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Soil Moisture Sensors: Performance in Homes irrigating with Reclaimed Water

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OUTLINE

- Automatic irrigation system
- Soil moisture sensor system
- Reclaimed water (RW)
- Research in homes using RW
  - Objectives
  - Methodology
  - Results
  - Conclusions

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Automatic Irrigation System

- In-ground
- Controlled by a timer

POTABLE WATER USE

- **Automatic systems vs non-automatic:**
  - **47% more water (*Mayer et al., 1999*)**
  - **160% more water (*Mayer et al., 2016*)**
- **Homeowners in Central FL tend to over-irrigate by 140% more than the calculated irrigation water required (*Haley et al., 2007*)**

Automatic Irrigation System

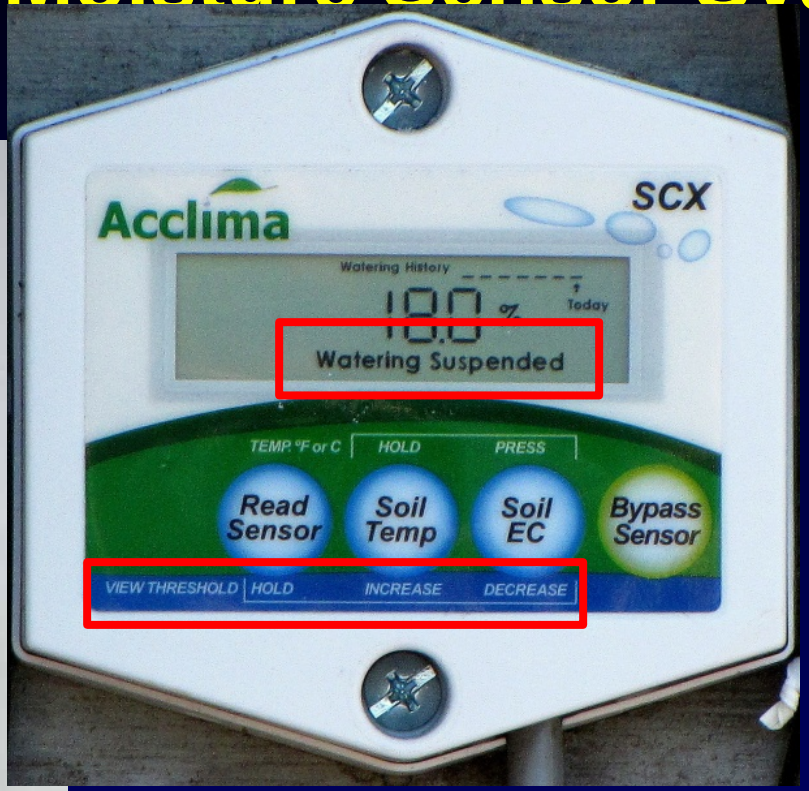
Soil Moisture Sensor System (SMS)

Probe

Controller

Timer

Soil Moisture Sensor System (SMS)



Probe

Controller

Timer

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Water savings potential

- ***Previous research with SMSs***
  - Turfgrass plot conditions: 44-72%
    (Cardenas-Lailhacar et al., 2008 and 2010; McCready et al., 2009; Grabow et al., 2013)
  - Turf quality above minimum acceptable

Water savings potential

Research in residential settings

State	Author	Year	Savings (%)	Compared to
Utah	Allen	1997	10	Control group
Colorado	Qualls et al.	2001	27	Theoretical requirement
Florida	Haley & Dukes	2012	65	Control group
N. Carolina	Nautiyal et al.	2014	42	Control group
Florida	Davis & Dukes	2015	44	Historical use

- Turf quality above minimum acceptable

Reclaimed Water (RW) in the US

State	Population (2006 est)	Reported Reuse[1] in Millions of Gallons per Day	Reuse per Capita in Gallons per Day per Person	Rank
Florida	18,019,093	663.0	36.79	1
California	36,121,296	580.0[2]	16.06	2
Virginia	7,628,347	11.2	1.46	3
Texas	23,367,534	31.4	1.34	4
Arizona	6,178,251	8.2	1.33	5
Colorado	4,751,474	5.2	1.09	6
Nevada	2,484,196	2.6	1.03	7
Idaho	1,461,183	0.7	0.50	8
Washington[3]	6,360,529	0	0	9

RW users in Florida (2016)

User	Quantity
Residences	397,750
Parks	1,053
Golf courses	574
Schools	381
Cooling towers	90

Why is it different?

- **RW may contain higher levels of salts than potable water**
- **Salts can affect the readings of the SMSs**

- Homes connected to RW have autom. irrigation system
- RW has become a limited resource in certain municipalities in FL

Photo: Michael Gutierrez

Main objective:

In homes that used RW

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Compare (treatments)

1)  .....Monitoring only = MO

2)  +  .....Rain sensor = RS

3)  +  +  ....RS + educational materials = EDU

4)  +  .....Soil moisture sensor = SMS

Secondary objective:

- **Estimate the water applied by the different treatments, compared to a theoretical requirement**

