSAs formed in 2017 and submitted their Groundwater Sustainability Plans (GSPs) to the Department of Water Resources (DWR) in 2020.
- GSAs have 20 years to implement the GSPs and bring the groundwater basins into balance through increasing supplies (recharge) and reducing demands (pumping).
- GSAs are the heart of SGMA development and implementation plans --- they have a difficult job and need technical assistance.

California GSA Service Areas



McMullin Area GSA

Example: Field Database

Field Boundaries & Cropping Patterns

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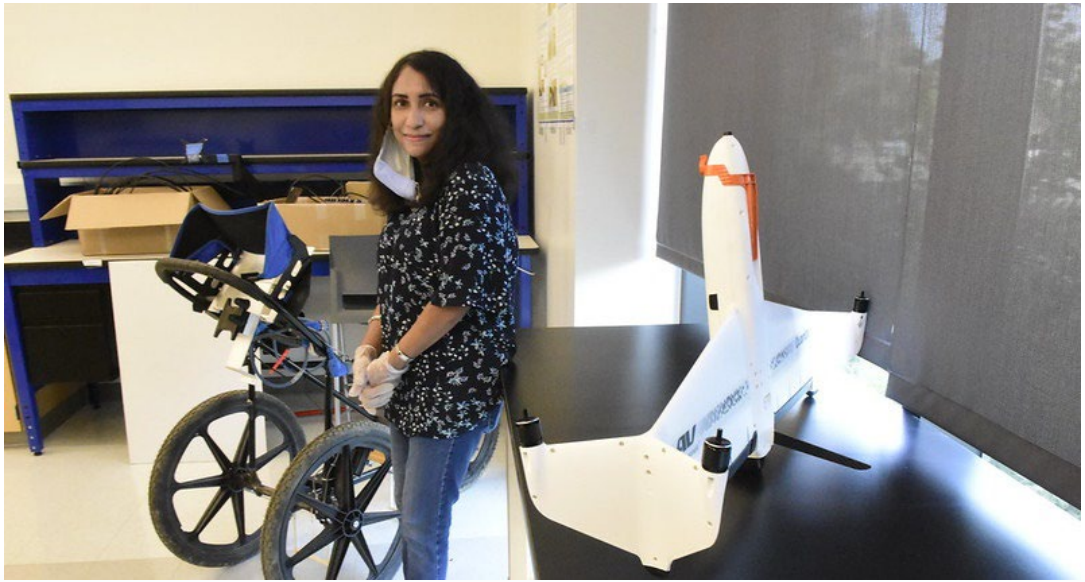
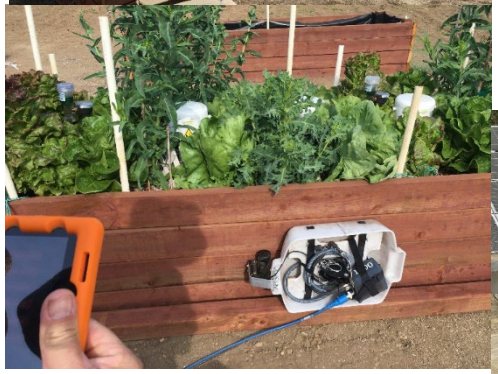


DR. DILRUBA YEASMIN

California State University, Fresno – The Center for Irrigation Technology

Highlights of Research Work



Lettuce Root Study By GPR

GPR Evaluation of Rootstock Response

UAV Research at JARC Robotics lab

Dr. Yeasmin, 2021 Projects

- A Remote Sensing Approach to Identify Critical Areas in California Orchards for Improving Irrigation Water Management through Precision Agriculture Technology

-Funded by Irrigation Innovation Consortium , Foundation of Food and Agriculture Research (FFAR)

- Water-Smart Planning: A Satellite Imagery based Remote Sensing Approach to Evaluate Crop Water Status in California Orchards

-Funded by Agricultural Research Institute (ARI) Grant

- A Ground Penetrating Radar (GPR) Based Evaluation of Rootstock Response to the Application of Fertilizer of Natural Origin in Orchards and Vineyards to Promote Root Vigor for Long Term Economic Viability

-Funded by Agricultural Research Institute (ARI) Grant

- A Pilot Study on the Effects of Aboveground Manipulation of Light and Microclimate by Opti-Harvest Devices on Root System Development in Agricultural Crops by GPR

-Funded by Opti-Harvest Inc.

- Improving water and nitrogen use efficiency in lettuce by selecting for root characteristics

-Funded by CalPoly Pomona Campus ARI grant

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DR. FLORENCE CASSEL

Research focus this past year: Sorghum

- Why sorghum?
  - Background
    - CA leads dairy production in US; also has large cattle industry.
    - > 7 M tons of feeds produced annually in CA to sustain this production, particularly in Central Valley (CV).
    - Major forages in CA: corn and alfalfa. Corn is predominant in CV but production has been declining after last drought.
  - Sorghum: good potential as forage crop:
    - Drought tolerant; high water and nutrient use efficiency (WUE, NUE).
    - High salinity tolerance (6.8 dS/m vs. 1.7 dS/m for corn).

    ⇨ Could be viable alternative to corn under limited water supplies or in marginal soils in California.

① Development of crop water requirement estimates and new crop coefficients for sorghum

CSUF: Florence Cassel, Shawn Ashkan, Dave Goorahoo; UC: Robert Hutmacher

- Goal: Improving irrigation scheduling, optimizing water use efficiency.
- Team: CSU, UC, private industries.
- Study location: Five Points - UC Westside Research & Extension Center.
- Method:
  - Determination of evapotranspiration (ET) using precision weighing lysimeters (2 m x 2 m x 2.25 m) positioned on mechanical scales.
  - Most accurate method

  → based on water balance approach.

② Yield and Nutritional Quality of Forage Sorghum and Corn Grown under Different Irrigation and Nitrogen regimes

Florence Cassel, Dave Goorahoo

- **Objectives:**
  - Compare yield, WUE, NUE, nutritional quality of sorghum and corn.
  - Determine feasibility of transitioning from furrow to drip, & with deficit practices.
- **Team: CIT, Plant Science, private industries.**
- **Study location: CIT, CSU Fresno.**
- **Method:**
  - 3 irrigation regimes: Drip (100% ET_c), Drip (70% of ET_c), Furrow (100% ET_c)
  - 4 Nitrogen fertilizer rates: 0, 84, 168, and 252 kg N ha^{-1}

- **Key results of 2-year study:**
  - **Sorghum outperforms corn in terms of yield, WUE, and NUE, irrespective of irrigation methods, level of water application, and N fertilization rates.**
  - **Under deficit irrigation, sorghum produced greater biomass per unit of water applied.**
  - **Sorghum yield can be sustained with low N rates (84 kg N ha^{-1}).**
  - **Sorghum had lower protein and higher fiber content → more adapted to low-energy animal diets, in regions of limited water supplies.**

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DR. DAVE GOORAHOO

Effect of AirJection Irrigation on Soil Nitrogen Cycle Gene Communities

D. Goorahoo[1,2], F. Cassel S.[1,2], L. Dejean[3] , and C. Muraka[1,2]

[1]Department of Plant Science, CSU Fresno

[2]Center for Irrigation Technology, CSU Fresno

[3]Department of Chemistry, CSU Fresno

CSU ARI PI meeting
October 23, 2020

Potential of AirJection to Optimize WUE and NUE

- **Generally, AirJection® Irrigation led to a proportional increase of Bacteria versus Archaea.**

- **While the AirJection Irrigation did not have a significant impact on nitrogen fixation or ammonia oxidation, the practice of adding aerated water via the buried drip line did have a significant impact on denitrification genes suggesting lower NOx production potential and thus likely increased availability of nitrate in the root zone.**

- **This might be hypothesized to enhance nitrogen use efficiency potential with AirJection, and with the judicious water management within the root zone, plant nitrate uptake can be enhanced with a potential reduction in nitrate leaching.**

Quantifying Antioxidant Glutathione Levels in Tomato Leaves and Fruits

C. Muraka[1,2] , L. Dejean[3] , F. Cassel S.[1,2], and D. Goorahoo[1,2]

[1]Department of Plant Science, CSU Fresno

[2]Center for Irrigation Technology, CSU Fresno

[3]Department of Chemistry, CSU Fresno

FRESNO STATE
Jordan College of Agricultural Sciences and Technology

CSU ARI PI meeting
October 23, 2020

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CIT in the Future

- Maintain focus on 3rd party testing, applied research, entrepreneurship, and education
- Expand scope to include software testing of irrigation management tools

➢ Convergence of sensing & control components into fully automated systems

➢ Increasing adoption of management software

➢ Testing algorithms separately from hardware

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Thank You!

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BACKUP SLIDES

Irrigation Innovation Consortium

Who We Are: Irrigation industry leaders, researchers, and other partners working together to advance efficient and effective water management

Our Mission: To drive development and adoption of advanced irrigation technologies and strategies

What We Do: We support collaborative research, training, and demonstrations, to generate and share useful, actionable knowledge.

IRRIGATION INNOVATION CONSORTIUM

Water for Food
DAUGHERTY GLOBAL INSTITUTE
at the University of Nebraska

TEXAS A&M AGRILIFE RESEARCH

Regional Collaborators

FRESNO STATE
Discovery. Diversity. Distinction.

COLORADO STATE UNIVERSITY

K-STATE
Research and Extension

IRRIGATION INNOVATION CONSORTIUM

IIC Partners

IRRIGATION INNOVATION CONSORTIUM

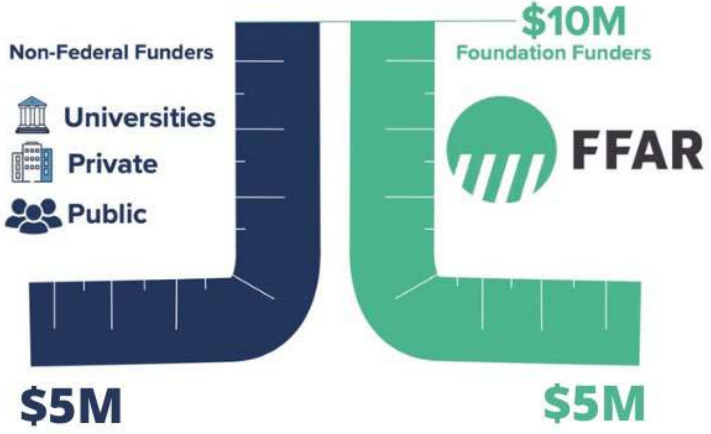
Driving adoption
Improving tools
Managing critical water resource challenges

Our Activities:

- Integrating irrigation management technologies
- Supporting cost-effective and scalable tools
- Encouraging effective irrigation scheduling and water delivery
- Training for advanced water management
- Building diverse knowledge networks
- Demonstrating potential benefits and savings (water, labor, other)
- Harnessing the creativity and capacity of public and private partners

IIC by the Numbers

- ~$4 million invested since via project partner contributions and FFAR match
- 30+ high-quality, collaborative research projects
- 45+ private & public entities have contributed expertise or matching support
- More than 150 researchers involved and students trained

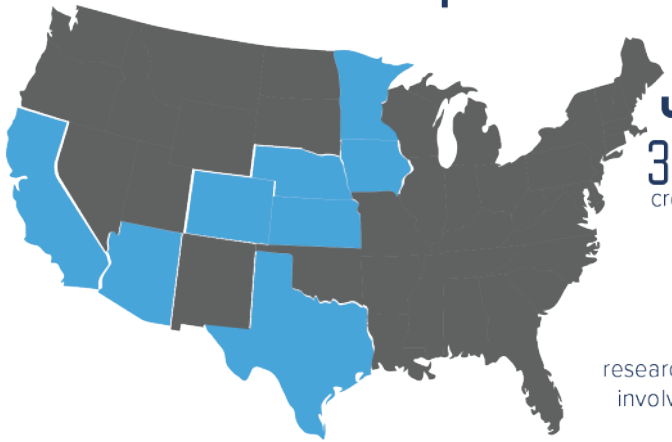


2018-2021 $2.5M allocated by IIC to support research, matched ~1:1 for an investment of >$5M.

45 private companies and public entities have supported IIC research efforts through contributing expertise, to the research itself, or matching support.

Each IIC-supported research project has at least one industry partner and one IIC-affiliated university partner.

Research Footprint



JOBS

34.5 created

75 sustained

150 researchers and students involved in IIC reseach

*In addition to the highlighted states, IIC-supported a study of the economic impact of the irrigation industry industry in the United States that will be released in fall 2021.

"IIC connected us with other researchers and industry experts."
Trenton Franz, UNL

Research Based Best Practices for Smart Controller Implementation

Michael Dukes, University of Florida/IFAS

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Research Based Best Practices for Smart Controller Implementation

American Society of Irrigation Consultants Conference
New Orleans, LA
Apr. 26, 2022

Michael D. Dukes, PhD., P.E., C.I.D.

Agricultural & Biological Engineering

University of Florida/IFAS

Florida in 2018

- 4th fastest growing state
- 20.61 million as of 2018

From Florida 2070: http://1000friendsofflorida.org/florida2070/

Water 2070

- +15 million people
- Development related water demand +100%
- **“The single most effective strategy to reduce water demand in Florida is to significantly reduce the amount of water used for landscape irrigation.”**

http://1000friendsofflorida.org/water2070/wp-content/uploads/2016/11/water2070summaryreportfinal.pdf

Goodbye ~~grass~~ irrigation

MENU

SOUTHERN NEVADA WATER AUTHORITY

Removing "useless" grass

A law enacted by the Nevada Legislature in 2021 prohibits using Colorado River water delivered by Water Authority member agencies to irrigate nonfunctional grass.

The law requires the removal and/or replacement of this grass throughout Southern Nevada at commercial, multi-family, government and other properties. It does not apply to grass in homeowners' yards, or to grass used for recreation at schools and parks.

Nonfunctional grass must be removed or replaced by the end of 2026.

Removing this grass in our valley will reduce Southern Nevada's Colorado River consumption and protect our community's water supply.

The Water Authority Board of Directors established a citizens advisory committee to help the Water Authority implement the new law. Their activities included defining what constitutes "nonfunctional" grass.

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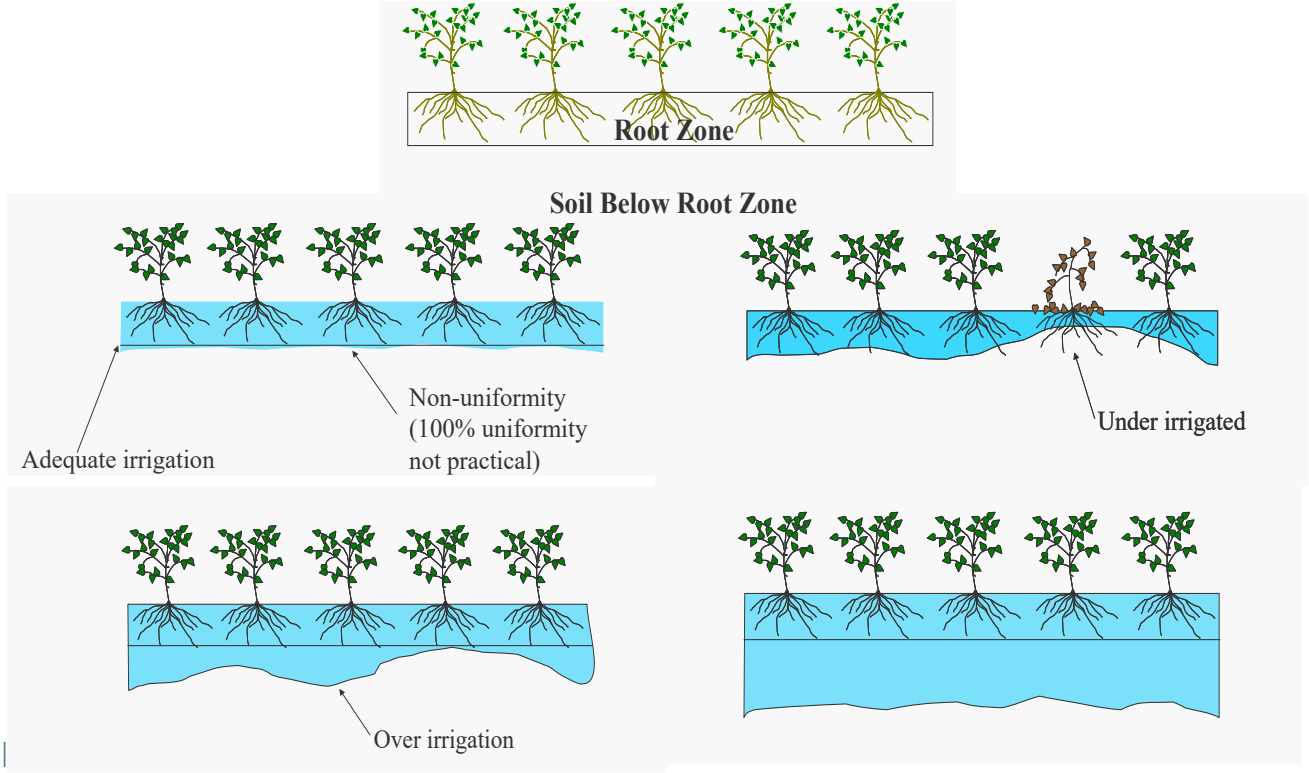
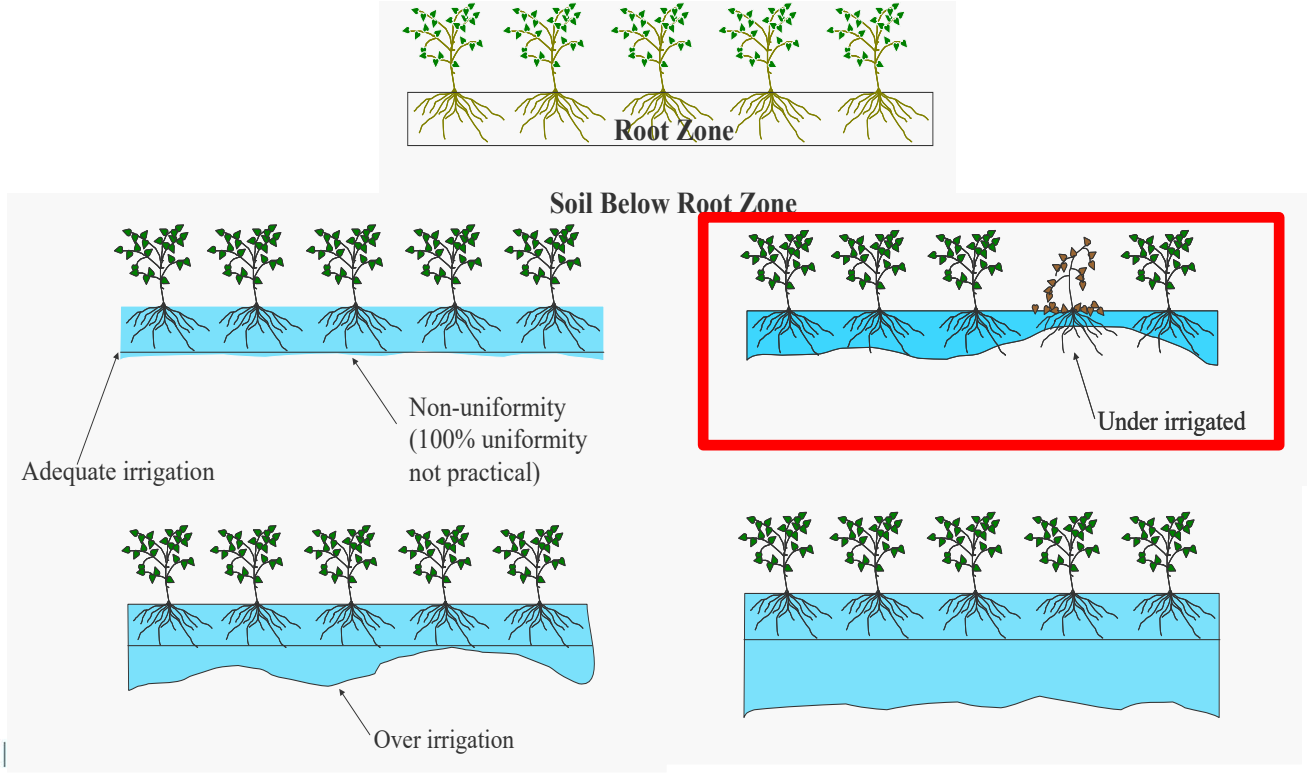
Irrigation Efficiency:
Design/maint. + Management



