This presentation premiered at WaterSmart Innovations

watersmartinnovations.com
Soil Moisture Sensors: Performance in Homes irrigating with Reclaimed Water

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WaterSmart Innovations 2017
5 October 2017; Las Vegas, NE
OUTLINE

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

<table>
<thead>
<tr>
<th>State</th>
<th>Author</th>
<th>Year</th>
<th>Savings (%)</th>
<th>Compared to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utah</td>
<td>Allen</td>
<td>1997</td>
<td>10</td>
<td>Control group</td>
</tr>
<tr>
<td>Colorado</td>
<td>Qualls et al.</td>
<td>2001</td>
<td>27</td>
<td>Theoretical requirement</td>
</tr>
<tr>
<td>Florida</td>
<td>Haley &amp; Dukes</td>
<td>2012</td>
<td>65</td>
<td>Control group</td>
</tr>
<tr>
<td>N. Carolina</td>
<td>Nautiyal et al.</td>
<td>2014</td>
<td>42</td>
<td>Control group</td>
</tr>
<tr>
<td>Florida</td>
<td>Davis &amp; Dukes</td>
<td>2015</td>
<td>44</td>
<td>Historical use</td>
</tr>
</tbody>
</table>

- Turf quality above minimum acceptable
# Reclaimed Water (RW) in the US

<table>
<thead>
<tr>
<th>State</th>
<th>Population (2006 est)</th>
<th>Reported Reuse in Millions of Gallons per Day</th>
<th>Reuse per Capita in Gallons per Day per Person</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>18,019,093</td>
<td>663.0</td>
<td>36.79</td>
<td>1</td>
</tr>
<tr>
<td>California</td>
<td>36,121,296</td>
<td>580.0(^2)</td>
<td>16.06</td>
<td>2</td>
</tr>
<tr>
<td>Virginia</td>
<td>7,628,347</td>
<td>11.2</td>
<td>1.46</td>
<td>3</td>
</tr>
<tr>
<td>Texas</td>
<td>23,367,534</td>
<td>31.4</td>
<td>1.34</td>
<td>4</td>
</tr>
<tr>
<td>Arizona</td>
<td>6,178,251</td>
<td>8.2</td>
<td>1.33</td>
<td>5</td>
</tr>
<tr>
<td>Colorado</td>
<td>4,751,474</td>
<td>5.2</td>
<td>1.09</td>
<td>6</td>
</tr>
<tr>
<td>Nevada</td>
<td>2,484,196</td>
<td>2.6</td>
<td>1.03</td>
<td>7</td>
</tr>
<tr>
<td>Idaho</td>
<td>1,461,183</td>
<td>0.7</td>
<td>0.50</td>
<td>8</td>
</tr>
<tr>
<td>Washington</td>
<td>6,360,529</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>
## RW users in Florida (2016)

<table>
<thead>
<tr>
<th>User</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residences</td>
<td>397,750</td>
</tr>
<tr>
<td>Parks</td>
<td>1,053</td>
</tr>
<tr>
<td>Golf courses</td>
<td>574</td>
</tr>
<tr>
<td>Schools</td>
<td>381</td>
</tr>
<tr>
<td>Cooling towers</td>
<td>90</td>
</tr>
</tbody>
</table>
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 automated irrigation system

• RW has become a limited resource in certain municipalities in FL
Main objective:

In homes that used RW
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
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)
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
Methodology (Cont.)

- Homes Recruitment

Letter (Pinellas Co. Utilities) → http://irrigation.ifas.ufl.edu/study → Informed Consent → Survey
Methodology (Cont.)

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

2. Do you water your lawn turf (grass) and landscape (bedded areas) with different sprinkler head types?
   - Yes
   - No
   - Don’t know

3. Do you water your lawn turf (grass) and landscape (bedded areas) for different lengths of time?
   - Yes
   - No
   - Don’t know

4. How long do you typically water your lawn turf (grass) 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 interest with your irrigation system by marking the number which best describes:
   - [ ] 1
   - [ ] 2
   - [ ] 3
   - [ ] 4
   - [ ] 5
   - [ ] 6
   - [ ] 7
   - [ ] 8
   - [ ] 9
   - [ ] 10
   - [ ] Don’t know

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 ET weather-based irrigation controller will appropriately schedule irrigation events?
    - Yes
    - No
    - Don’t know