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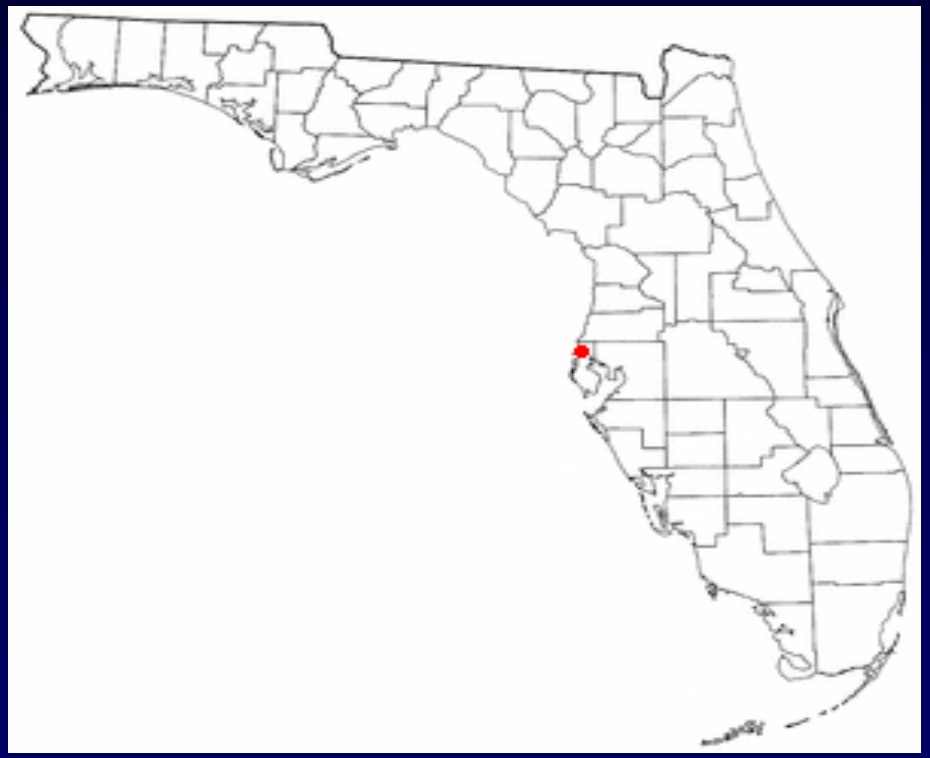
Methodology

- Pinellas County Utilities (PCU) + UF
- PCU sent to UF a list of homes using RW
- UF preselected homes in the vicinity of Palm Harbor



Methodology (Cont.)

- **Homes Recruitment**

Letter
(Pinellas Co. Utilities)

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Methodology (Cont.)

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Institute of Food and Agricultural Sciences
Agricultural and Biological Engineering Department

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PO Box110570
Gainesville, FL 32611-0570
352-392-1864 x 234
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September 14, 2010

Dear Pinellas County Reclaimed Water Customer:

As you may have heard, reclaimed water is becoming a limited resource; such that new water shortages and restrictions for landscape irrigation may become possible in the future. Pinellas County Utilities (PCU), in cooperation with the University of Florida, would like to help you.

You are receiving this letter because PCU has recognized you as a potential participant in a new water conservation study in lawn/landscape irrigation. New irrigation controllers (which allow irrigation only when necessary) can be used as an alternative to day-of-week irrigation restrictions, and could help to minimize future water shortages and restrictions.

Selected properties are eligible to receive state of the art irrigation controllers and other irrigation equipment. All of these will be provided, installed, and monitored at no cost or effort from you. And the equipment is yours to keep when the study is complete! In addition, every property selected for the study will receive a complimentary evaluation of their irrigation system. The only requirement is that you have an in-ground irrigation system using reclaimed water.

To learn more and sign up as a potential participant type the following internet link: **http://irrigation.ifas.ufl.edu/rw.shtml** or contact Bernard Cardenas at (352) 392-1864 ext. 234.

This study is funded by South West Florida Water Management District (SWFMD) in cooperation with Pinellas County Utilities (PCU) and performed by the University of Florida - Institute of Food and Agricultural Sciences (UF-IFAS).

Be part of this innovative research and help yourself and your community!

Sincerely,

Bernard Cardenas
Research Coordinator

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Methodology (Cont.)

- **Homes Recruitment**

Letter
(Pinellas Co. Utilities)

http://irrigation.ifas.ufl.edu/study

Informed Consent

Survey

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Methodology (Cont.)

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Institute of Food and Agricultural Sciences

Survey ID No. ☐☐☐☐

Please complete this survey regarding your experiences with irrigation technology. Upon completion, please return to a member of the UF irrigation research team. Thanks!

1. Do you adjust your watering schedule thought the year?
   - ☐ Monthly
   - ☐ Seasonally
   - ☐ Not really
   - ☐ Other: _____

2. Do you water your lawn (turfgrass) and landscape (bedded areas) with different sprinkler head types?
   ☐ Yes ☐ No ☐ Don't know

3. Do you water your lawn (turfgrass) and landscape (bedded areas) for different lengths of time?
   ☐ Yes ☐ No ☐ Don't know

4. How long do you typically water your lawn (turfgrass) each time you irrigate?
   _____

5. Do you have a rain shut off device attached to your irrigation system?
   ☐ Yes ☐ No ☐ Don't know

6. Please rate your current interaction with your irrigation system by marking the number which best describes?
   [1] *Set & Forget* [2] [3] [4] [5] *Very Interactive*

7. On average, how many hours of the day are you out of the home? _____ hrs.

8. Do you feel that your irrigation system is adequately irrigating your lawn and landscape?
   ☐ Yes ☐ No ☐ Don't know

9. Do you trust that a rain bypass device will appropriately bypass irrigation events?
   ☐ Yes ☐ No ☐ Don't know

10. Do you trust that an ET (weather-based) irrigation controller will appropriately schedule irrigation events?
    ☐ Yes ☐ No ☐ Don't know

11. Prior to this study, were you familiar with any of the following? Mark all that apply.
    - ☐ Rain sensors
    - ☐ Soil moisture sensors
    - ☐ ET controllers

12. Have you ever participated in an outdoor water use conservation program?
    ☐ Yes ☐ No ☐ Don't know

13. Please rate you level of familiarity regarding the characteristics of your lawn and landscape from 1 to 5 (with 5 being highest):

	5	4	3	2	1	Don't Know
Plant types	☐	☐	☐	☐	☐	☐
Water needs of different plant types	☐	☐	☐	☐	☐	☐
Soil type	☐	☐	☐	☐	☐	☐
Sun and Shade patterns	☐	☐	☐	☐	☐	☐
Plant root depths	☐	☐	☐	☐	☐	☐
Slope pattern of yard	☐	☐	☐	☐	☐	☐
Usable rainfall percent	☐	☐	☐	☐	☐	☐

Please rate you level of familiarity regarding the characteristics of your irrigation system from 1 to 5 (with 5 being highest):