Irrigation Efficiency:
Design/maint. + Management



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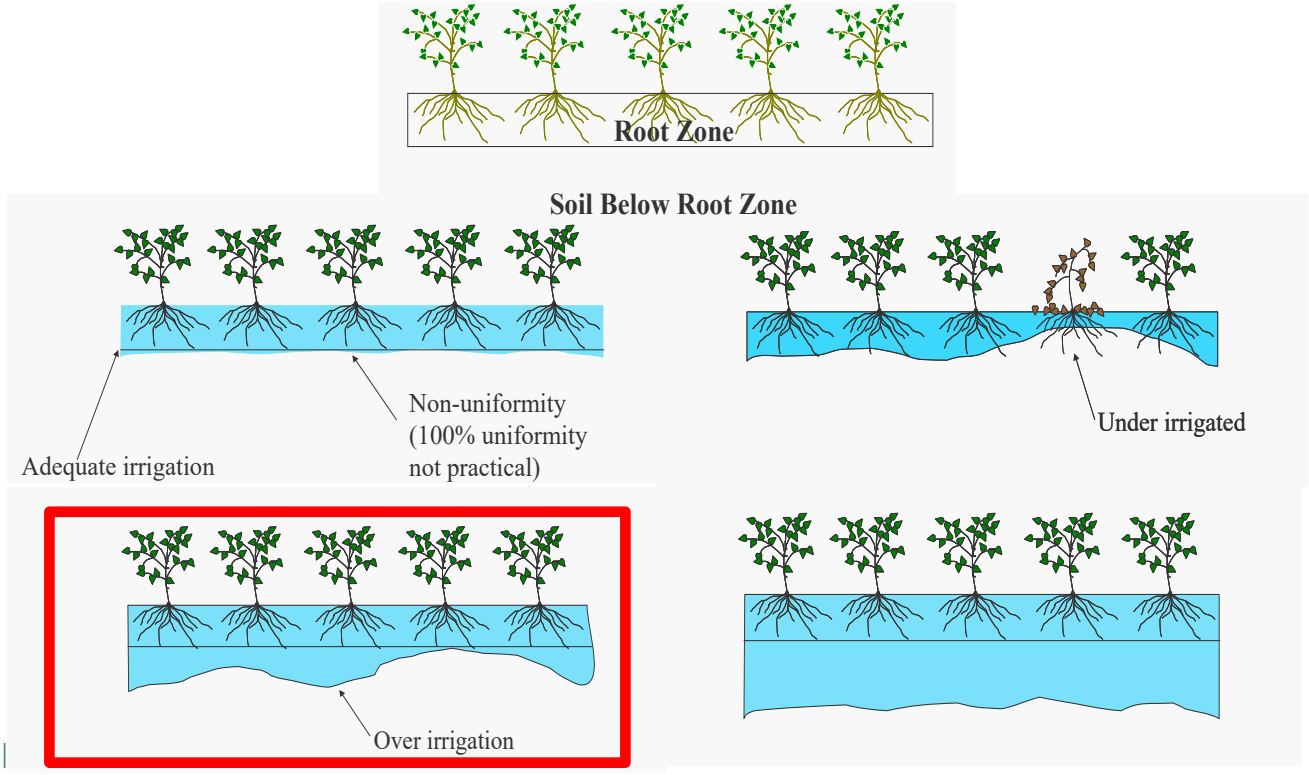

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Broken Sprinklers

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Photo credit: Mary McCready

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What's Wrong Here?

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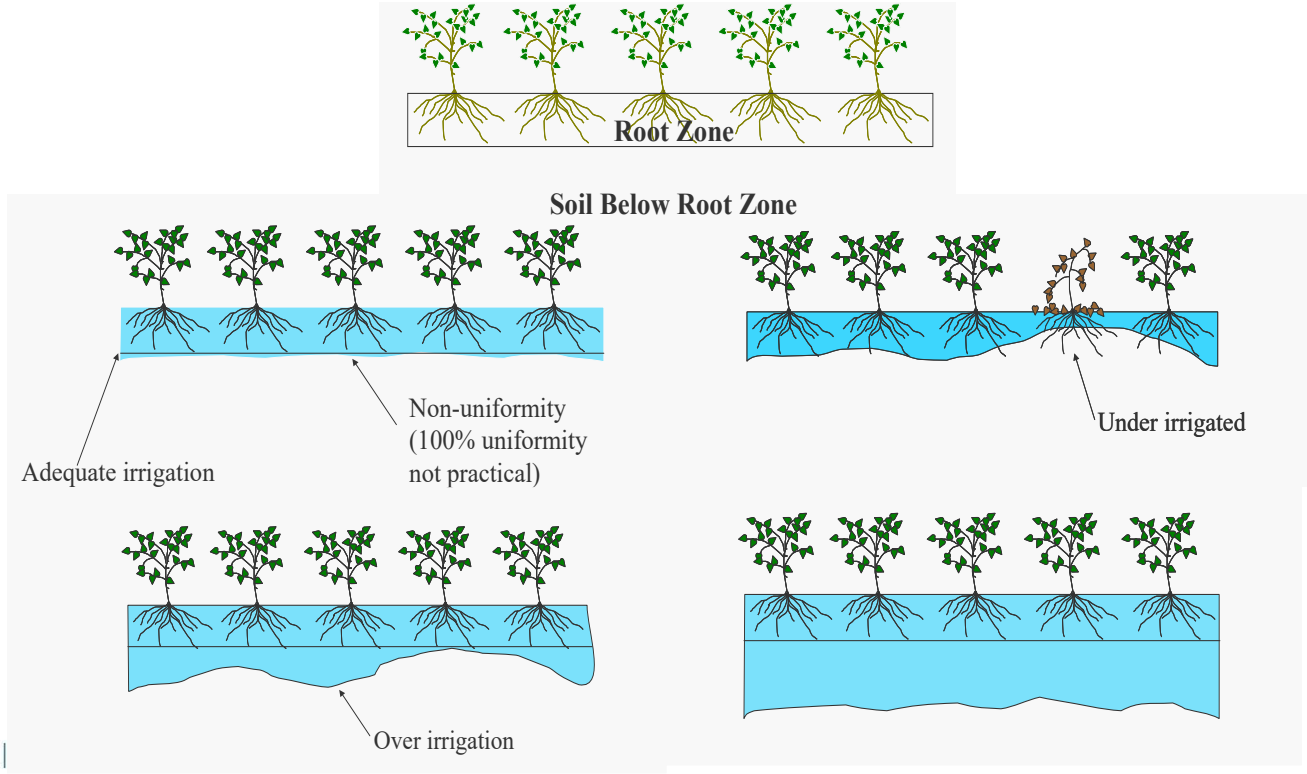
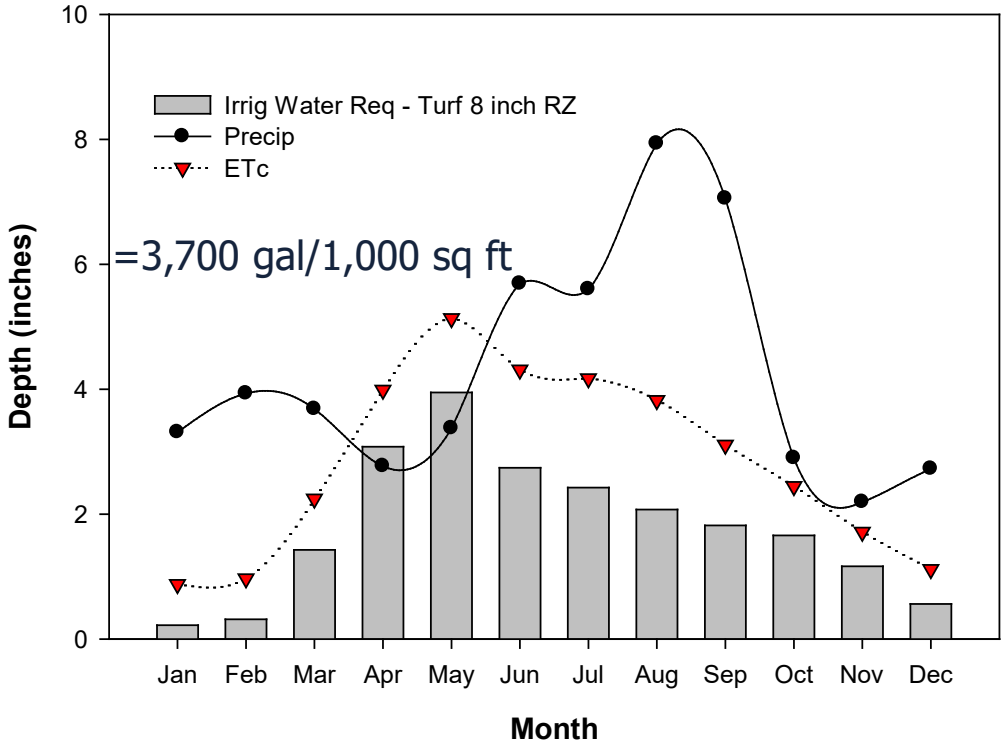
Irrigation Efficiency:
Design/maint. + **Management**



Irrigation Requirements

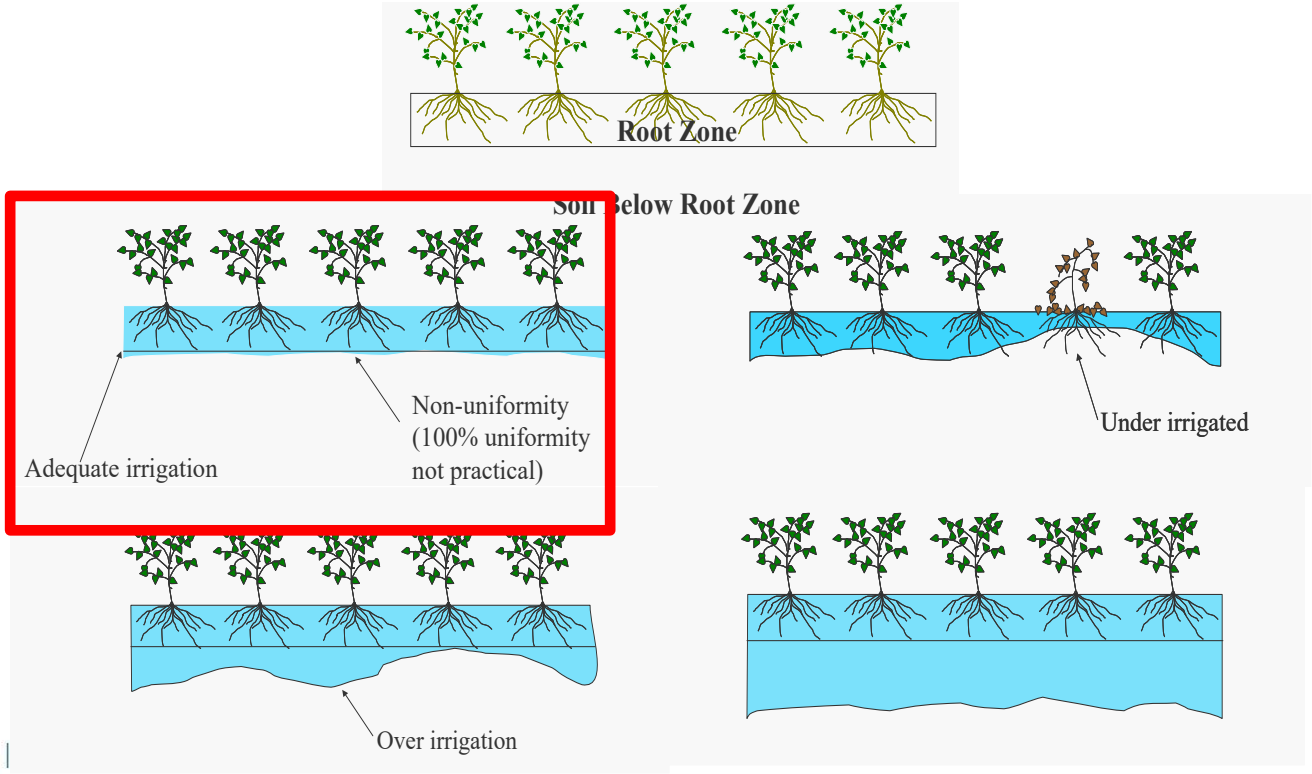
1” = 623 gal/1,000 sq ft



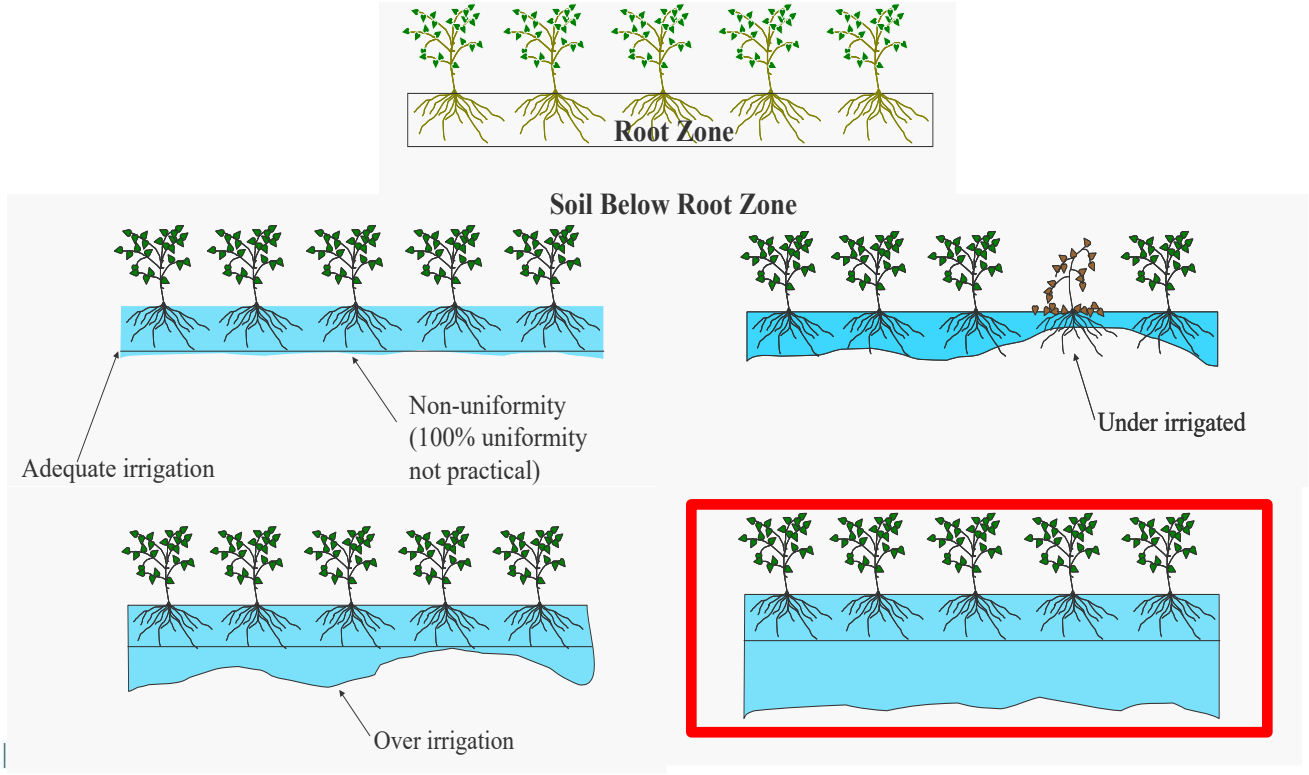
Turfgrass Annual Water Req.

N FL, 33 inches/yr
S FL, 43 inches/yr

Irrigation Efficiency:
Design/maint. + **Management**

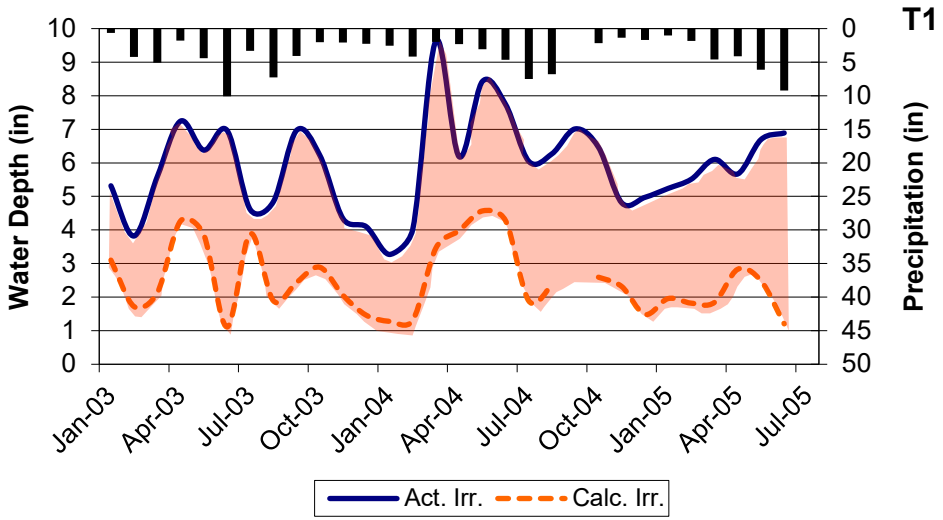


Irrigation Efficiency:
Design/maint. + **Management**



Central Florida – Typical Irrigator

- Irrigation:
  - Actual, 70 inches/yr
  - Max need, <30 inches/yr
- Rainfall, 50 inches/yr



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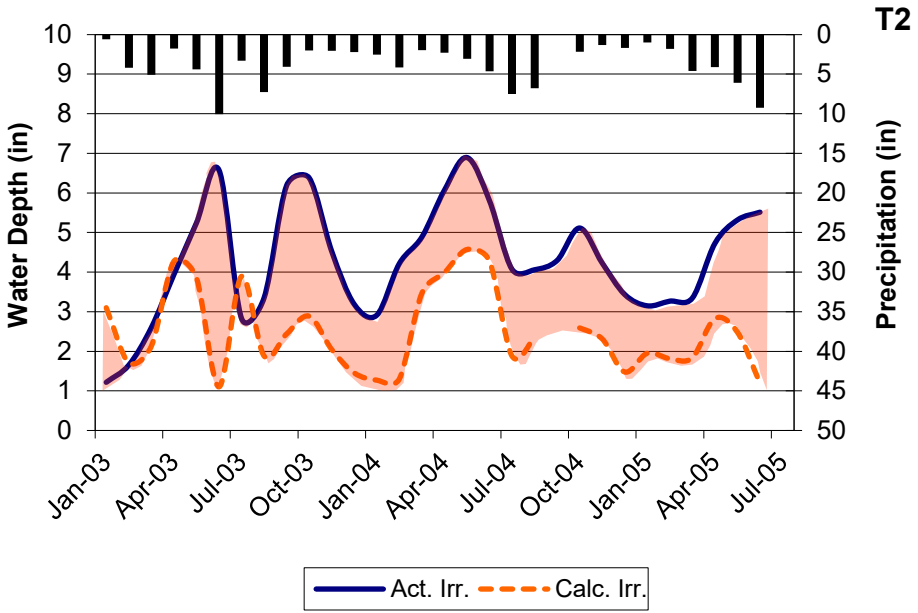
Smart Irrigation Controller

The **Irrigation Association** defines "**smart controllers**" as **controllers** that reduce outdoor water use by monitoring and using information about site conditions (such as soil moisture, rain, wind, slope, soil, plant type, and more), and applying the right amount of water based on those factors".