11. Have you ever participated in an irrigation water use conservation program?
    - Yes
    - No
    - Don’t know

12. Please rate the level of familiarity regarding the characteristics of your lawn and landscape from 1 to 10 (with 1 being highest):

<table>
<thead>
<tr>
<th>Plant types</th>
<th>Water needs of different plant types</th>
<th>Soil type</th>
<th>Sun and Shade patterns</th>
<th>Plant rock depths</th>
<th>Usable rainfall percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] 1</td>
<td>[ ] 2</td>
<td>[ ] 3</td>
<td>[ ] 4</td>
<td>[ ] 5</td>
<td>[ ] 6</td>
</tr>
</tbody>
</table>

13. Please rate your level of familiarity regarding the characteristics of your irrigation system from 1 to 10 (with 1 being highest):

<table>
<thead>
<tr>
<th>Irrigation zone locations</th>
<th>Sprinkler location on slope</th>
<th>Sprinkler head types</th>
<th>Efficiency of irrigation system</th>
<th>Approximate precipitation rates</th>
<th>Locally permitted irrigation hours</th>
<th>Locally permitted irrigation days</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] 1</td>
<td>[ ] 2</td>
<td>[ ] 3</td>
<td>[ ] 4</td>
<td>[ ] 5</td>
<td>[ ] 6</td>
<td>[ ] 7</td>
</tr>
</tbody>
</table>

14. Please rank 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 increase the lawn area of my yard.
   - I would like to learn more about landscape water use before deciding what, if any, actions to take.

15. If the three top statements best describe your attitude toward your home’s present landscape, how would you rate your agreement to the following statements?

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

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

18. In your opinion, how effective are (would be) each of the following for increasing water conservation?
   - Water restrictions
   - Rain shut-off devices
   - Increased water rates
   - Landscape ordinances that limit turfgrass areas
   - Local conservation programs
   - Irrigation scheduling based on water needs of plants
   - Using native plants in the bedded areas

Thank you for your participation.
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 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 and 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 lawn grass
   - 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
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.
Methodology (Cont.)

- Homes Recruitment

Pre-selected homes
Methodology (Cont.)

- Homes Recruitment

Pre-selected homes  Irrigation Audit
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
Methodology (Cont.)

- Homes Recruitment

Pre-selected homes → Irrigation Audit → Selected homes
Methodology

- Recruited 64 homes in Pinellas Co.
Methodology (Cont.)

- Homes Recruitment

  - 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.
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)
Experimental Treatments

Homes are subdivided into 4 groups

1) Monitoring only = MO

2) Rain sensor = RS

3) Rain sensor + educational materials = EDU

4) Soil moisture sensor = SMS
Turf Quality
## RESULTS
(Jan. 2011 - Sep. 2013)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Depth per event (mm)</th>
<th>Events per week (#)</th>
<th>Depth per week (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MO</td>
<td>15.4 ns&lt;sup&gt;y&lt;/sup&gt;</td>
<td>2.7 a&lt;sup&gt;z&lt;/sup&gt;</td>
<td>42 a</td>
</tr>
<tr>
<td>RS</td>
<td>15.4 ns</td>
<td>2.4 a</td>
<td>37 a</td>
</tr>
<tr>
<td>EDU</td>
<td>14.4 ns</td>
<td>2.3 a</td>
<td>33 a</td>
</tr>
<tr>
<td>SMS</td>
<td>14.1 ns</td>
<td>1.7 b</td>
<td>24 b</td>
</tr>
</tbody>
</table>

<sup>x</sup> 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.

<sup>y</sup> ns = No significant difference.

<sup>z</sup> Different letters within a column indicate statistical difference at P<0.05 (Duncan's multiple range test).
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(Jan. 2011 - Sep. 2013)

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<td>2.7 a(^z)</td>
</tr>
<tr>
<td>RS</td>
<td>15.4 ns</td>
<td>2.4 a</td>
</tr>
<tr>
<td>EDU</td>
<td>14.4 ns</td>
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</tr>
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</tbody>
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<tbody>
<tr>
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<td>2.7 a&lt;sup&gt;z&lt;/sup&gt;</td>
<td>42 a</td>
</tr>
<tr>
<td>RS</td>
<td>15.4 ns</td>
<td>2.4 a</td>
<td>37 a</td>
</tr>
<tr>
<td>EDU</td>
<td>14.4 ns</td>
<td>2.3 a</td>
<td>33 a</td>
</tr>
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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.