	5	4	3	2	1	Don't Know
Irrigation zone locations	☐	☐	☐	☐	☐	☐
Sprinkler location on slope	☐	☐	☐	☐	☐	☐
Sprinkler head types	☐	☐	☐	☐	☐	☐
Efficiency of irrigation system	☐	☐	☐	☐	☐	☐
Sprinkler precipitation rates	☐	☐	☐	☐	☐	☐
Locally permitted irrigation hours	☐	☐	☐	☐	☐	☐
Local permitted irrigation days	☐	☐	☐	☐	☐	☐

14. Please mark the top three statements that best describe your attitude toward your home's present landscape (in order of priority, 1 through 3).
    - — I am reasonably content with my present landscape and am not considering any changes.
    - — I prefer less lawn (turfgrass) and would like to remove some of it.
    - — I prefer more lawn (turfgrass) and would like to increase the lawn area of my yard.
    - — I would like to learn more about landscape water use before deciding what, if any, actions I take.
    - — I don't think my neighbors (and/or Homeowners Association) would accept the changes I would like to make.
    - — I would like to consider changes but don't have the ***time***.
    - — I would like to consider changes but don't have the ***money***.

15. Does your house have any of the following appliances or devices that are intended for water savings?

(check all that apply)

Already Have	I/We installed	
☐	☐	Low-flow faucet or showerhead
☐	☐	Low-flow toilet
☐	☐	Water-efficient dishwasher
☐	☐	Water-efficient washing machine
☐	☐	Tankless water heater
☐	☐	Rain barrel
☐	☐	Micro or Drip irrigation
☐	☐	Other: _____

16. Does your house have any appliances or devices intended for energy savings?

(check all that apply)

Already Have	I/We installed	
☐	☐	Compact fluorescent light bulbs
☐	☐	Energy-saving power strips
☐	☐	High-efficiency clothes dryer
☐	☐	High-efficiency air conditioner
☐	☐	Tankless water heater
☐	☐	Solar water heater
☐	☐	Solar panels
☐	☐	Other: _____

17. Please rate your agreement to the following statements:

	Strongly Agree	Agree	Neither	Disagree	Strongly Disagree	Don't Know
I am technologically savvy.	☐	☐	☐	☐	☐	☐
I do not feel my conservation of water affects the overall supply.	☐	☐	☐	☐	☐	☐
Because my irrigation system functions poorly, I don't irrigate.	☐	☐	☐	☐	☐	☐
I don't irrigate because of environmental concern.	☐	☐	☐	☐	☐	☐
I spend a lot of time outside my home in my lawn/landscape.	☐	☐	☐	☐	☐	☐
I am very concerned about the appearance of my yard.	☐	☐	☐	☐	☐	☐
I am not aware of water restrictions in my area.	☐	☐	☐	☐	☐	☐
I am aware of lawn appearance requirements in my neighborhood.	☐	☐	☐	☐	☐	☐
I think a rain shutoff device is very important.	☐	☐	☐	☐	☐	☐
Conservative outdoor water-use practices save money.	☐	☐	☐	☐	☐	☐
I often observe my neighbors overirrigating.	☐	☐	☐	☐	☐	☐
When it does not rain regularly, I tend to water my lawn a little extra.	☐	☐	☐	☐	☐	☐
I water less in the winter months.	☐	☐	☐	☐	☐	☐
Native plants in the landscape tend to look un-maintained.	☐	☐	☐	☐	☐	☐
New irrigation systems are required to have rain shutoff devices.	☐	☐	☐	☐	☐	☐
Water conservation is a contribution to energy savings.	☐	☐	☐	☐	☐	☐
We are all responsible for water conservation in our community.	☐	☐	☐	☐	☐	☐

18. In your opinion, how effective are (or would be) each of the following to increase water conservation:

	Very Effective	Effective	Neither	Ineffective	Very Ineffective	Don't Know
Water restrictions	☐	☐	☐	☐	☐	☐
Rain-shut off devices	☐	☐	☐	☐	☐	☐
Increased water rates	☐	☐	☐	☐	☐	☐
Landscape ordinances that limit turfgrass area	☐	☐	☐	☐	☐	☐
Local conservation programs	☐	☐	☐	☐	☐	☐
Irrigation scheduling based on water needs of plants	☐	☐	☐	☐	☐	☐
Using native plants in the bedded areas	☐	☐	☐	☐	☐	☐

Thank you for your participation!

Methodology (Cont.)

1. Please provide the following information:
   - ☐ First name
   - ☐ Last name
   - ☐ Street address
   - ☐ City
   - ☐ Zip code
   - ☐ Home telephone number
   - ☐ Mobile number
   - ☐ Email address
2. Which is(are)the most convenient way(s) to contact you?
   - ☐ Mail
   - ☐ Home telephone number
   - ☐ Mobile number
   - ☐ Email address
3. How long have you lived at this address?
   - ☐ Less than one year
   - ☐ 1-4 years
   - ☐ 5-10 years
   - ☐ More than 10 years
4. Are you a year-round (12-month) resident at this address?
   - ☐ Yes
   - ☐ No
   - ☐ Comments
5. Do you live in a subdivision or planned community?
   - ☐ Yes
   - ☐ No
   - ☐ Comments
6. If yes, what is the name of the subdivision or planned community that you live in?
7. How do you irrigate your lawn and/or landscape?
   - ☐ Time controlled irrigation in-ground system.
   - ☐ Manually operated in-ground irrigation.
   - ☐ Hose-end sprinkler(s).
   - ☐ Do not irrigate.
   - ☐ Comments
8. What water source(s) do you use to irrigate your lawn and/or landscape?
   - ☐ County water
   - ☐ Well
   - ☐ Lake/pond
   - ☐ Do not irrigate
   - ☐ Don't know
9. Approximately how much of your yard receives full sun all day?
   - ☐ 100% grass/ no landscape plants
   - ☐ 75% grass/25% landscape plants
   - ☐ 50% grass/50% landscape plants
   - ☐ 25% grass/75% landscape plants
   - ☐ 100% landscape plants/ no lawngrass
   - ☐ Other (please specify)
   - ☐ Don't know
10. How old are most of your landscape plants (trees, shrubs, ground covers?
    - ☐ Less than 1 year
    - ☐ 1 to 5 years
    - ☐ 6 to 10 years
    - ☐ Over 10 years old
    - ☐ Comments
11. What type of lawn do you have?
    - ☐ St. Augustine
    - ☐ Bahiagrass
    - ☐ Bermudagrass
    - ☐ Mostly weeds
    - ☐ Don't know
    - ☐ Comments
12. How old most of your lawn?
    - ☐ Less than 1 year
    - ☐ 1 to 5 years
    - ☐ 6 to 10 years
    - ☐ Over 10 years old
    - ☐ Comments
    - ☐

Methodology (Cont.)