(www.**irrigation.org**)

Central Florida – Monthly Time Clock Adjustment

- 30% savings by adjusting time clock monthly



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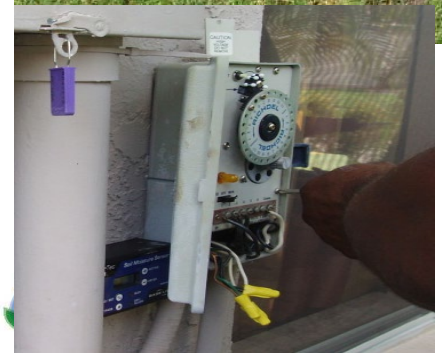
Soil Moisture Sensor (SMS) Controller



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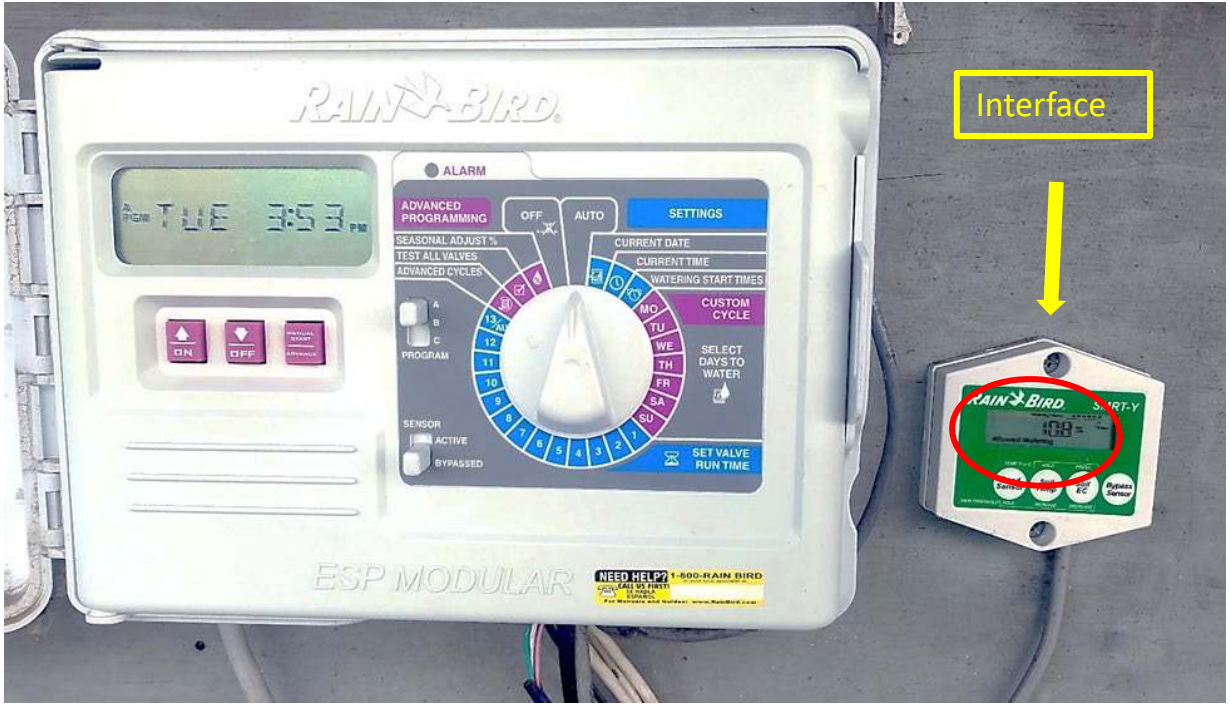
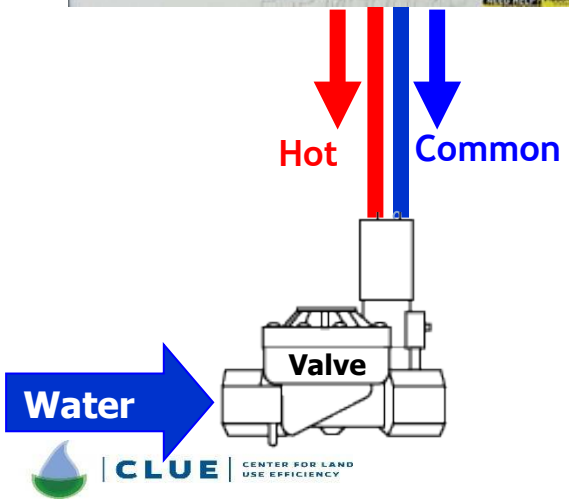
SMS controller connected to the timer



Time



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Water content (7%) below the set point (12%)

Common

Water

Valve

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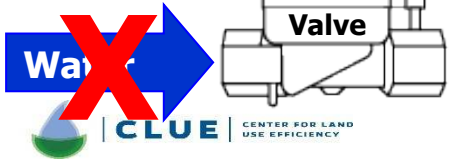
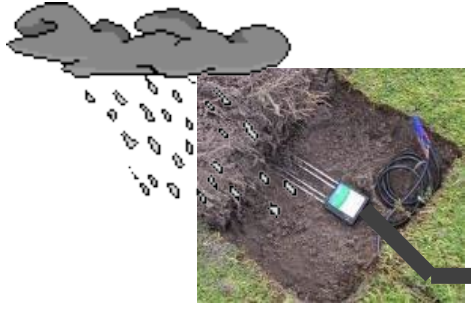
Water content (13%) above the set point (12%)

Common





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SMS Probe Location

SMS Probe Location

Probe Installation

- How deep?
  - In the root zone
  - Where most roots are
  - Rule of thumb: the center of the sensor should be ~3” deep

SMS Probe Installation

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SMS Calibration

First: Saturate the soil where the probe is

Bucket or hose method

Manual start of the zone

Programming Timer (Base Controller)

- Follow local restrictions
- Schedule events as frequent as needed to meet plant demands
  - E.g. 2 events/d; 3 d/wk FL conditions
- Runtime should be set to replace ET
  - 1.5 in/wk ET
  - 0.5 in/d; 3 d/wk → runtime depends on application rate

Initial Plot SMS Studies – Rainy Conditions

Treatment	TOTAL (in)	Savings compared to 2-WOS (%)
2-WOS	59.6	0
SMS Based		
Avg	16.5	72
1-d/w	16.5 *b*	72
2-d/w	18.8 *a*	68
7-d/w	14.3 *c*	76

WOS = without sensor
SMS = soil moisture sensor
Avg = average

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Turfgrass Quality

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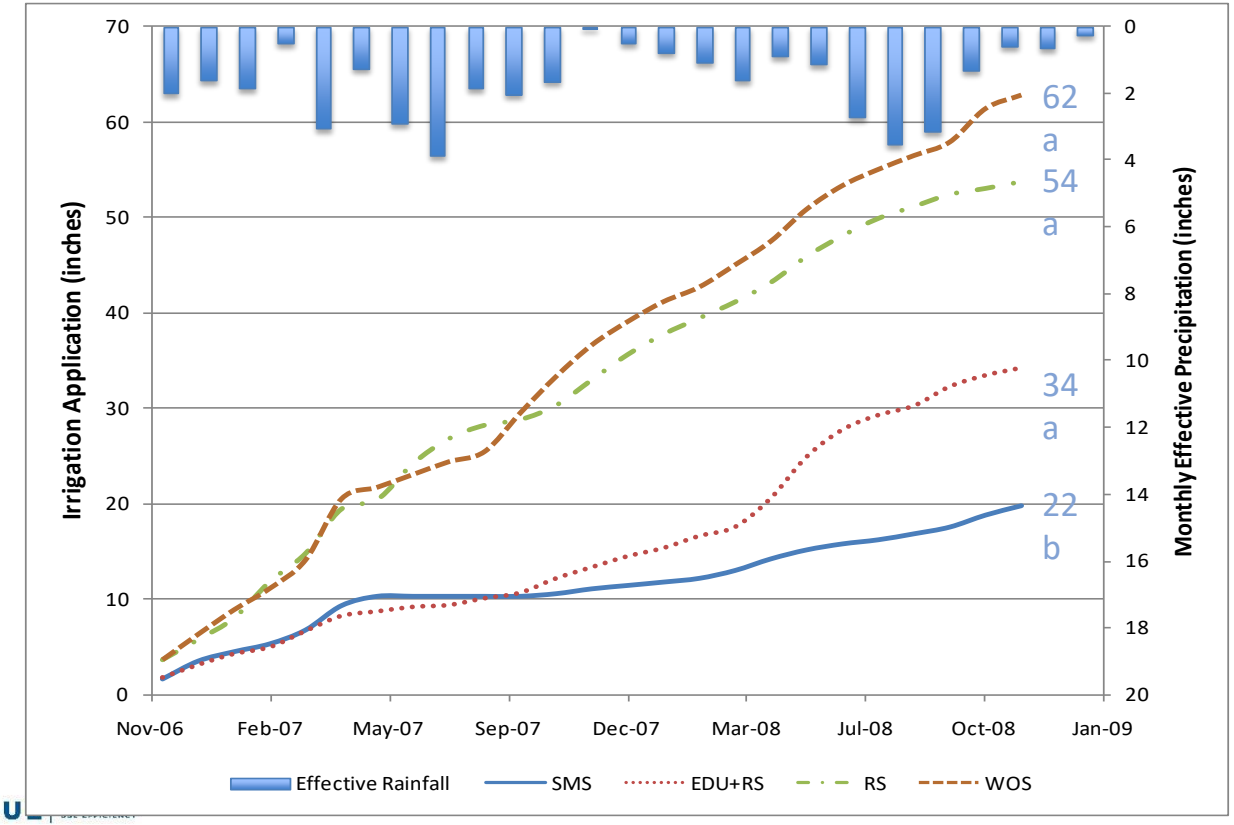
Initial Plot SMS Studies – Dry Conditions

Treatment	TOTAL (in)	Savings compared to 2-WOS (%)
2-WOS	25.9	0
SMS Based		
Avg	11.9	54
1-d/w	14.9 *a*	43
2-d/w	11.7 *b*	55
7-d/w	9.2 *c*	64

WOS = without sensor
SMS = soil moisture sensor
Avg = average

Pinellas County Homes, Irrigation
Nov 06 – Dec 08



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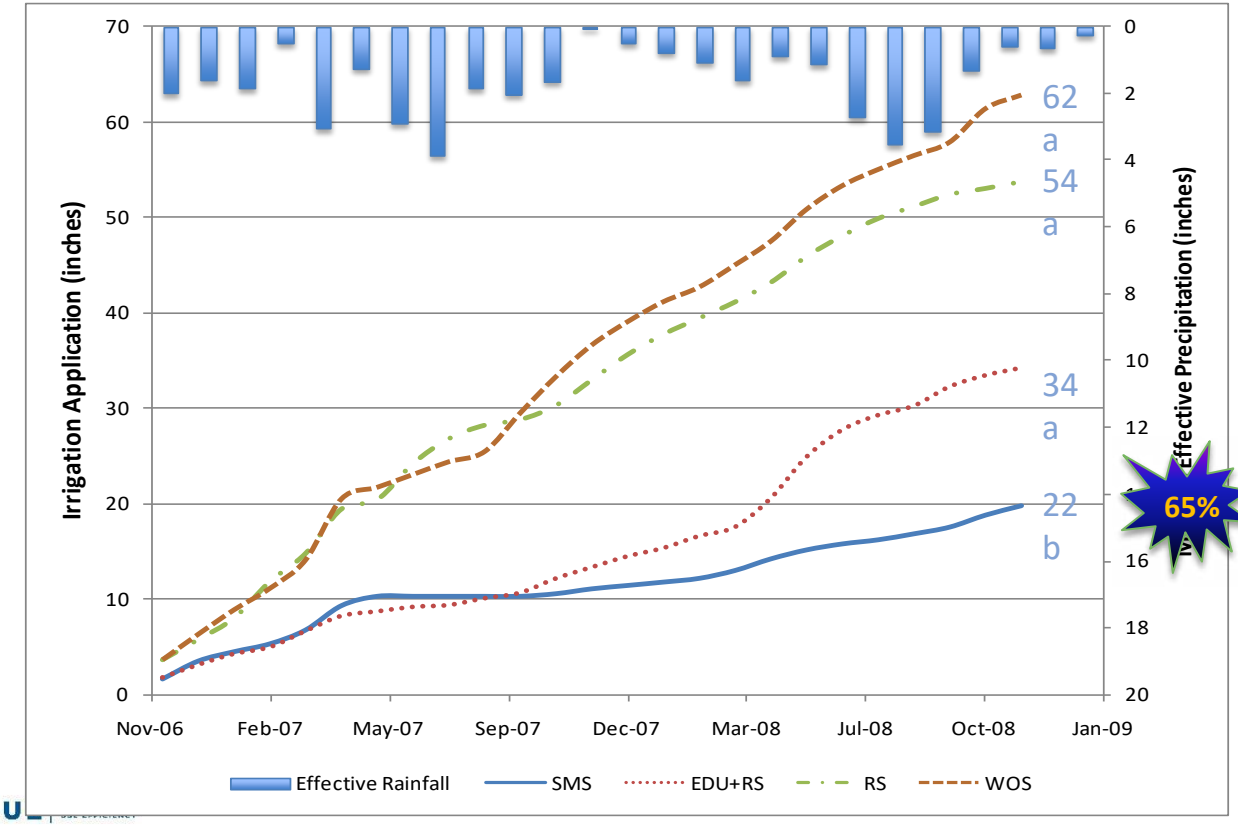
Pinellas County Homes, Irrigation *Savings* Nov 06 – Dec 08



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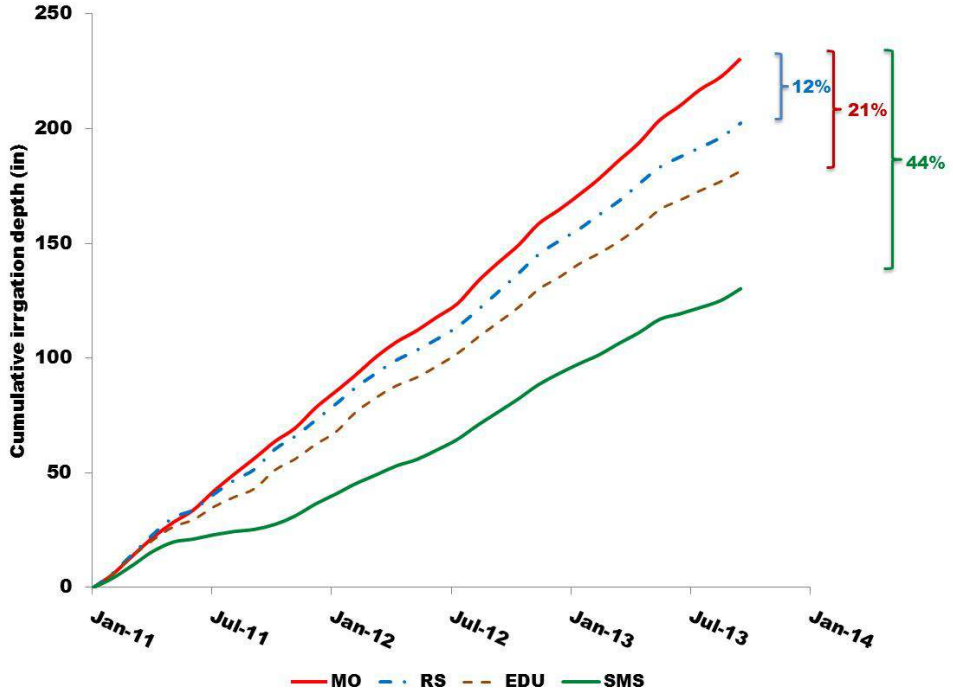
Pinellas County SMS Homes with Reclaimed Irrigation Water



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Evapotranspiration (ET) Controllers

Signal

Onsite weather measurement

How Do ET Controllers Work?

- Soil moisture balance
  - Daily ET measure or signal
  - Irrigation calculated
- % adjust
  - Base schedule input for peak demand (e.g. May runtimes)
  - Adjust based on local measurement
- Replace ET since last irrigation

Programming ET Controllers

- Inputs
  - Application rate of zone
  - Plant type
  - Microclimate or
  - Base schedule for region
- Weather data
  - Onsite
  - Remote

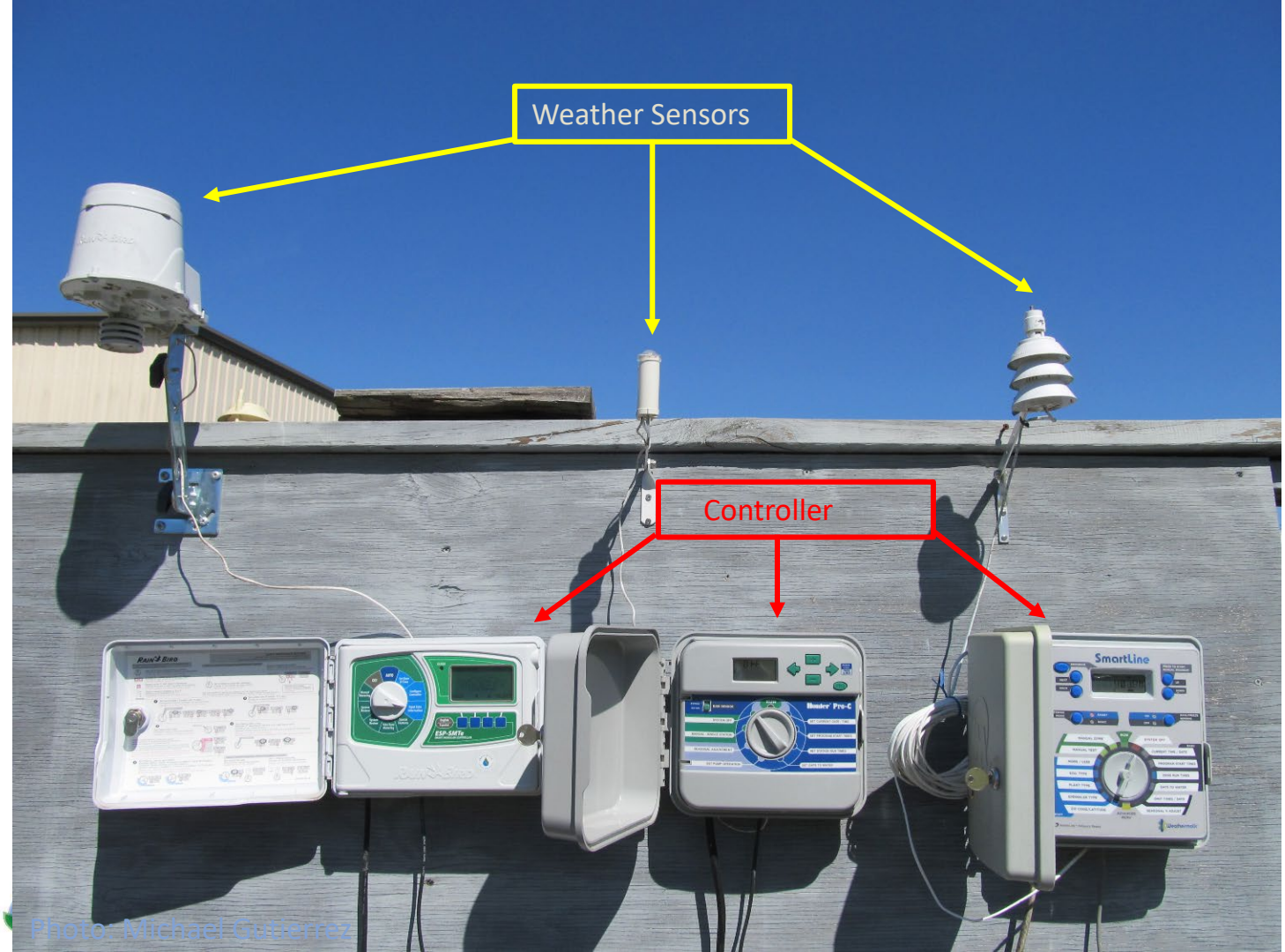

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Photo: Michael Gutierrez

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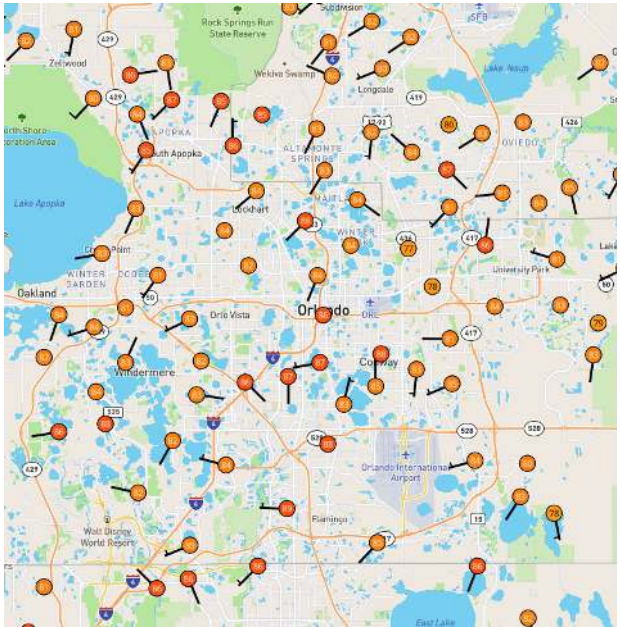
RAIN BIRD