- **Homes Recruitment**

Letter
(Pinellas Co. Utilities)

http://irrigation.ifas.ufl.edu/study

Informed Consent

Survey

Pre-selected homes

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Methodology (Cont.)

Project requirements:

- **Homes were located in the vicinity of Palm Harbor,**
- **were clustered in residential developments or subdivisions,**
- **had an automatic irrigation system,**
- **were using RW as their irrigation source,**
- **the owners lived in the home.**

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Methodology (Cont.)

- **Homes Recruitment**

Pre-selected homes

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Methodology (Cont.)

- **Homes Recruitment**

Pre-selected homes

Irrigation Audit

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Methodology (Cont.)

Additional project requirements:

- **a properly working automatic irrigation system,**
- **well established St. Augustinegrass with a minimum acceptable or higher turfgrass quality,**

Calculate irrigated area/home ➡ water depth/home

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Methodology (Cont.)

- **Homes Recruitment**

Pre-selected homes | Irrigation Audit | Selected homes

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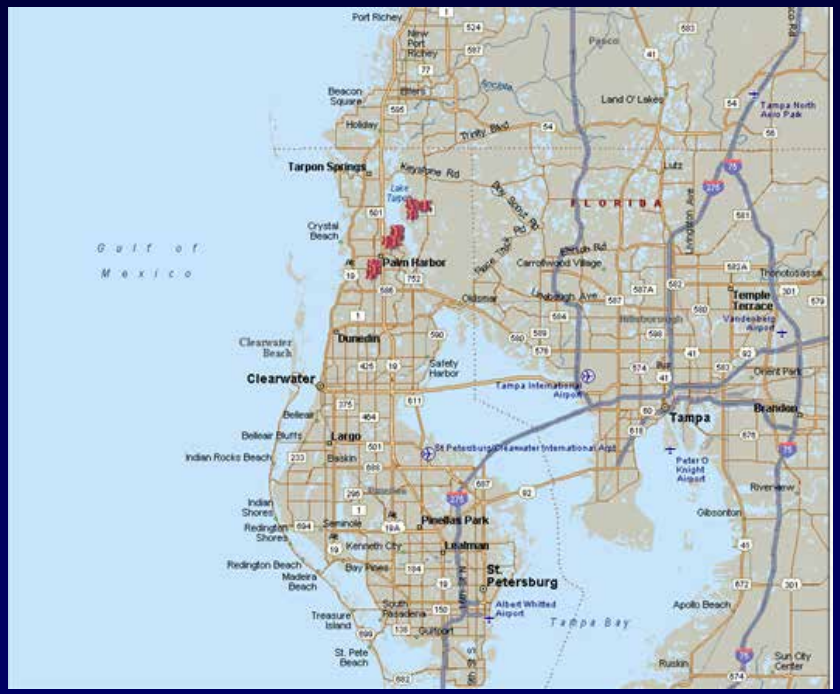
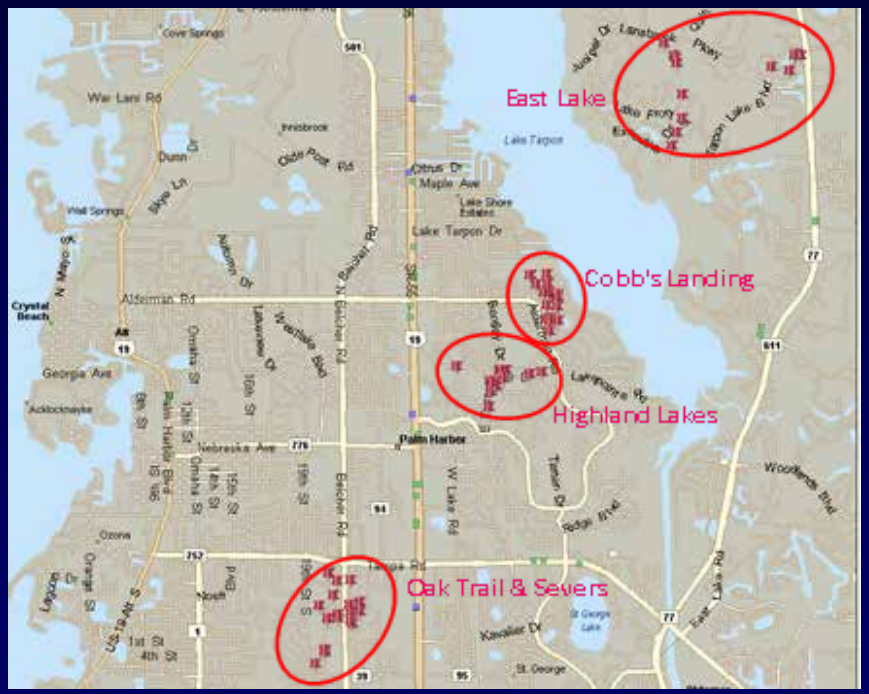
Methodology

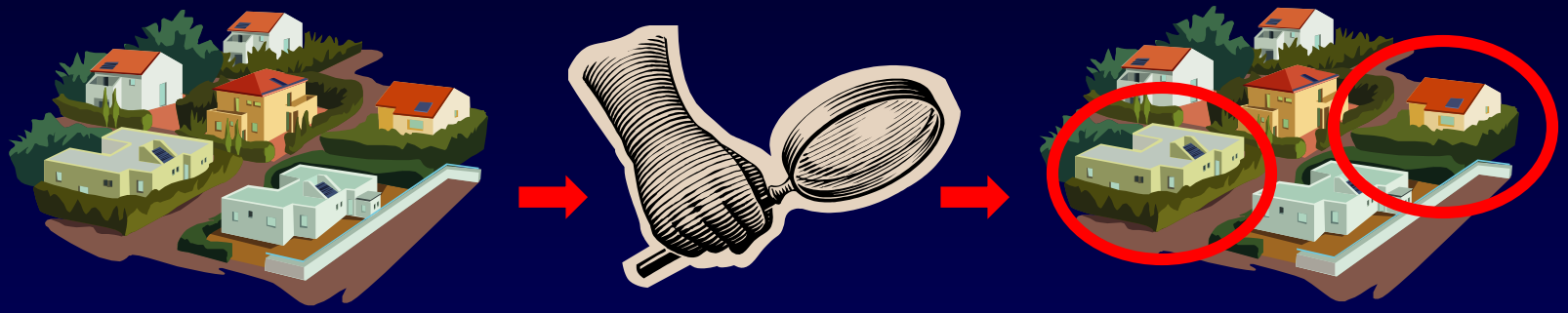
- Recruited 64 homes in Pinellas Co.





Methodology (Cont.)

- **Homes Recruitment**



Pre-selected homes → **Irrigation Audit** → **Selected homes**

- In each subdivision, 4 treatments were implemented.
- The homes were randomly assigned to one of the treatments, with a similar amount of replications (properties) per subdivision

Selected homes

↓

Assigned treatments

↓

Installed devices (Flowmeters, AMRs, SMSs, RSs)

↓

Initiated treatments

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Methodology (Cont.)

- **Data collection**
  - Collect weather data (hourly)
  - Rate and photograph turf quality/home seasonally (quarterly)
  - Record irrigation water use/home w/AMR technology (hourly)

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Experimental Treatments

Homes are subdivided into 4 groups

1) 

.....Monitoring only = MO

2)  + 

.....Rain sensor = RS

3)  +  + 

....RS + educational materials = EDU

4)  + 

.....Soil moisture sensor = SMS

Turf Quality

RESULTS (Jan. 2011 – Sep. 2013)

Treatment[x]	Depth per event (mm)	Events per week (#)	Depth per week (mm)
MO	15.4 ns[y]	2.7 a[z]	42 a
RS	15.4 ns	2.4 a	37 a
EDU	14.4 ns	2.3 a	33 a
SMS	14.1 ns	1.7 b	24 b

[x] Treatments are: MO, timer only; RS, timer plus rain sensor; EDU, timer plus rain sensor plus educational materials; SMS, timer plus soil moisture sensor system.

[y] ns = No significant difference.

[z] Different letters within a column indicate statistical difference at $P<0.05$ (Duncan's multiple range test).

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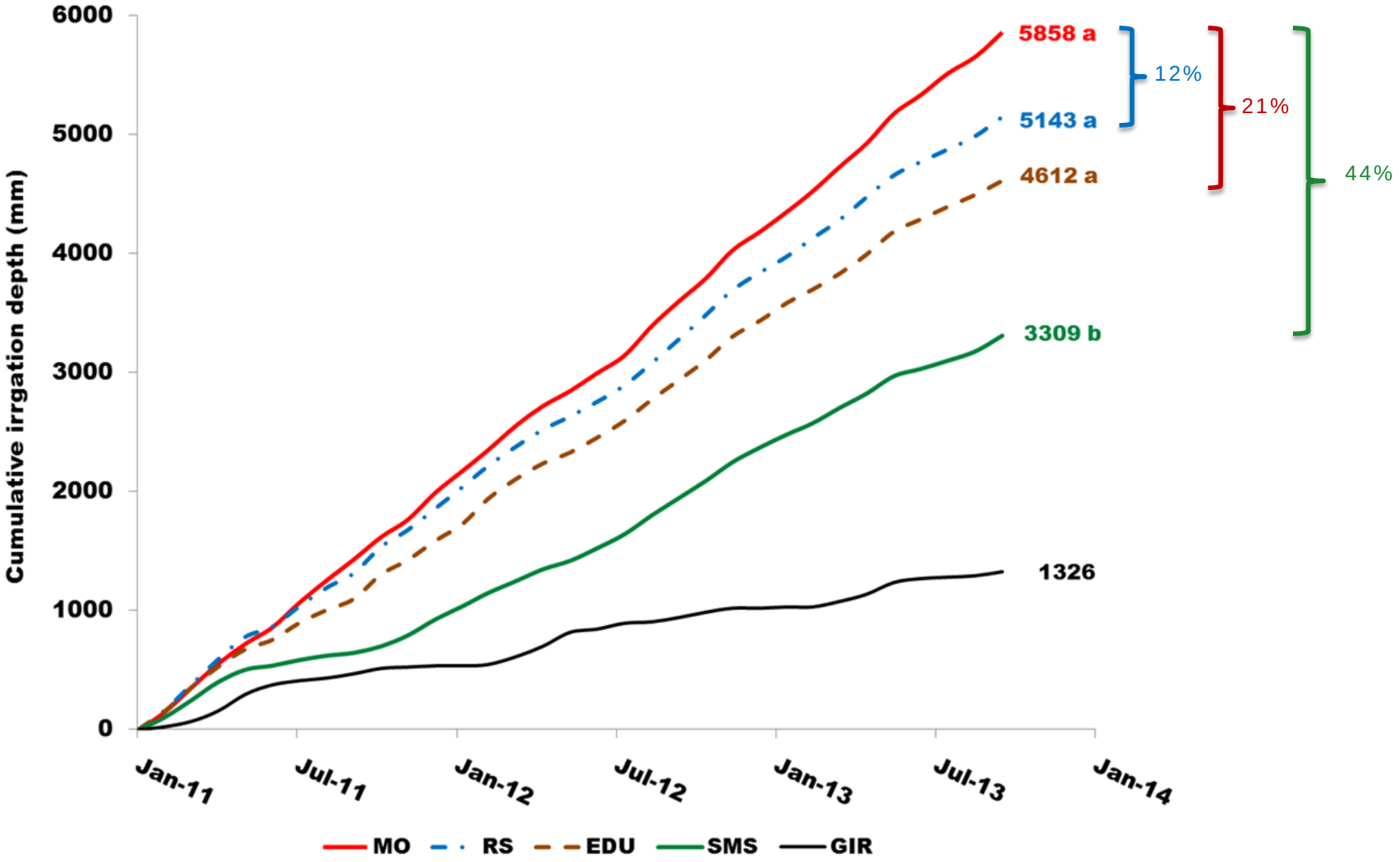