Weather Stations = Maintenance Req'd

Signal-Based & Data



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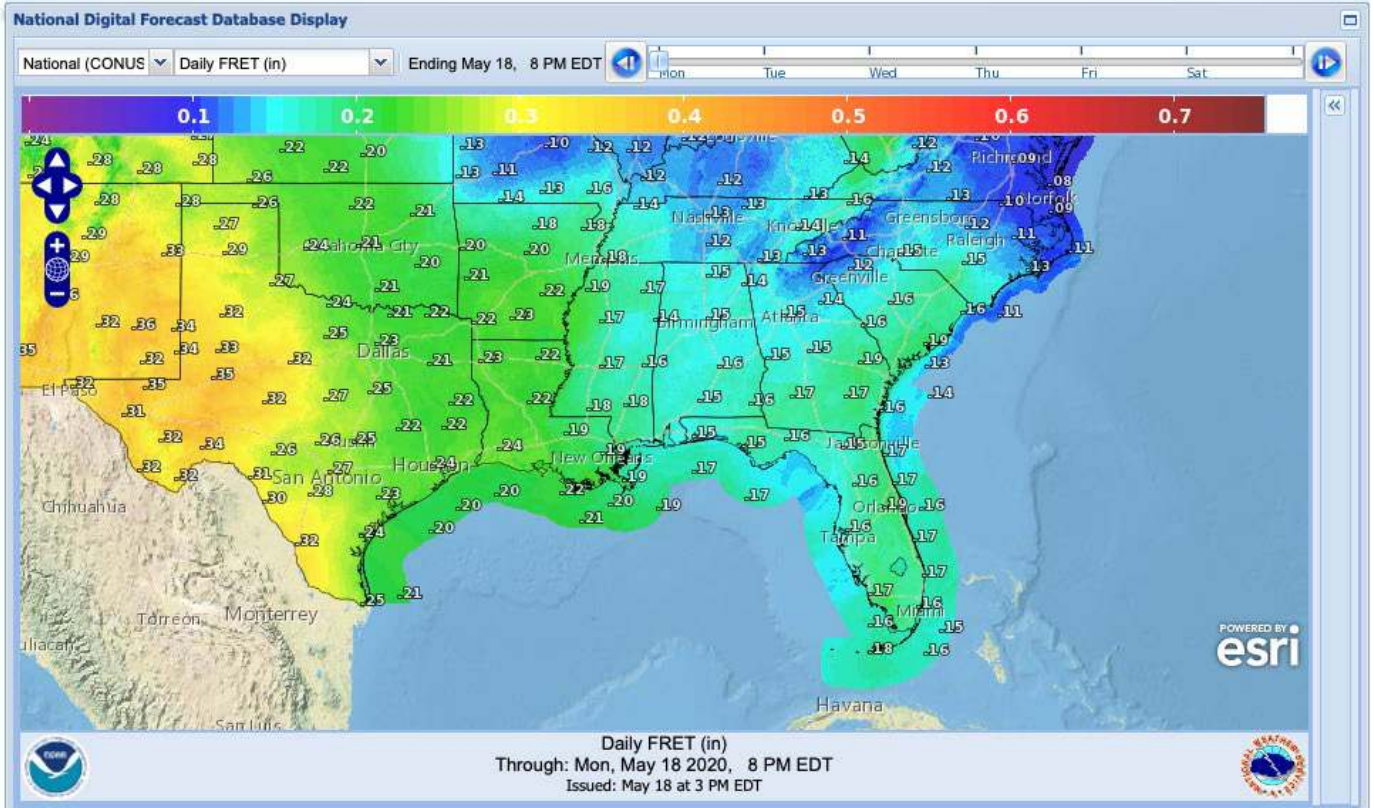
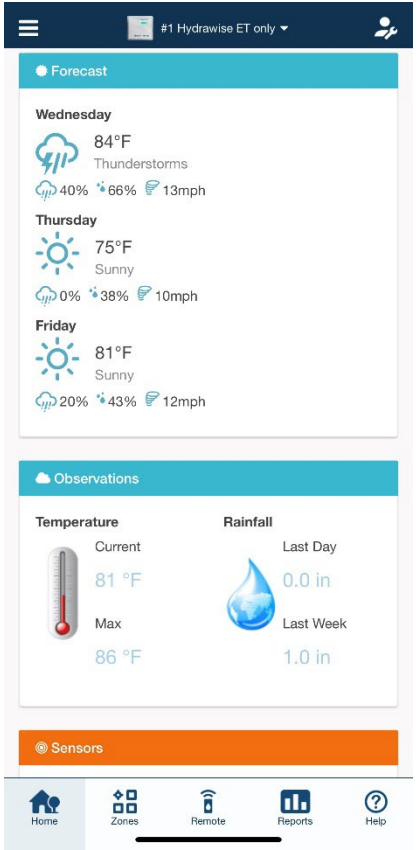
Graphical Forecasts

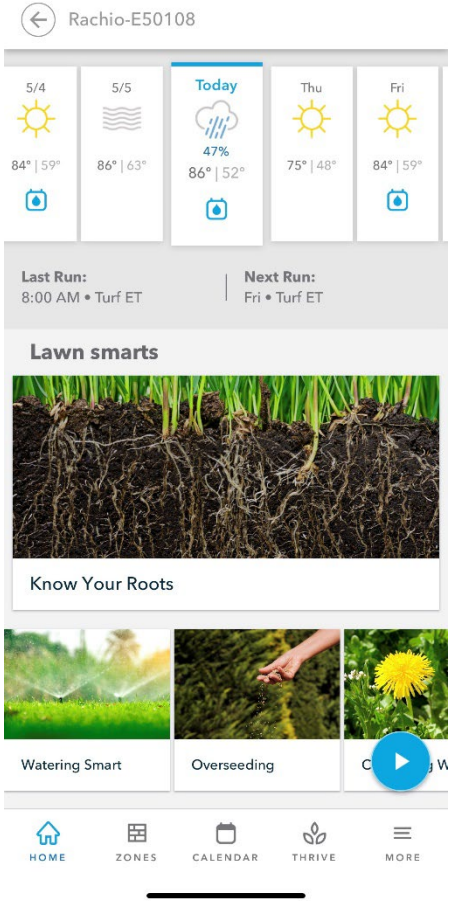
Weather.gov - National Digital Forecast Database Graphical Forecasts

National Weather Service
National Headquarters



App-Based ET Controllers





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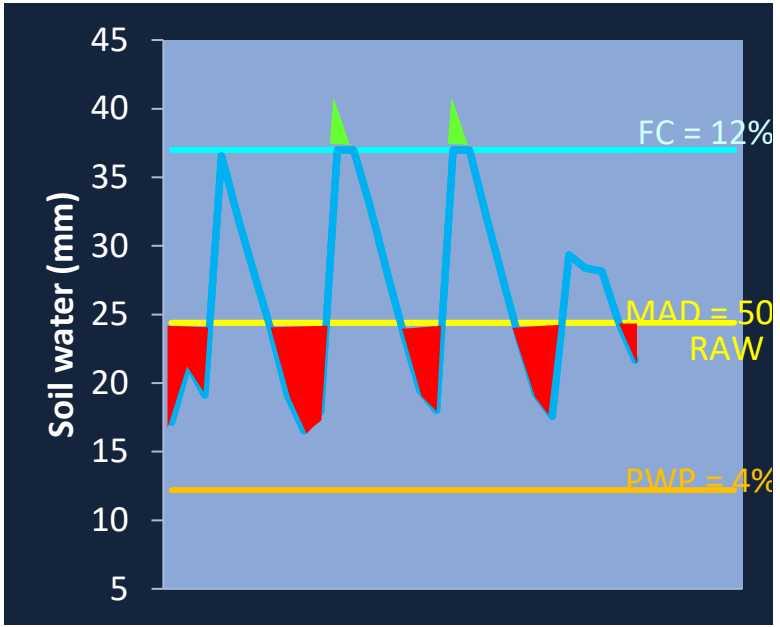
Comparison of Smart Controller Performance Simulation

- 5 years, 2002-06, Citra, FL

- ET-MB
- ET non-MB
- SMS bypass
- SMS on-demand
- No Irrig.
- Timer
- IFAS Time

Smart Controllers – Managing Soil Moisture

- Surplus: Irrigation exceeding water holding capacity
- Deficit: Lack of irrigation to meet plant needs



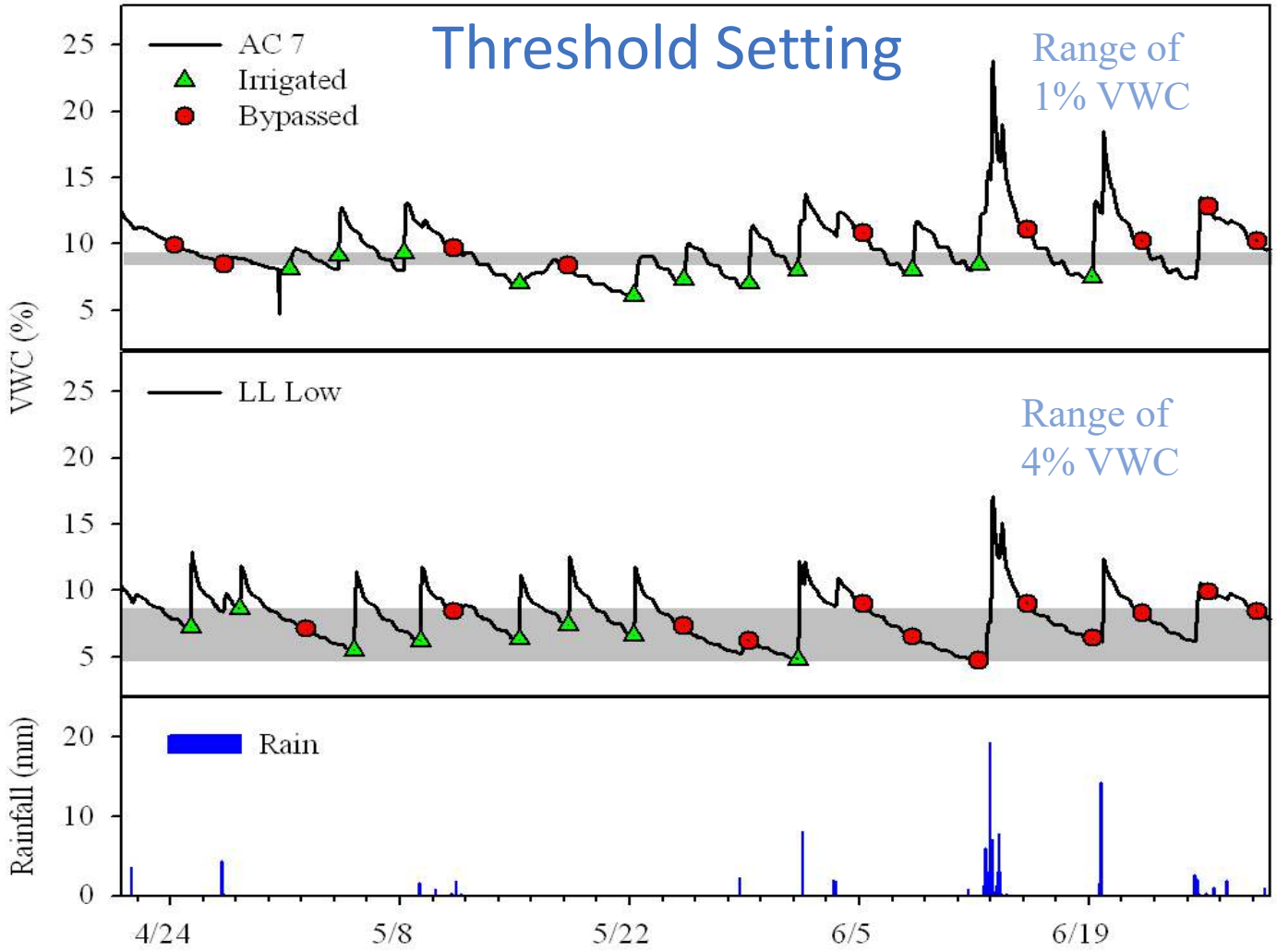
ET Algorithms

- ET-MB
  - Irrigates when soil moisture reaches 25%, irrigating up to 75% of RAW
  - Incorporates onsite rainfall into SMB
- ET non-MB
  - Irrigates M, Th
  - Application depth = 0.53”/event for June ET
  - Percent adjust relative to June ET of 0.14”/d
  - No irrig if rain >0.25” within previous 48 hour

SMS Algorithms

- SMS bypass
  - Irrigation window each day
  - If soil moisture <75% RAW
  - 0.23” applied (~25% of RAW)
- SMS on-demand
  - Irrigation any day
  - If soil moisture <10% RAW
  - Irrigates up to 90% RAW

Threshold Setting



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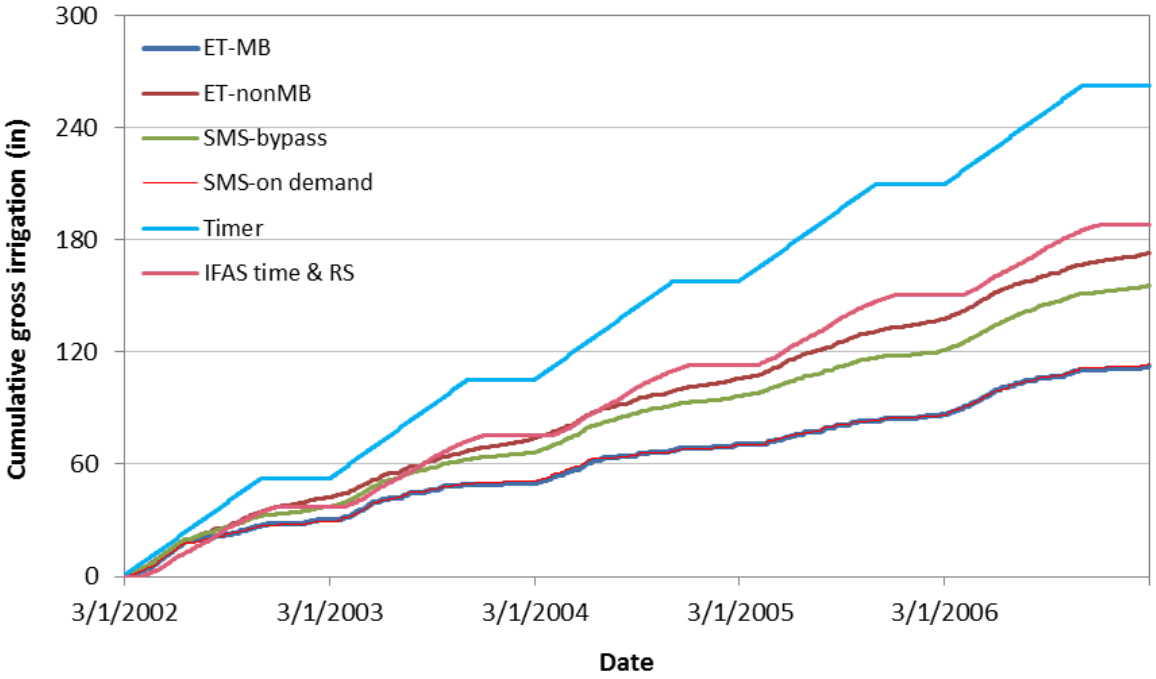
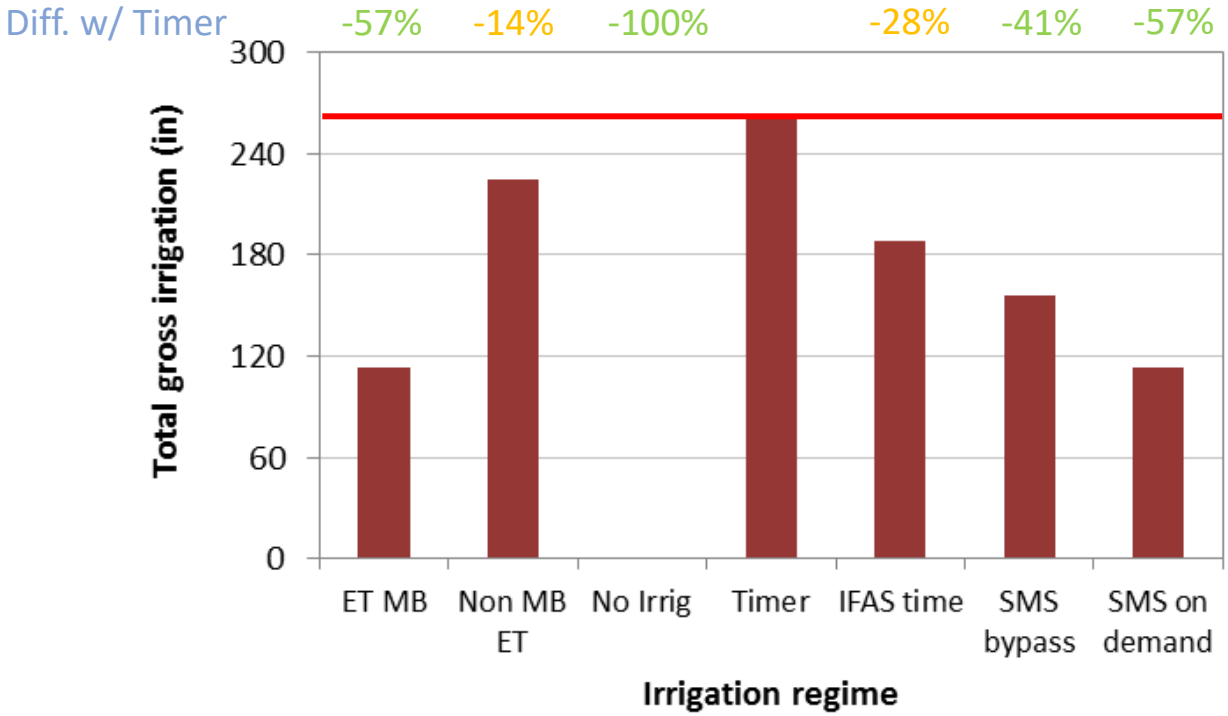
Time Schedules

- No Irrig.
- Timer
  - Mar- Oct irrigation
  - M, Th irrigation cycles
  - 0.75” gross irrig./cycle
- IFAS Time & RS
  - IFAS runtime recc., Apr-Nov, 0.35-0.70 in/event, 2 d/wk
  - No irrig if rain >0.25” within previous 48 hour

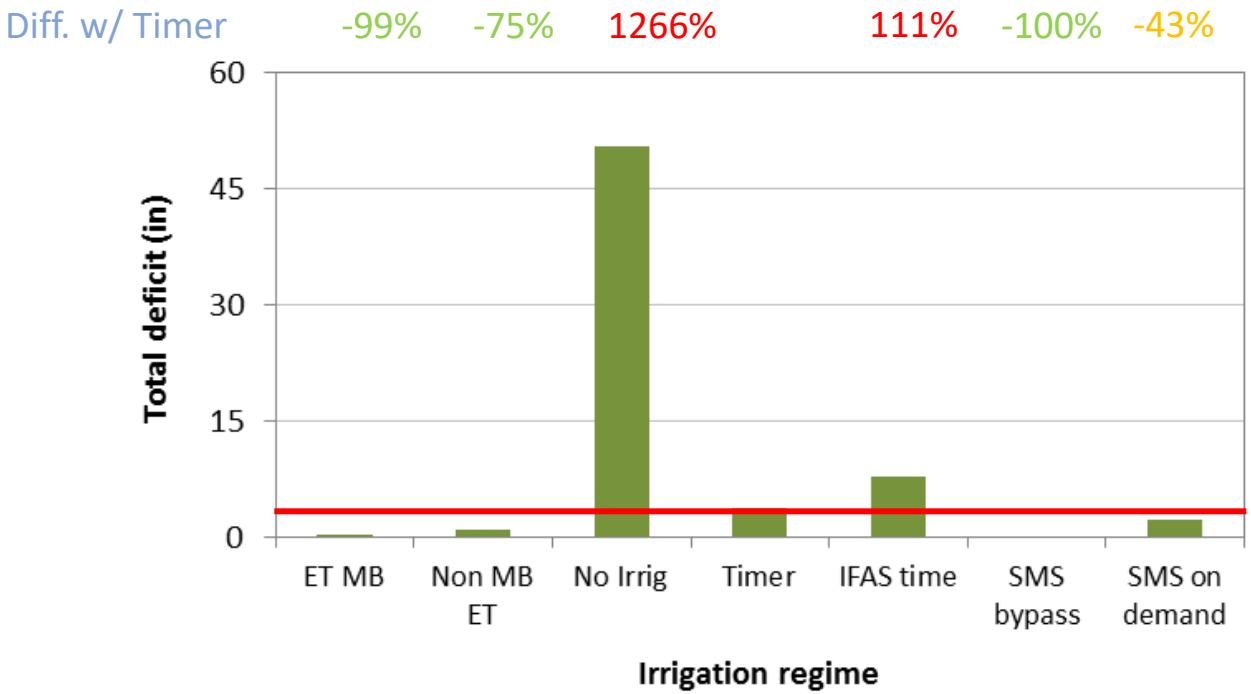
Gross Irrigation



Cumulative Gross Irrigation

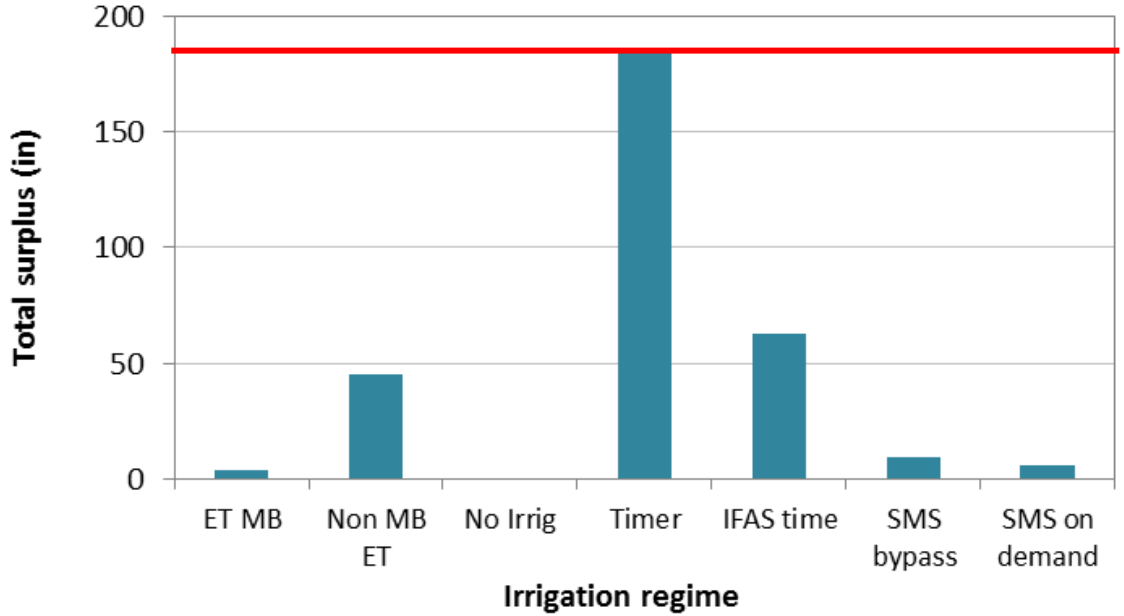


Cumulative Deficit

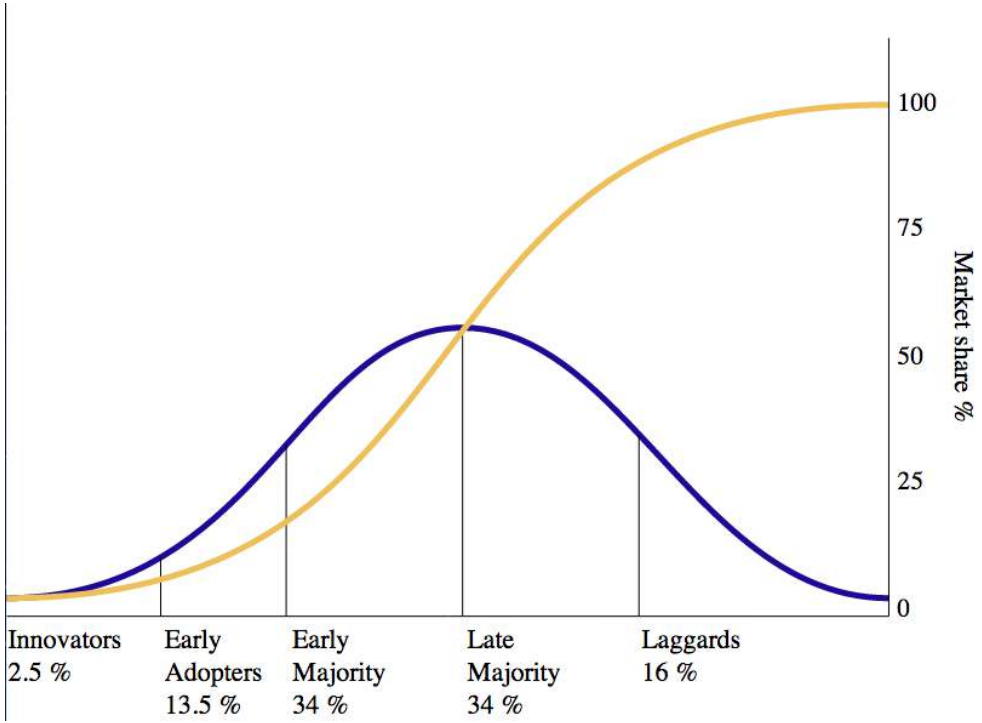


Cumulative Surplus

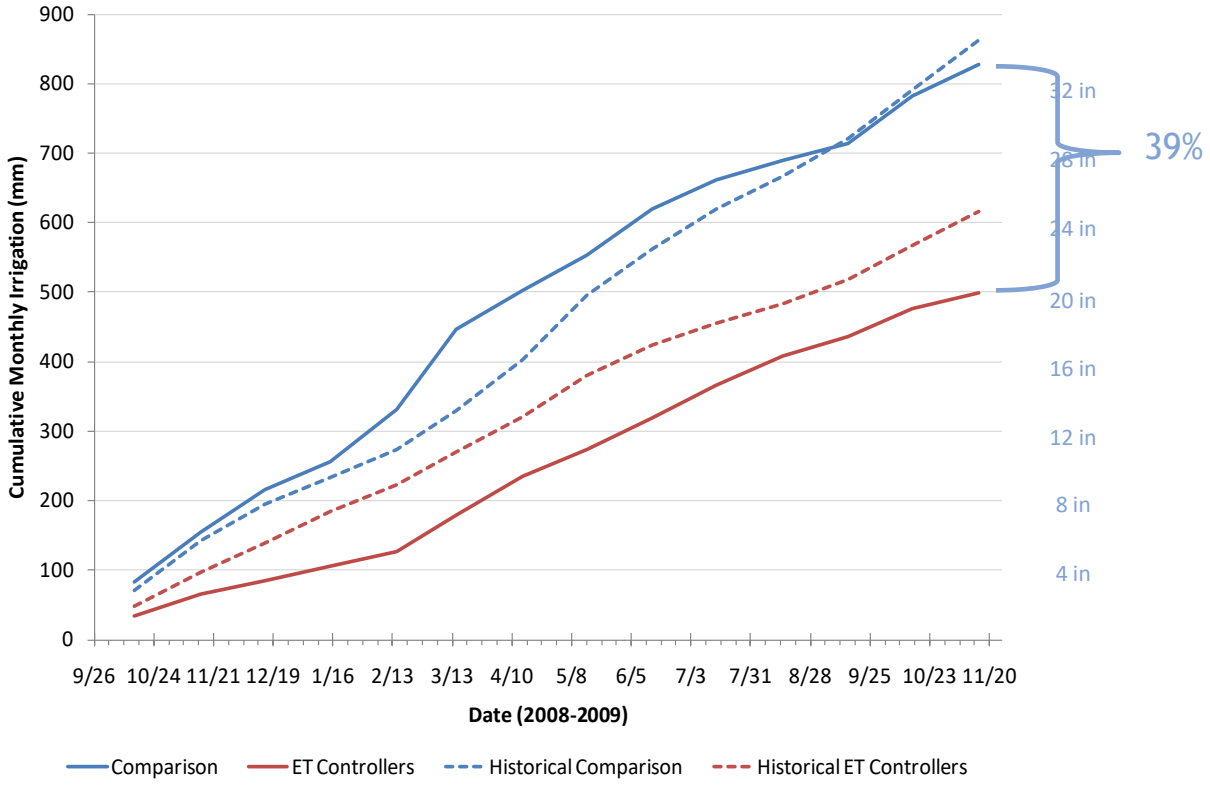
Diff. w/ Timer -98% -75% -100% -66% -95 -97%



Adoption of Technology



ET Controllers - Some Homes Have Water Savings



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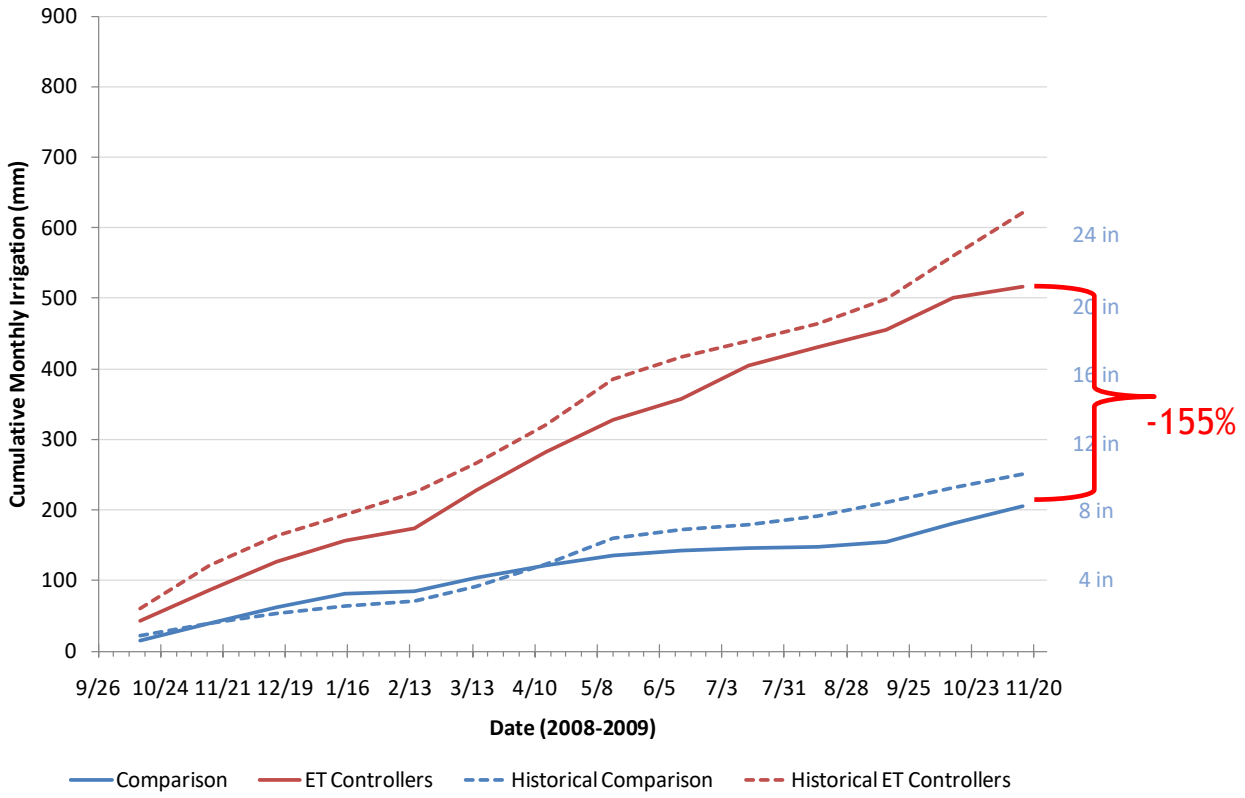
…..And Some Homes Have Increased Usage



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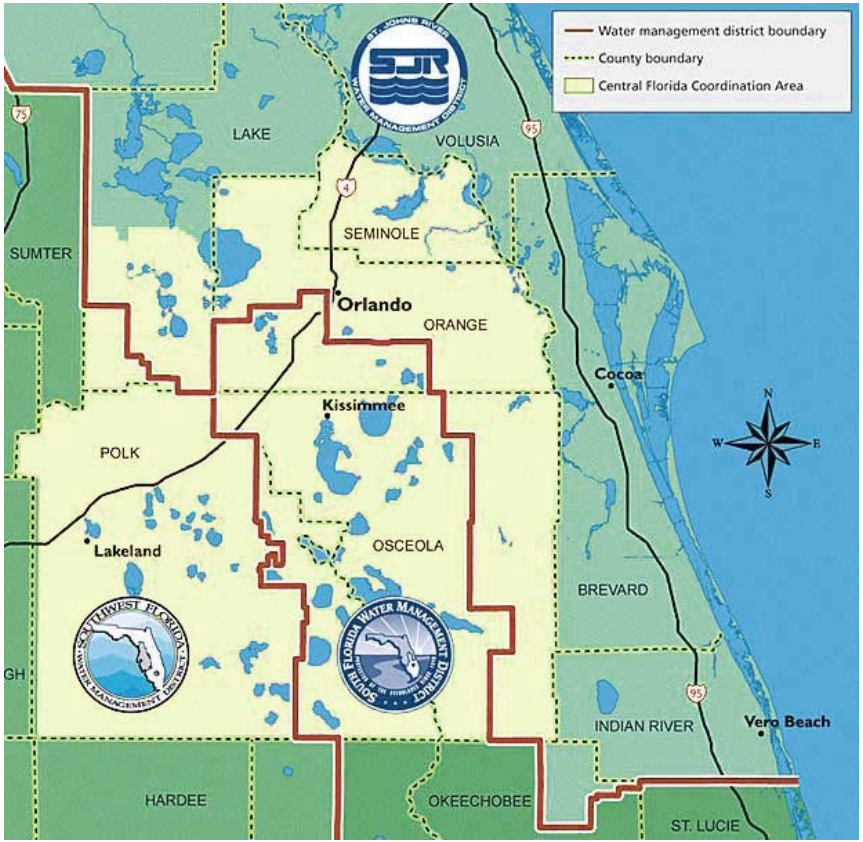
Orange County Utilities Smart Controller Project



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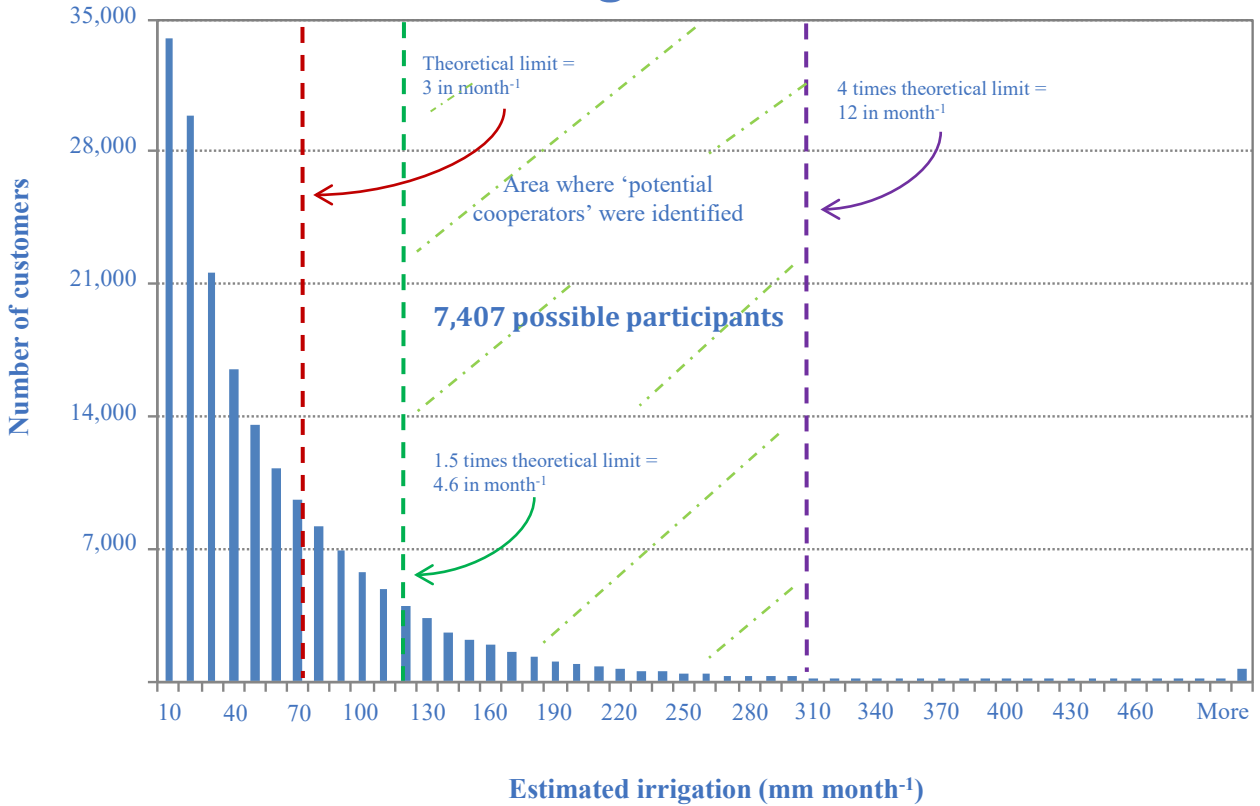
Orange County Evaluation Selection of Excess Irrigators