Cumulative mean irrigation by treatment, with statistical comparisons, versus calculated GIR. Different letters after cumulative irrigation depth indicate statistical difference at P<0.05 (Duncan's multiple range test).

Turfgrass quality

- No treatment differences.
- Always >5 (minimally acceptable).

CONCLUSIONS

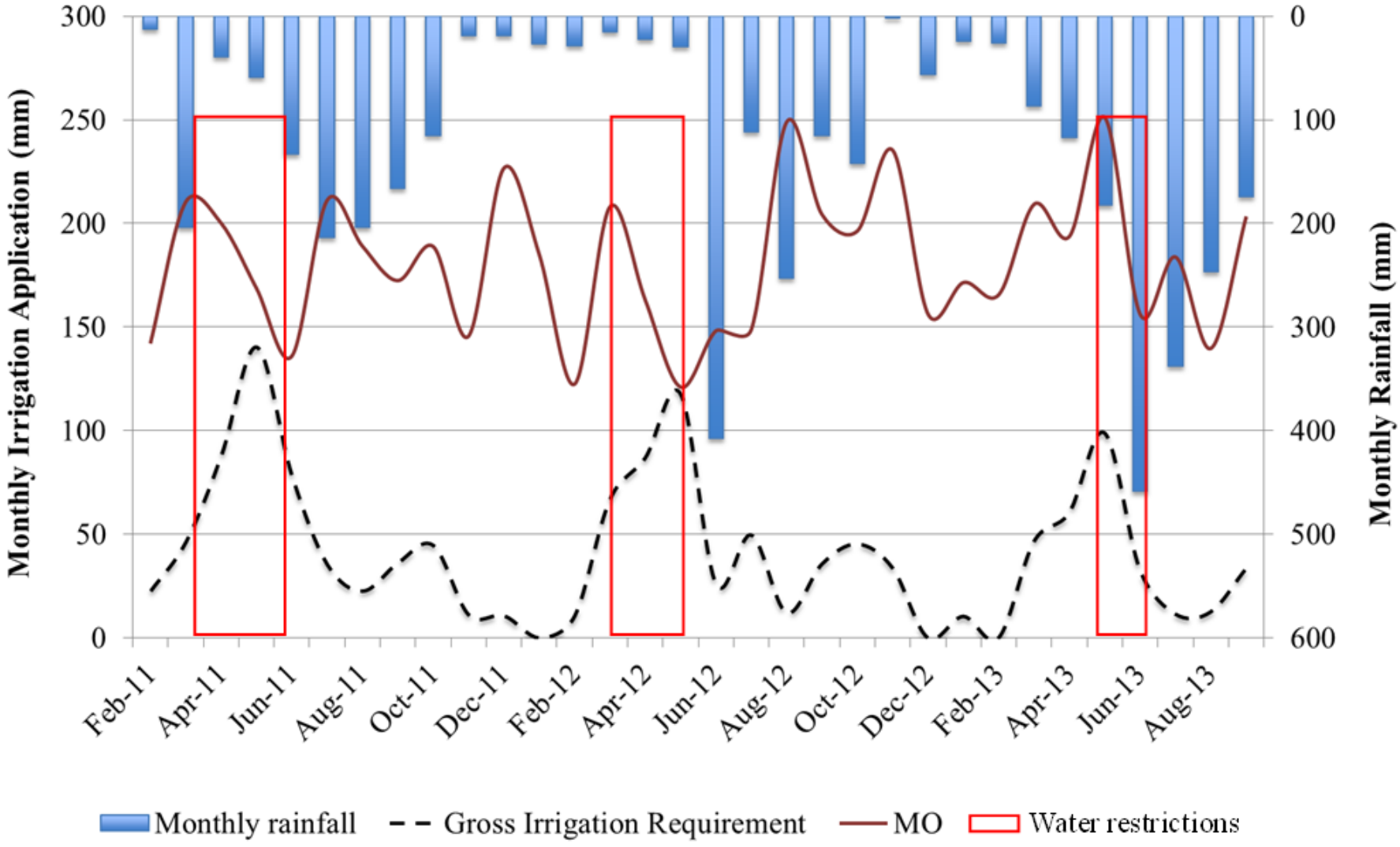
- SMS treatment was the only group of homes significantly different to the comparison group, MO (savings 44%)
- All treatments over-irrigated compared to the calculated GIR.
- SMS were the group that irrigated most properly; even when there is still room to improve their irrigation application.
- Opportunity not just to conserve but to make better use of the RW (connecting more houses to the RW system).
- This could, as a consequence, save an important amount of potable water currently destined for irrigation purposes.

CONCLUSIONS

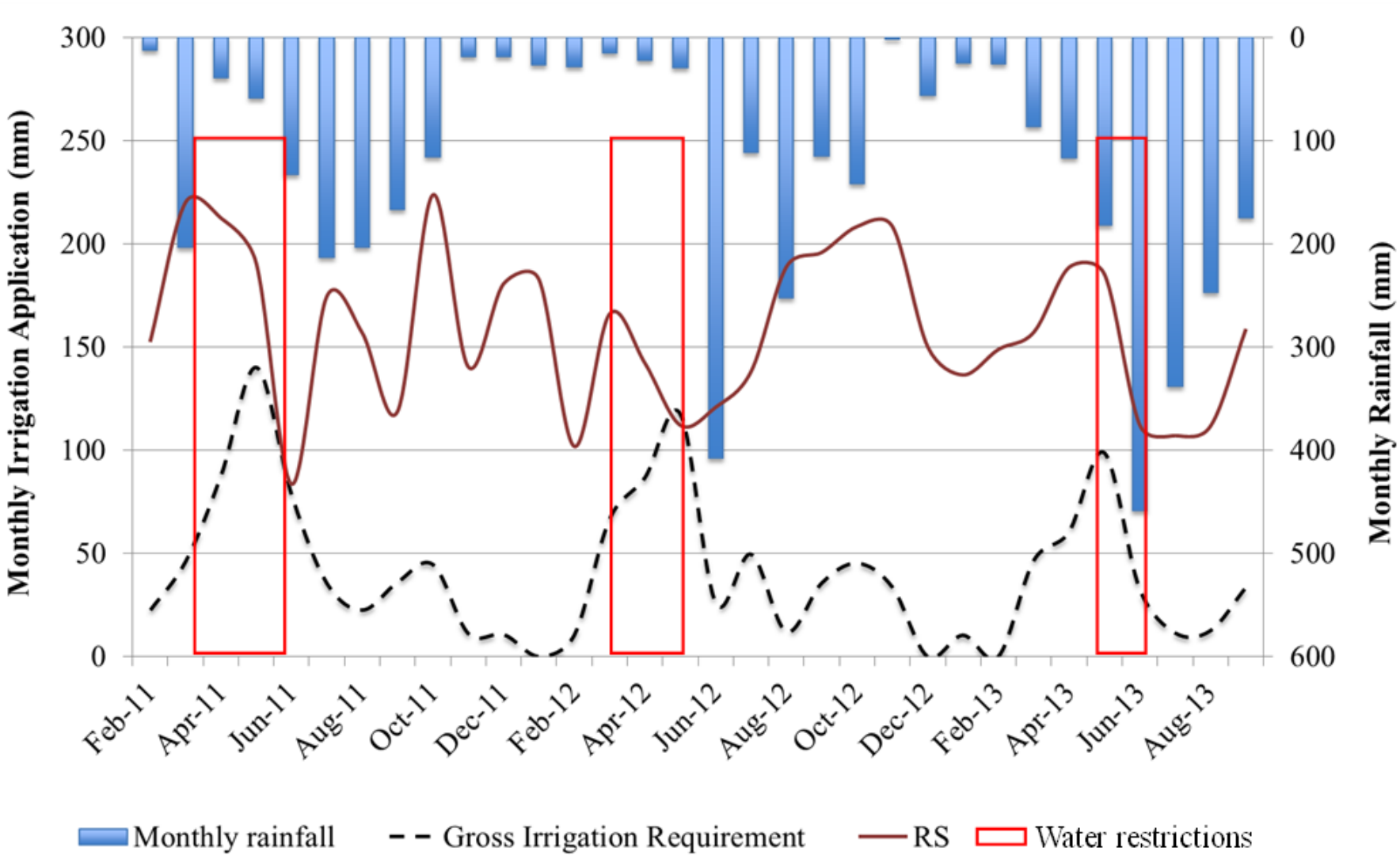
- These results concur with those yielded in previous studies irrigating with potable water.

- A study with a higher number of homes and for a longer period of data collection, may verify these promising results and could elucidate the use and acceptance of SMSs by homeowners.