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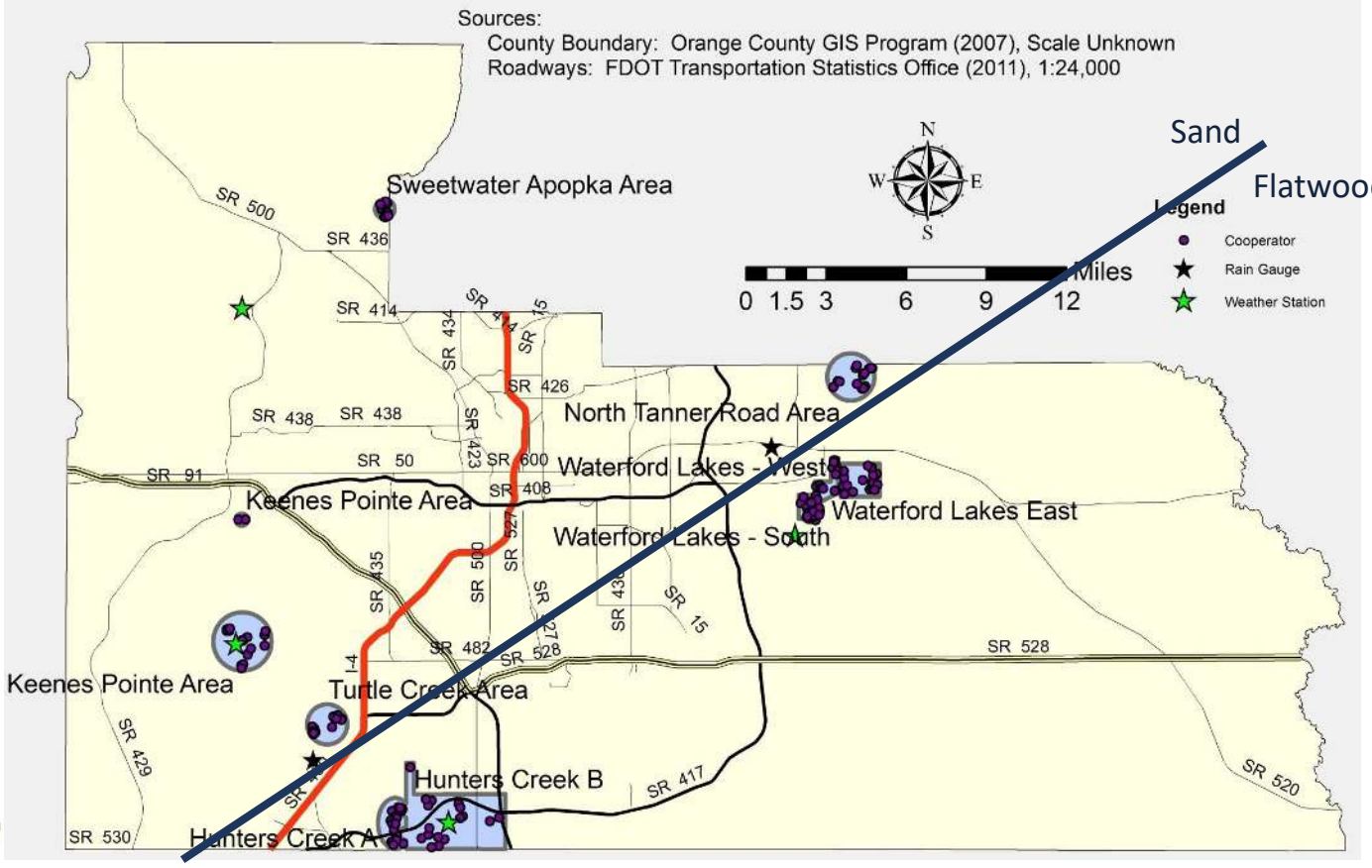
Summary of Participants



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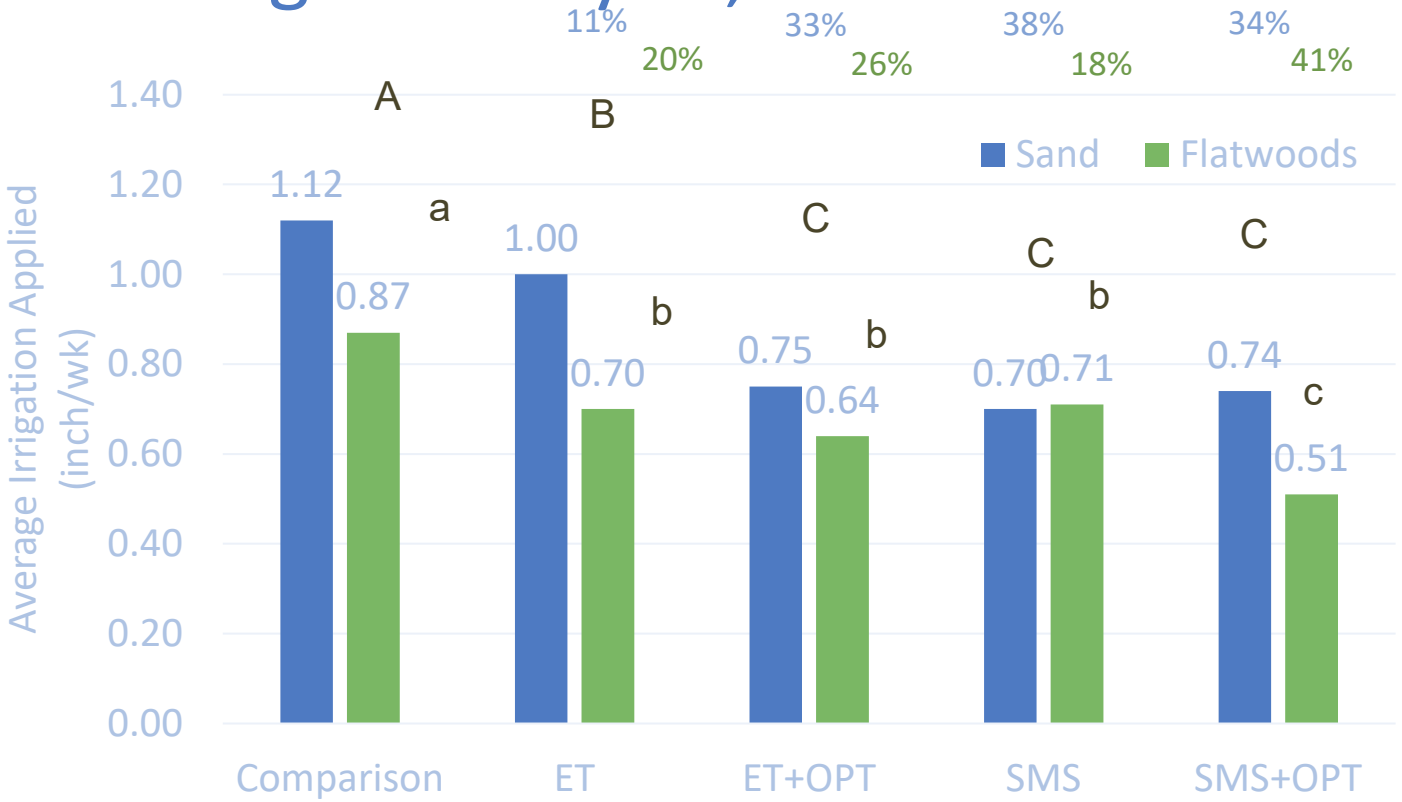
OCU Technologies & Expt. Design

Treatment	ET	ET+OPT	SMS	SMS+OPT	Comparison
Technology	Rain Bird ESP-SMT 	Rain Bird ESP-SMT	Baseline WaterTec S100 	Baseline WaterTec S100	--
Locations Installed	7	9	7	9	9
Number Installed	28	38	28	38	35

Orange County FL, Nov 2011-Feb 2017



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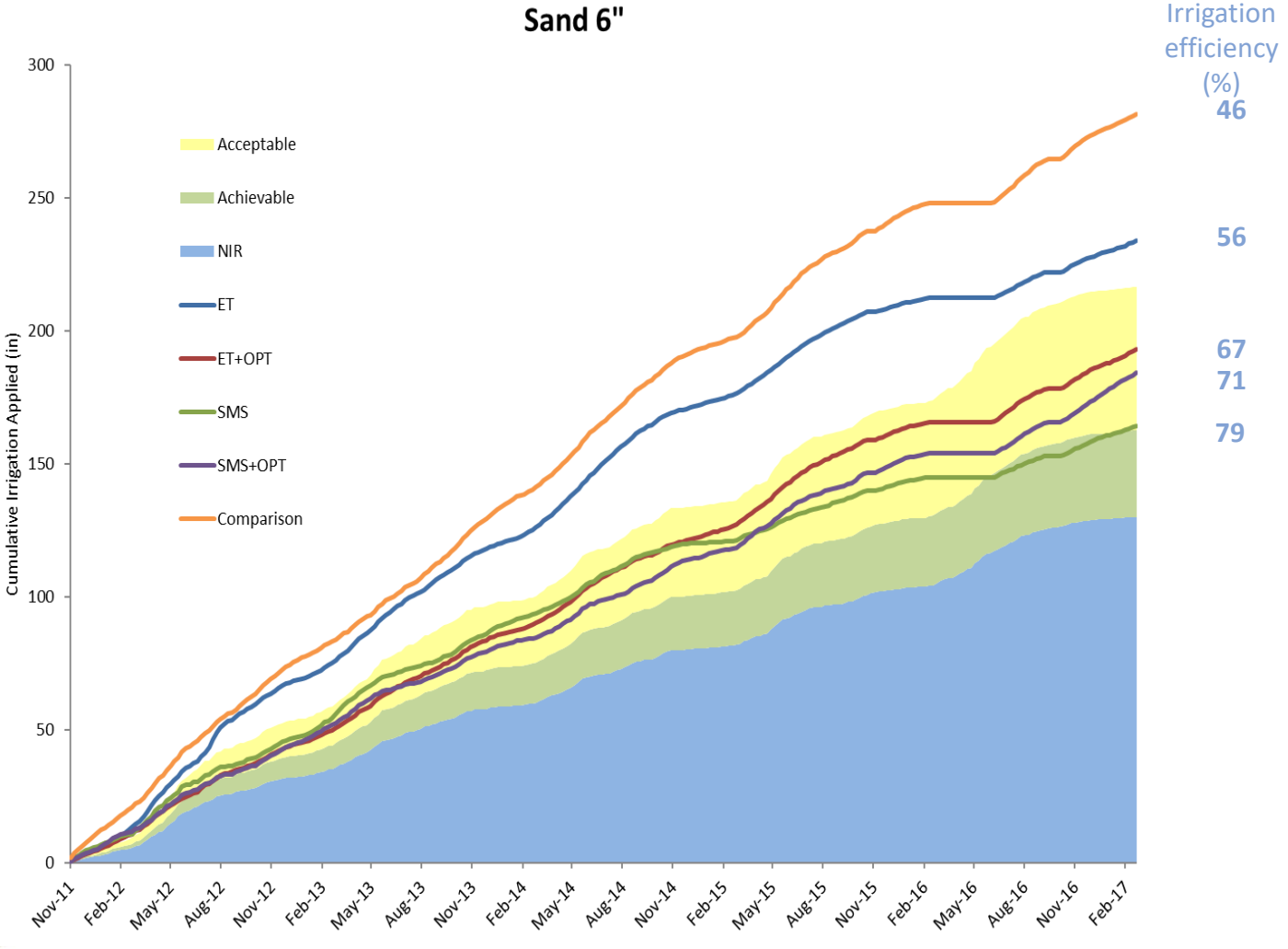
Do Smart Controllers Save Water?

- 2020 summary, https://elibrary.asabe.org/abstract.asp?aid=51812
- 51% savings in research
- 30% savings in practical application
- Negative savings
  - Improperly set up controllers
  - ET on deficit irrigating sites



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Acknowledgements: Water Research Foundation, Orange County Utilities, St. Johns River Water Management District, Southwest Florida Water Management District
Tampa Bay Water (Dave Bracciano), Shu Wang, Chuan Wang, Linda Young, Michael Gutierrez, Mackenzie Boyer, Bernardo Cardenas, Melissa Haley, Stacia Davis, Leah Meeks

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mddukes@ufl.edu http://abe.ufl.edu/mdukes/

Future Technology Trends

Dana R. Lonn, PE, Managing Director emeritus
Center for Technology, Research and Innovation

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NEW ORLEANS

Green Industry Challenge:

Water use efficiency

- *Water – the resource issue of the century worldwide*
- *Water supplies will diminish*
- *Climate change has and will change precipitation patterns*
- *We will be forced to manage landscapes with less water*
- *Irrigation water quality will continue to diminish – salinity*
- *Cost of water will continue to increase*
- *Water use regulations will increase*

Water management

- *Challenge is to increase efficiency & precision in order to reduce consumption*
- *Scheduling based upon data and future models*
- *Habitual over-waterers – significant room for improvement*
- *Demonstrate leadership*

Economic

- *Demand for higher productivity*
- *Rising cost of maintenance – labor, water, fuel, time, fertilizer, energy, etc.*
- *Socioeconomic and social justice issues*

Environmental

- *Water – quality and scarcity concerns drive need for conservation*
- *Resource use efficiency*
- *Drive to reduce carbon (GHG) emissions*
- *Reduce chemical inputs*
- *Natural Capital & Ecosystem services*
- *Biodiversity conservation*

Technological

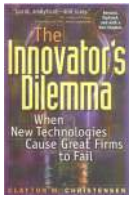
- *Improved sensors & connectivity*
- *Big data platforms*
- *GIS capability*
- *Improved maintenance equipment*

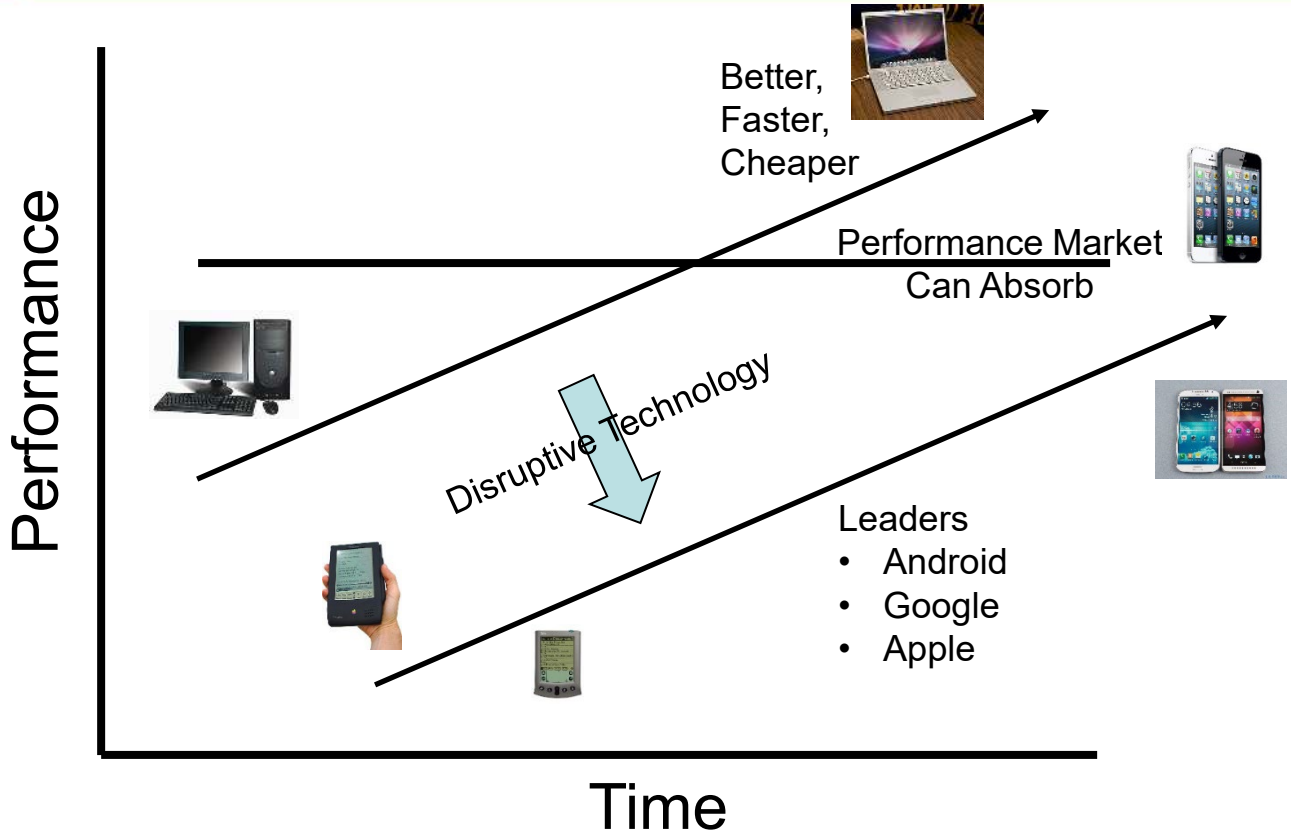
Objective is to provide landscape managers with actionable information that empowers them to reduce labor, financial, and material inputs thereby increasing profitability and reducing environmental impact.

PLACE MATTERS

PRECISION REQUIRES THINKING ABOUT LANDSCAPE MANAGEMENT IN GEOGRAPHIC SPACE

Innovator's Dilemma





What does the market need?

- Henry Ford

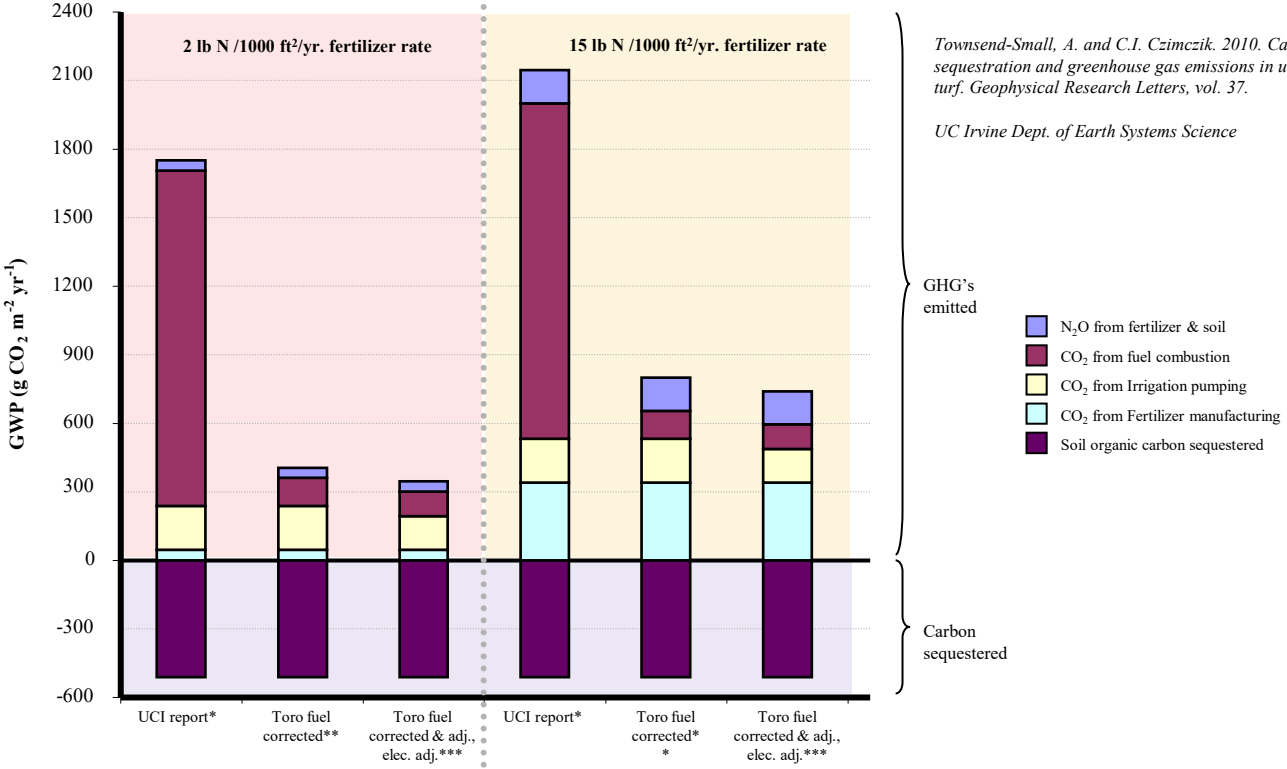
  "If I'd have asked my customers what they wanted, they would have told me 'A faster horse.'"

- Steve Jobs

  "*You can't just ask customers what they want and then try to give that to them. By the time you get it built, they'll want something new.*"

  "*It's really hard to design products by focus groups. A lot of times, people don't know what they want until you show it to them.*"

Carbon sequestered vs. GHG's emitted in park turf maintenance in Irvine, CA



Townsend-Small, A. and C.I. Czimczik. 2010. Carbon sequestration and greenhouse gas emissions in urban turf. Geophysical Research Letters, vol. 37.

UC Irvine Dept. of Earth Systems Science

* Values reported in the UCI research paper. Fuel was reported as total volume used per month for mowing, transport and leaf blowing on 494 total park acres.