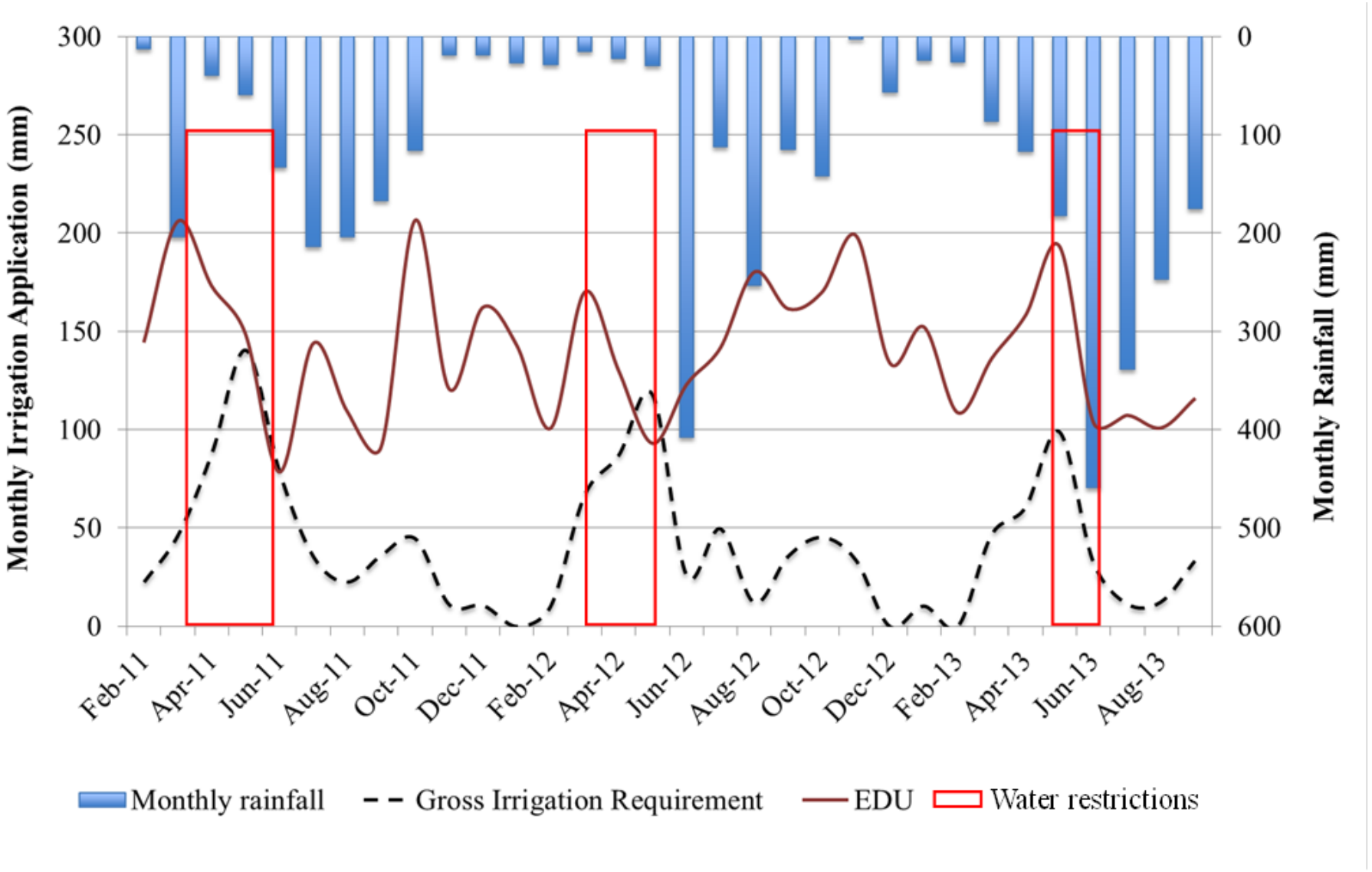

Questions?



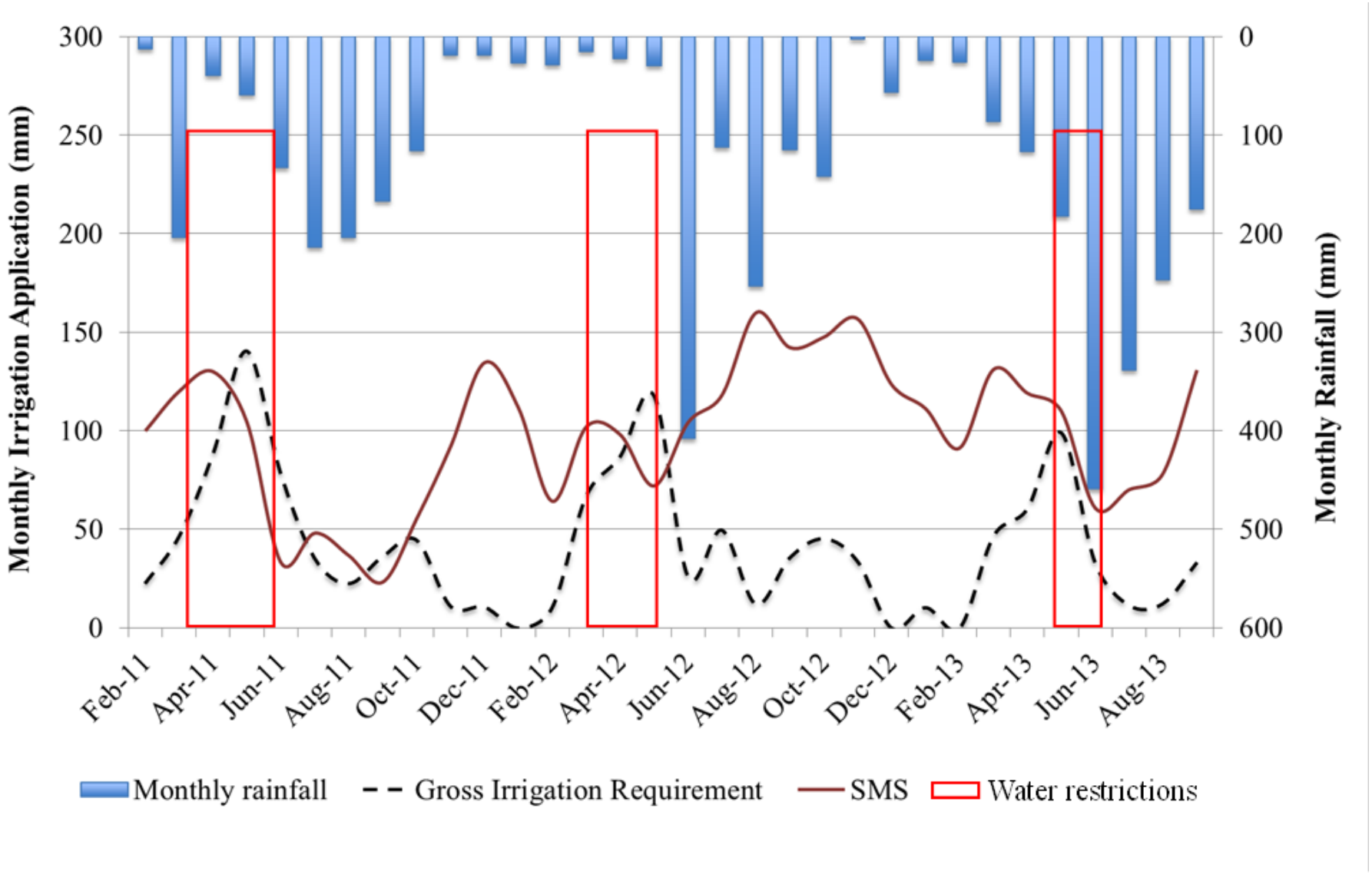
Monthly irrigation application for MO treatment compared to a calculated gross irrigation requirement based on a daily soil water balance model. Water restrictions were imposed during the time-frame encompassed in the red rectangles.



Monthly irrigation application for RS treatment compared to a calculated gross irrigation requirement based on a daily soil water balance model. Water restrictions were imposed during the time-frame encompassed in the red rectangles.



Monthly irrigation application for EDU treatment compared to a calculated gross irrigation requirement based on a daily soil water balance model. Water restrictions were imposed during the time-frame encompassed in the red rectangles.



Monthly irrigation application for SMS treatment compared to a calculated gross irrigation requirement based on a daily soil water balance model. Water restrictions were imposed during the time-frame encompassed in the red rectangles.