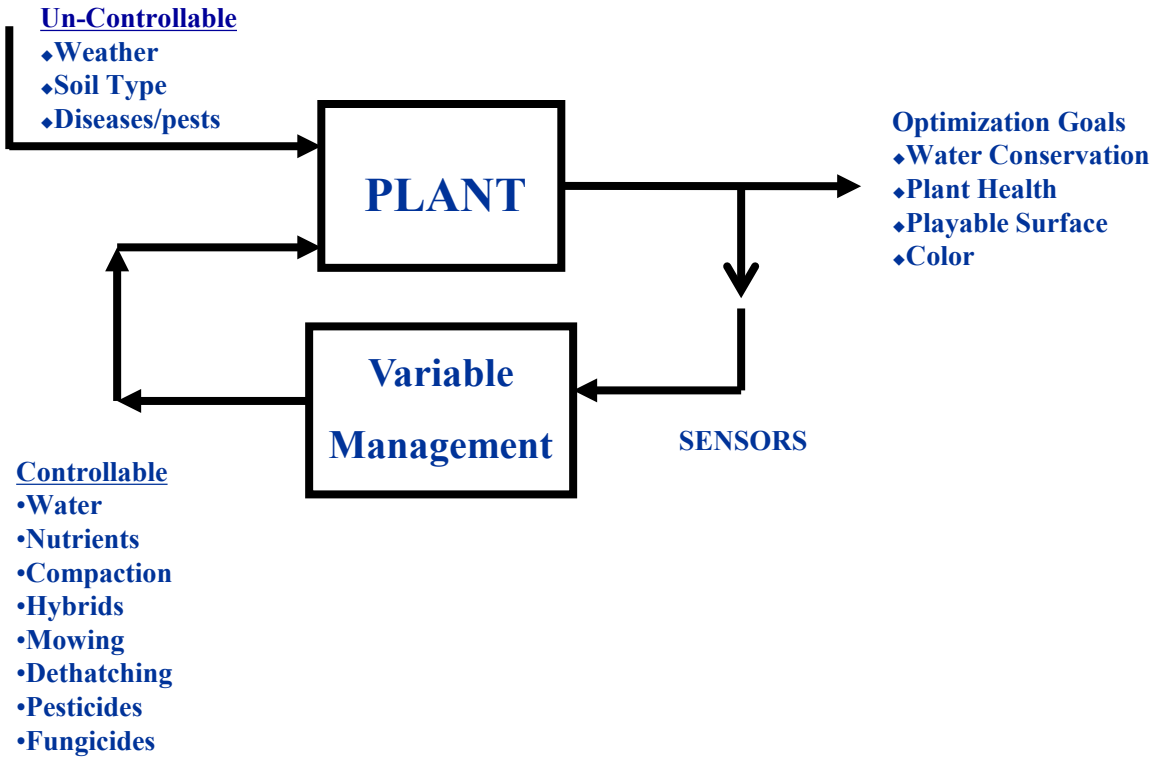
** Fuel calculation corrected using original Townsend-Small data.

*** Fuel calculation corrected and adjusted using Toro fuel use data and a turf acreage adjustment of 60% of total acreage. Electricity consumed in irrigation was also adjusted. Townsend-Small used a general value reported for agricultural irrigation that did not consider local ET. The adjusted value is the average of the highest estimated electricity usage based on 100% ET replacement, 70psi, 50% pumping efficiency, and the lowest estimated electricity usage based on 80%ET replacement, 70 psi, 70% pumping efficiency.

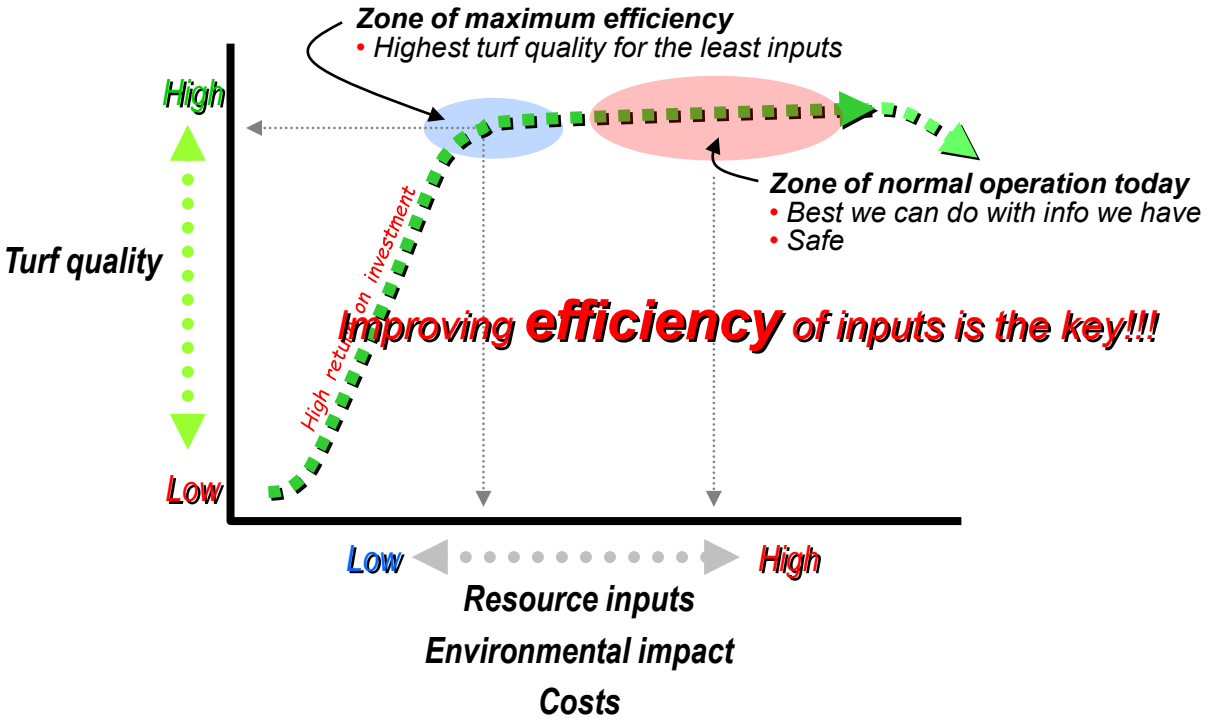
Customer Priorities

- Water Management
  - Water availability
  - Water quality – secondary sources
  - Cost of water
  - Water and its effect on turf performance
- Labor Productivity
- Environmental Concerns
  - Emissions – air, noise, chemicals
  - Cost of Energy
  - Carbon Footprint/Carbon Impact
  - Alternative Fuels

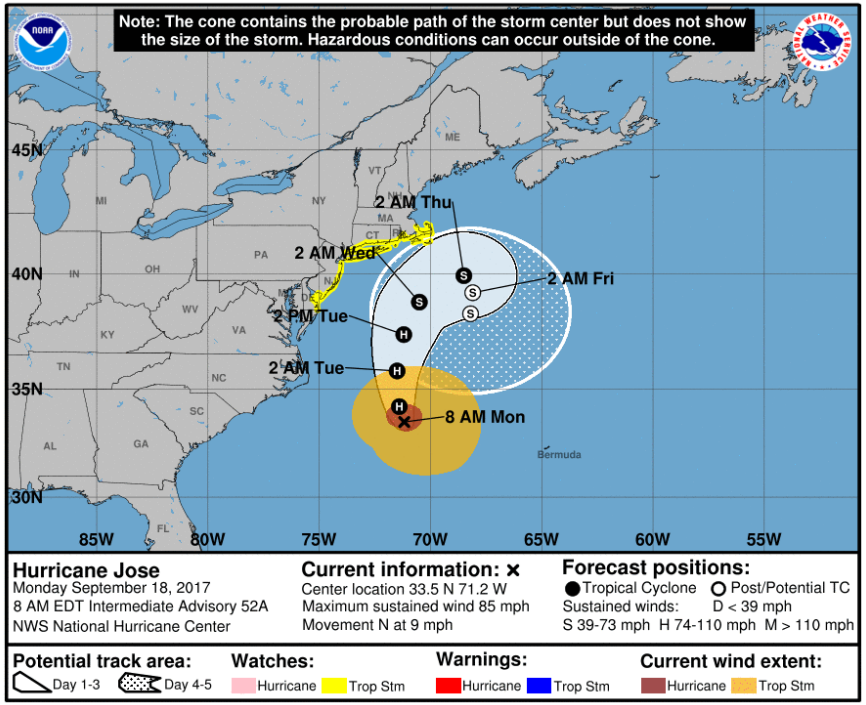
Precision Turf Management

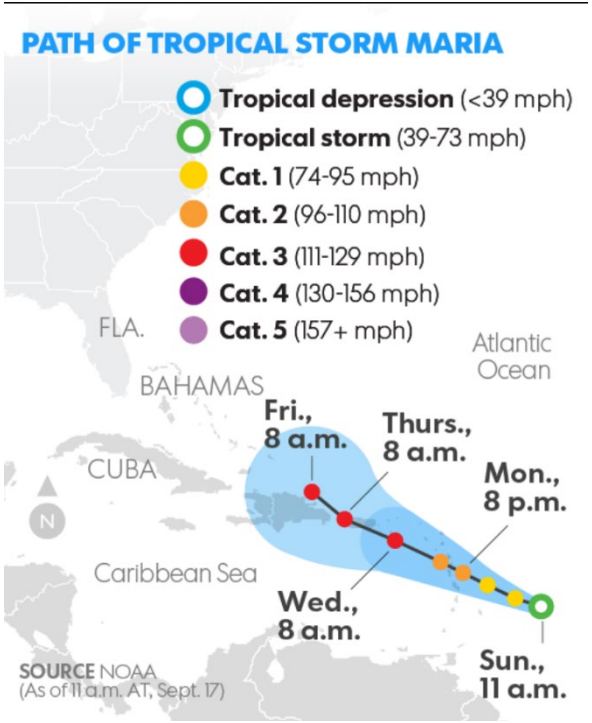


Turf Quality vs. Inputs



Predicting the Future



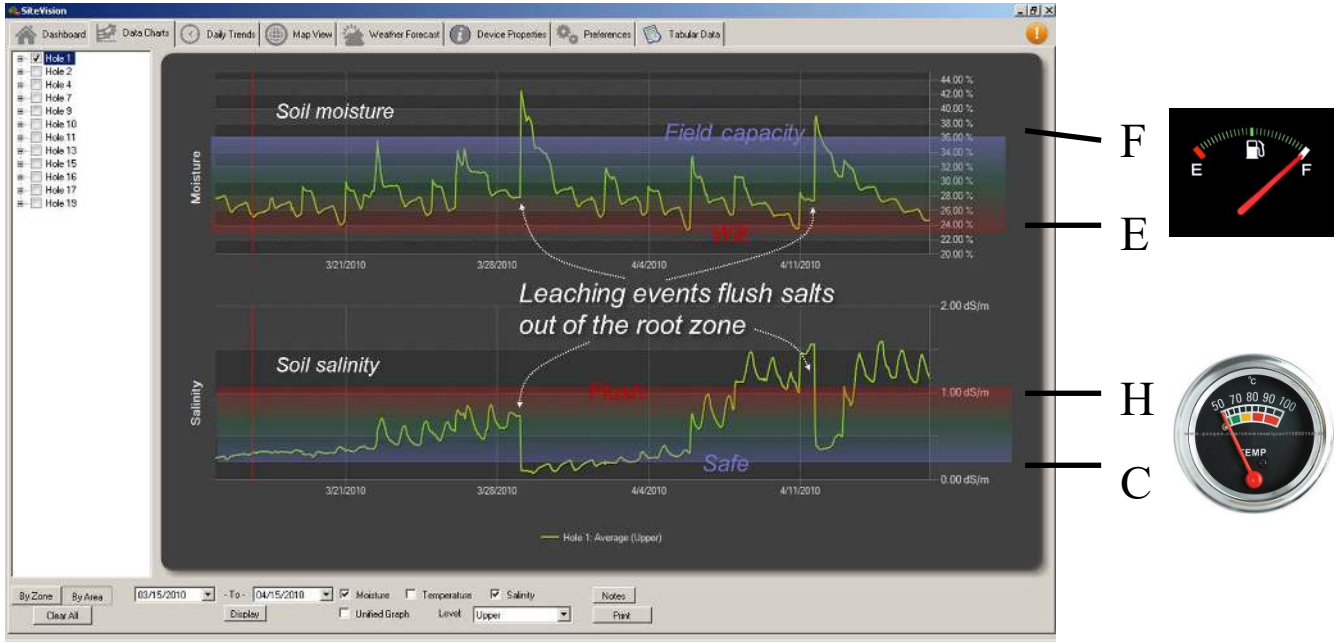


Soil Moisture Sensors

- Probe (Fieldscout TDR350, Pogo) (Spatial Data)
  - Point in time
  - Measure critical areas
  - Much like soil probe or pocketknife

- Fixed In-Ground (Turfguard) (Temporal Data)
  - Time history
  - Shows the impact of irrigation or rainfall events
  - Monitors trends

Data from Soil Sensors



- Allow us to precisely measure soil moisture
- Can calibrate sensors to “empty” and “full”
- Sensors are the most precise method of measuring plant available moisture

Agronomic Site Assessment

*Using Toro's **PrecisionSense**™ mobile mapping system*

- ***Soil moisture*** *(TDR)*
- ***Soil salinity*** *(conductance)*
- ***Soil compaction*** *(penetrometer)*
- ***Turf quality*** *(reflectance sensor)*
- ***Topographic relief*** *(GPS elevation)*

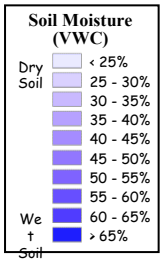
Precision Sense

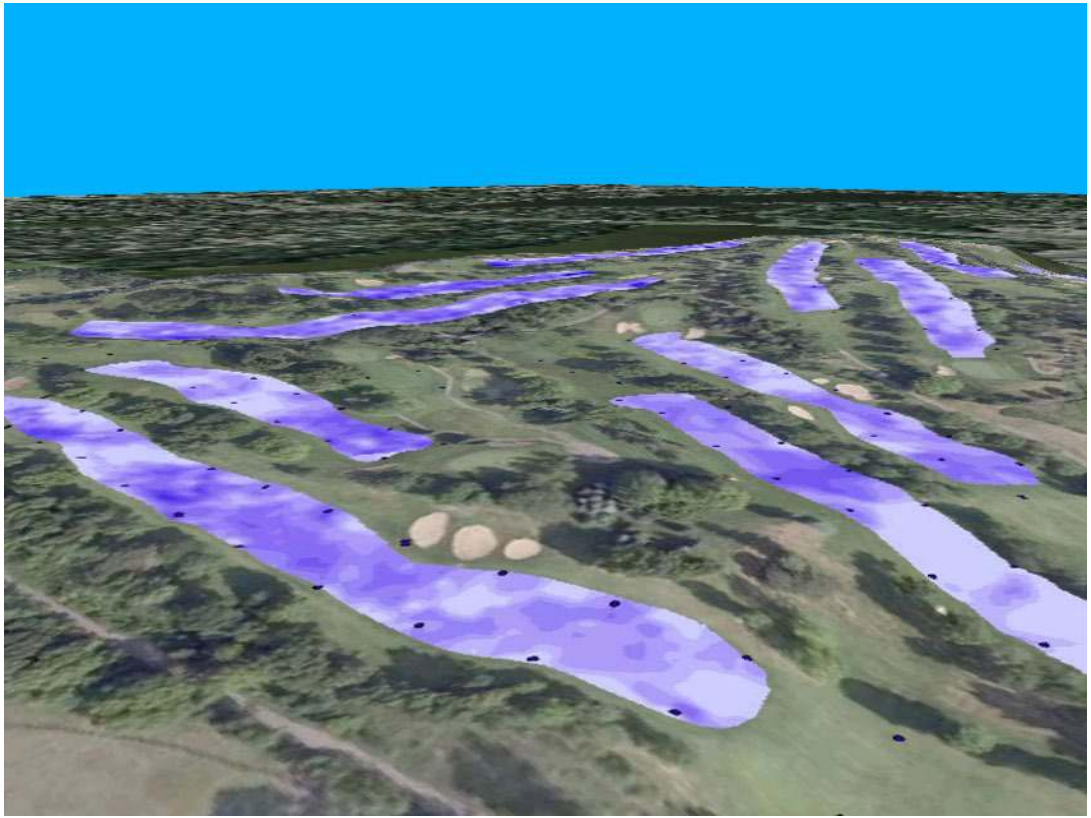
PRECISIONSENSE PLACES LANDSCAPE DATA INTO GEOGRAPHIC SPACE

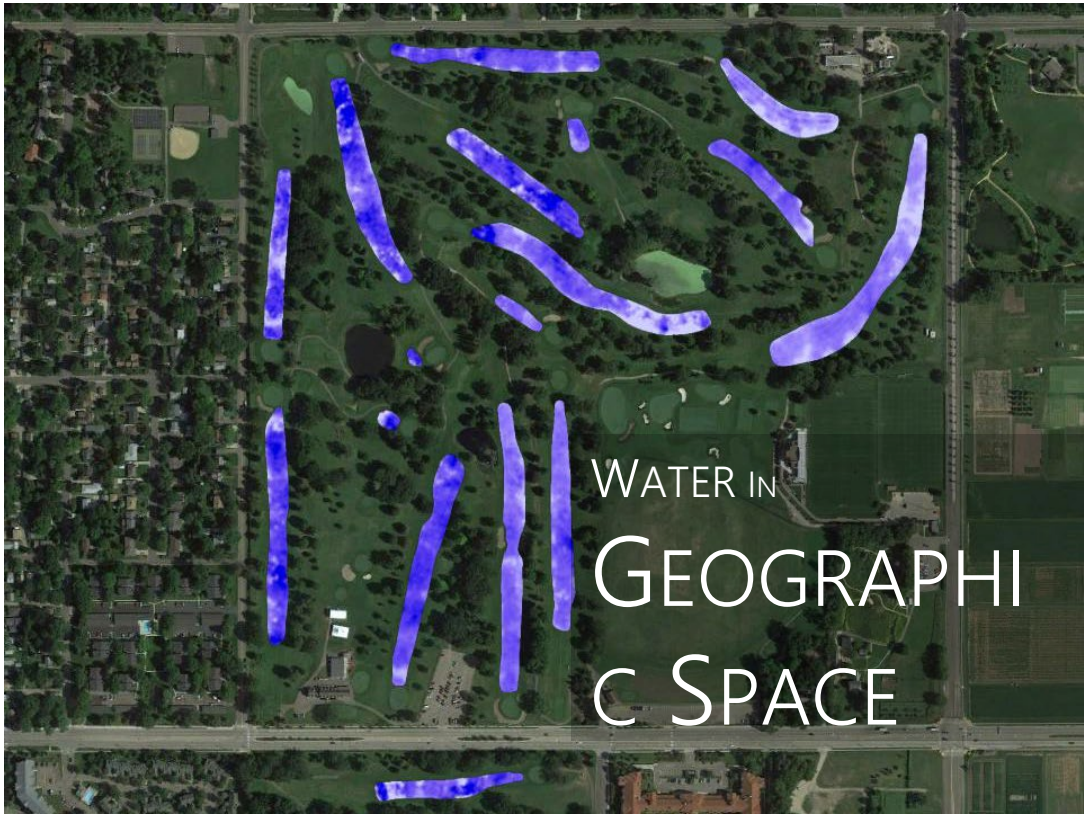
Soil moisture

Soil moisture variation & Topographic relief

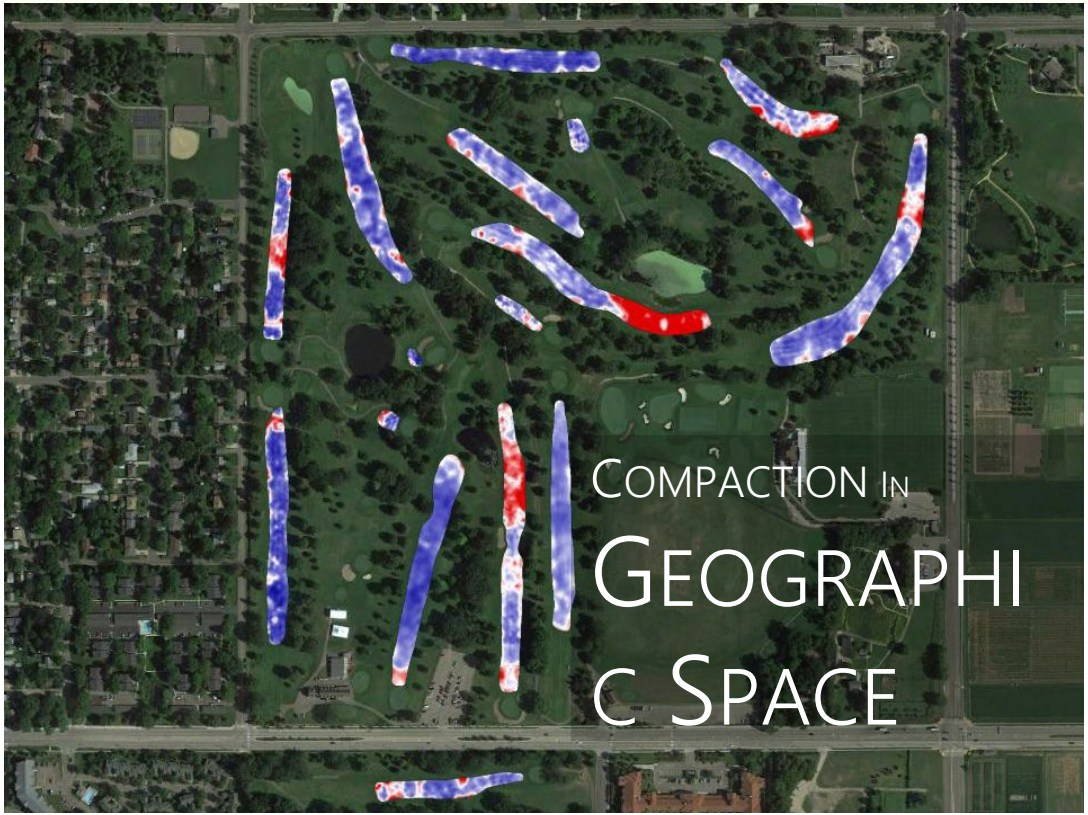
Measured by TDR & GPS elevation

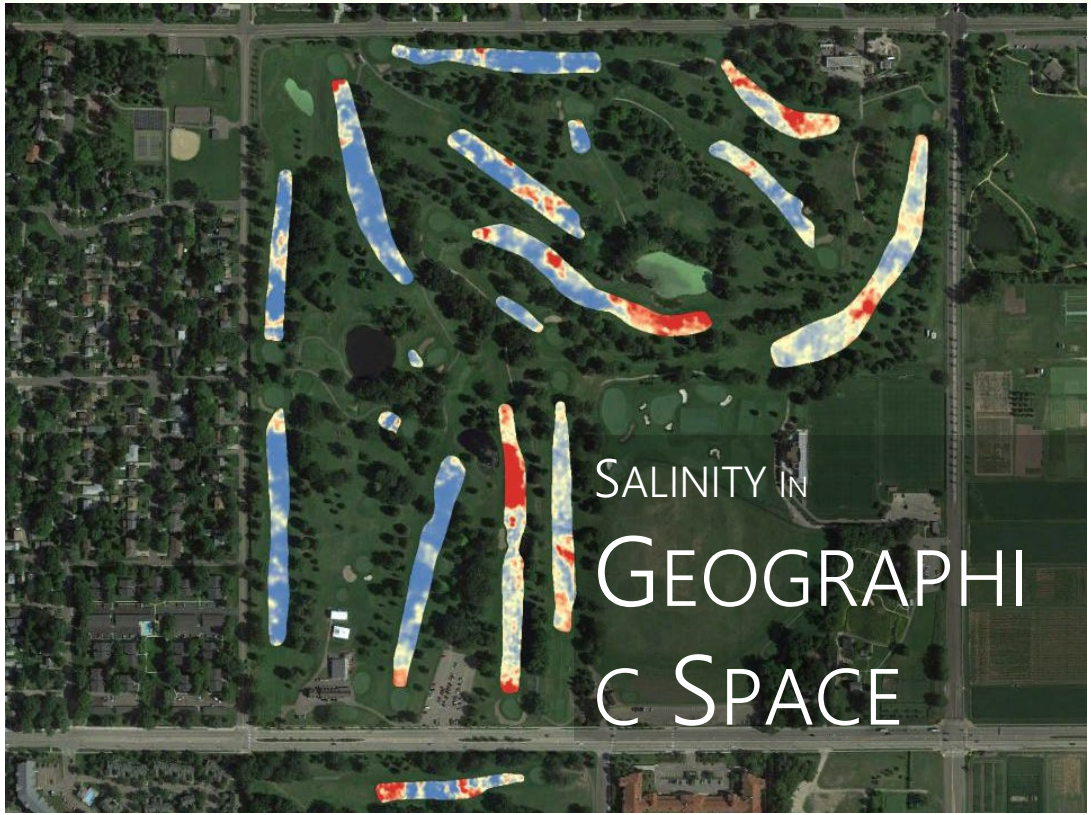






Water In Geographic Space


COMPACTION IN
GEOGRAPHI
C SPACE


Salinity in
Geographi
c Space

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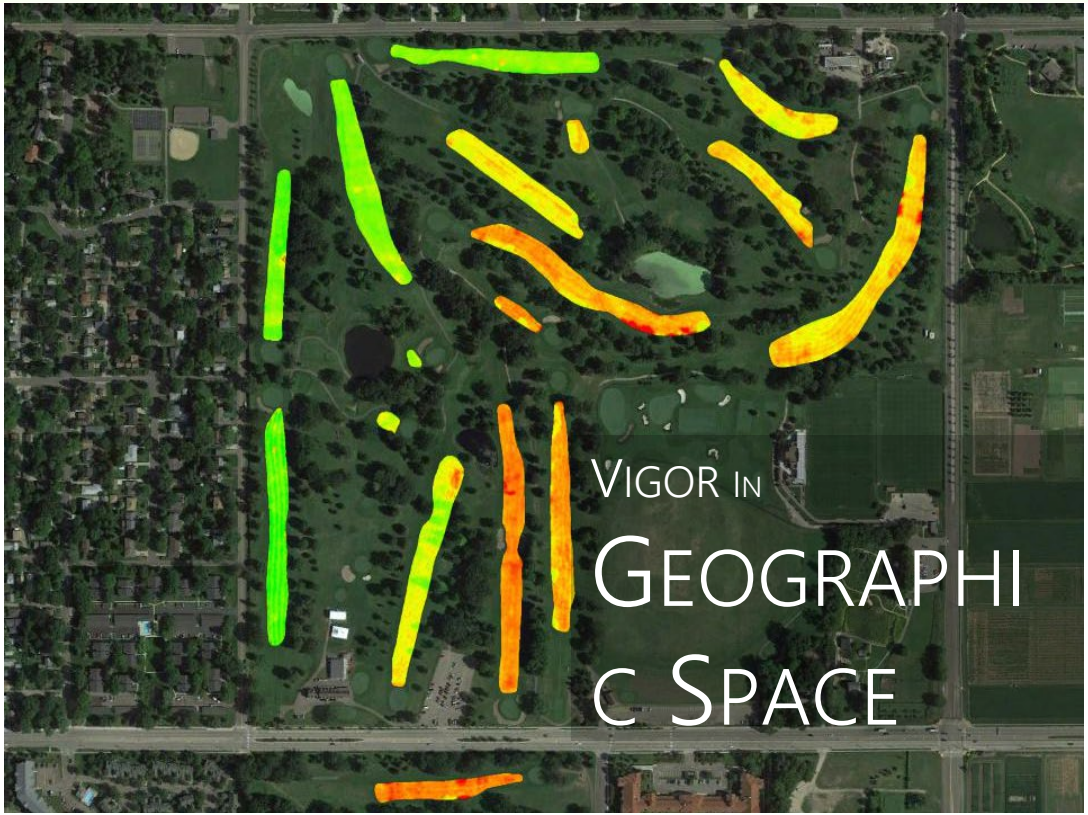
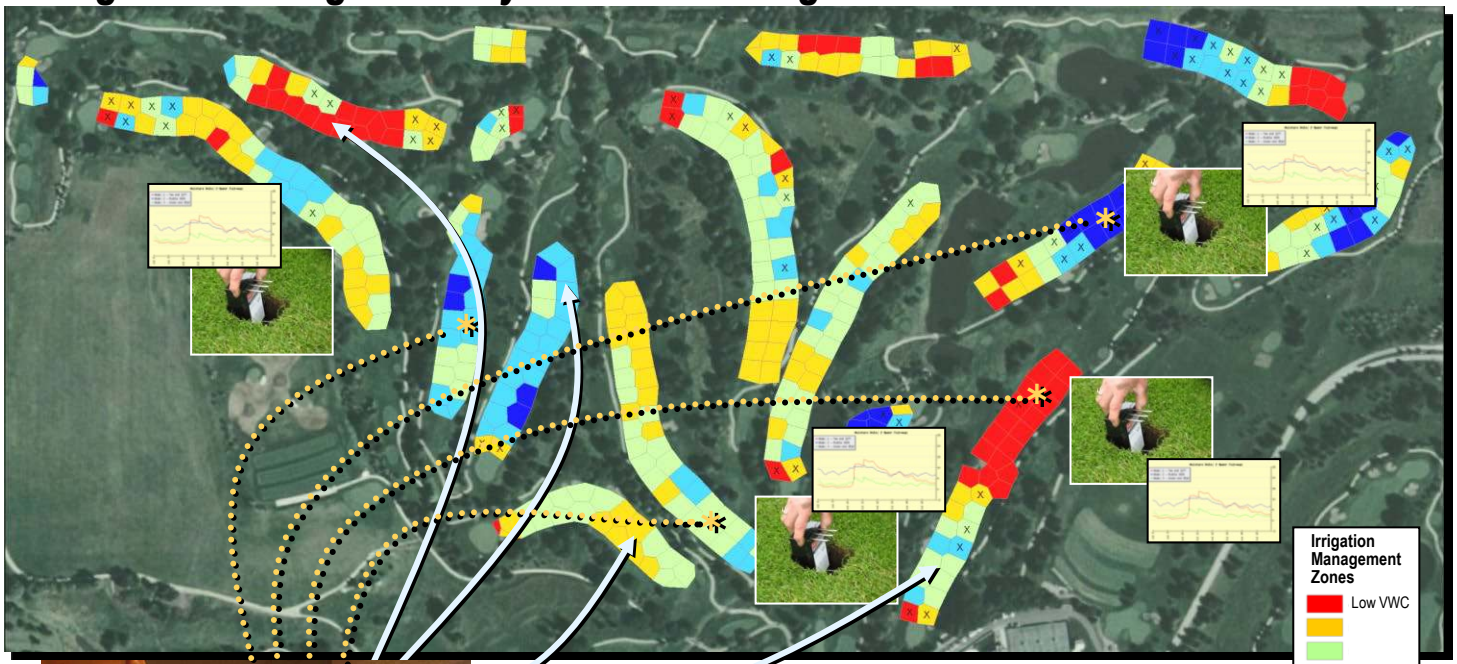
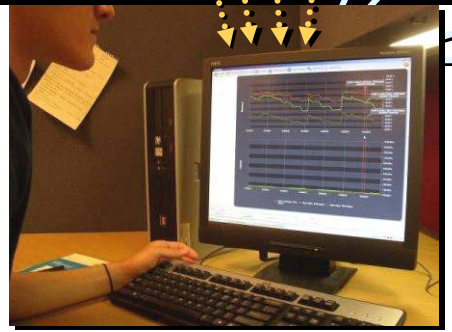


Irrigation Management by Zones with In-ground Soil Sensors

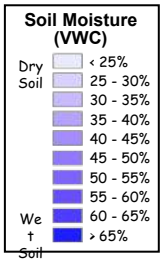




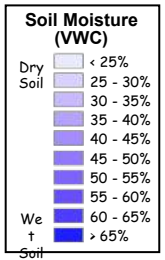
Implementation:

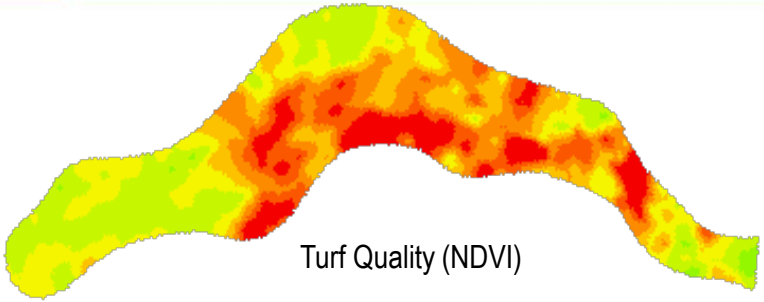
- In-ground soil moisture senor placement & installation in individual zones
- Irrigation control software customization – program by irrigation zone
- In-ground soil moisture sensors provide continuous feedback
- Readjust with experience
- Resample & remap???

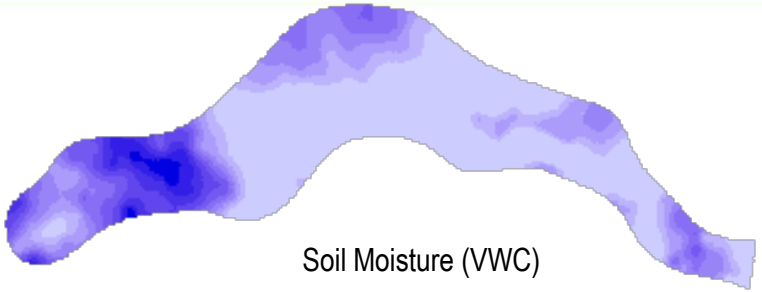
Poor irrigation distribution from soil moisture data

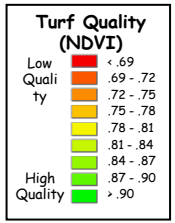


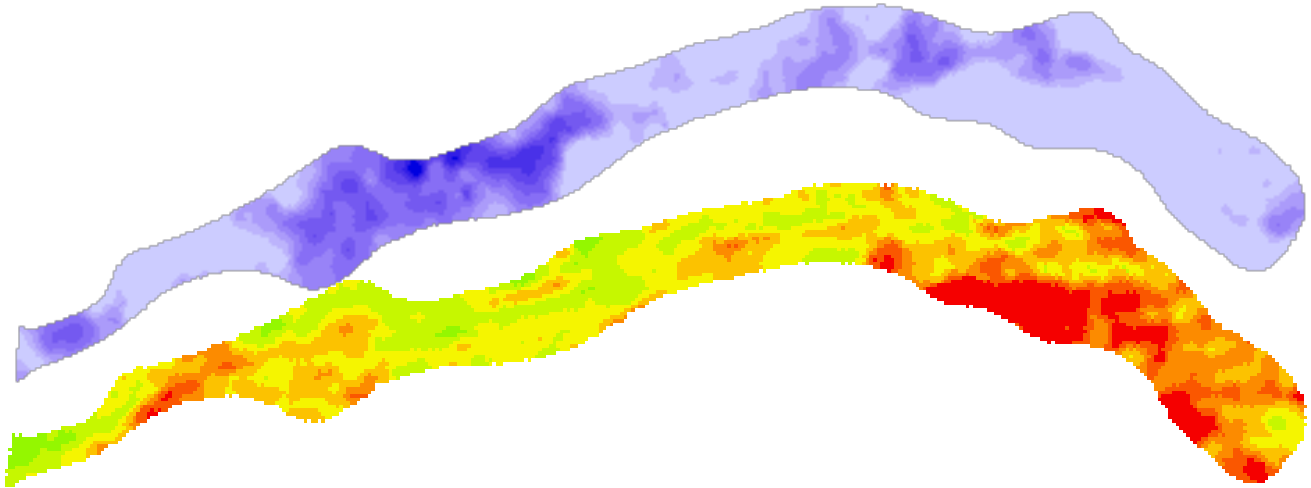
Influence of Soil Properties





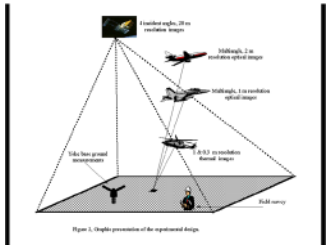


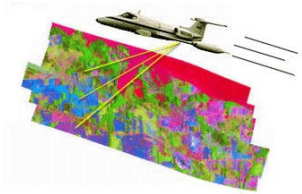


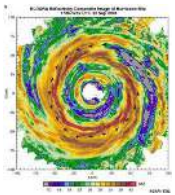


Remote Sensing

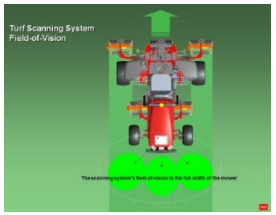
Early Days







Now



Future?

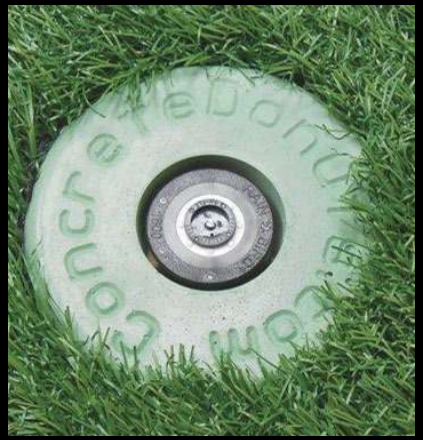
Remote Sensing Interpretation

Engineering Senior Design

- Capstone Class to complete an engineering degree
- Allow students to solve a customer problem
- Problem put in front of students
- Develop a machine to autonomously trim sprinker heads, drainage grates and cemetery markers
- Do the trimming with no human intervention
- This will be a multiyear effort with a number of teams
- Working with teams
  - University of St Thomas
  - University of Minnesota Twin Cities

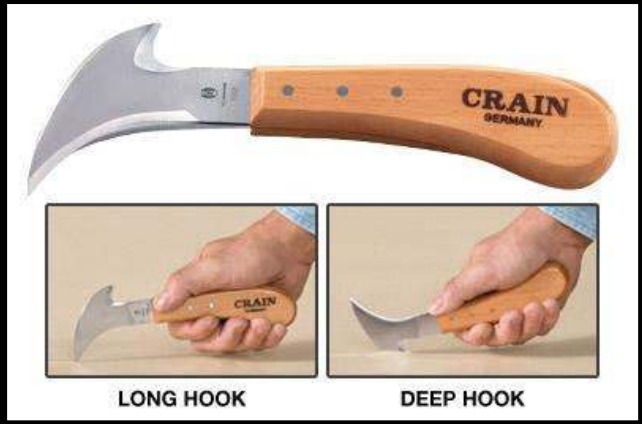
Overgrown grass covers infrastructure in turf fields

- Sprinkler heads, headstones, valve covers, etc.
- Covered infrastructure diminishes the appeal



The current trimming process is tedious and time consuming

- Trimming in-ground infrastructure is an intensive manual task
- Automating trimming will result in faster, more precise, and more frequent trims while saving money



What Next in Irrigation?

Sprinkler Feedback

- Sprinkler on/off
- Sprinkler run time
- Sprinkler arc
- Sprinkler rotation speed
- Sprinkler psi
- Sprinkler flow

Sensing

- Soil moisture
- Soil temperature
- Soil salinity
- Fertilizer presence
- Air temperature
- pH levels
- Remote Sensing
- Other?

Conclusions

Multiple forces are driving the turfgrass industry to seek innovative solutions to existing and future challenges

Several new technologies have enabled development of innovative products with increased capabilities.

Together with academia and turf managers, Toro is actively engaged in applied agronomic research to address the industry's greatest challenges.

What does this mean for the future?

- The future is “precision agriculture (turf management)”!
- Place matters
- Must move from art to science
- Must exist in the wireless, interconnected world
- Need to take action only what is needed, where it is needed, and when it is needed
- Must make irrigation decision in the context of what is going to happen forecast vs what has happened
- Must reduce the need for preventative treatments and move to curative treatments
- Must sense and act at a fidelity that relates to the agronomic variability
- Need to figure out how to sell long term benefits that have higher upfront investments
  - Easier in professional markets than consumer markets
- Value is in knowledge and how you react not data – still work to be done

How can ASIC help?

- Design systems to be simple to use
- Incorporate currently available sensing technology
- Provide opportunity to connect future technology
- Water plant material not just apply water
- Keep yourself current
- Educate the customer on appropriate technology and how it is applied and utilized

Become the Integrator vs the Contributor