Improving Operation Profitability with Wise Water Use

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Smart-Farms.net — Managing Irrigation and Nutrition via Distributed Sensing
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Three Economic Case-Studies

1. Water – Pot in Pot Nursery (TN)
2. Disease Management – Container Nursery (GA)
3. Floral Crop Quality – Greenhouse Cut-flower (MD)
Wireless Sensor Network Components

Greenhouse Zone

Wireless Communication Network

Irrigation Controller
Sensors

Valves

Irrigation Scheduler

Farm Zoning Module

Water Use Model

Crop Database

Local Computer

Grower Input

Remote Computer or Smartphone

Decision Support System

Wireless Sensor Network Components

Greenhouse Zone

Wireless Communication Network

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**Hale and Hines Nursery – Facts**

- 200 acres of pot-in-pot production
- Mostly 10, 15, 30 and 45 gal containers
- Spray-stake irrigation, 1 emitter per tree
- Irrigation scheduled by time, using programmable irrigation controller (TUCOR)
- Cyclic irrigation, 3-6 minutes per tree, 0.15 - 0.5 gal per cycle
- Irrigation is limited by total production (i.e. *pumping capacity and time*), not by water supply.

**Integration and Scaling 2013/14**

**Control Block (Nodes)**
- Set-point control (nodes)
- 8 species
- 2 container sizes (60L; 120L)
  - Irrigation Duration (set)

**Feedback:**
- Irrigation Frequency
- Flow meter Data

**Sensorweb**

**TUCOR Irrigation Controller**

**$45,000 Sensor Network**
Click on a location image above or click on a location name below to view nodes and growing tools at that location.

Grower Scheduled (Monitoring) Block
Remotely Scheduled (Control) Block

Water Use -- by Species -- and Season

A. Dogwood  
Slow growth rate, low water use

B. Red maple  
Fast growth rate, high water use
Sensor Networks – Water Conservation

Typically conserve between 40 and 70% of current BMP’s (cyclic, timed)

Sensor networks typically save water in four ways:

- **SPECIES:** (plant water use varies with growth rate; root & leaf morphology; root: shoot ratio)
- **HOURLY:** Reduced cycle DURATIONS
- **DAILY:** Sensors apply water based on environmental conditions (daily adjustments for rainfall, temperature, vapor pressure deficit)
- **SEASONALLY:** Most water conserved in Spring and Fall (better timing of applications to actual plant water use)

HortTechnology – Special Series
December, 2013
http://horttech.ashpublications.org

Economics of Water Use - ROI

<table>
<thead>
<tr>
<th>Costs and benefits</th>
<th>Water price [per 1000 gal (3,785 m³)]*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.7 year ROI</td>
</tr>
<tr>
<td>Benefits</td>
<td></td>
</tr>
<tr>
<td>Pumping cost savings</td>
<td>$8,137</td>
</tr>
<tr>
<td>Management cost savings</td>
<td>$12,150</td>
</tr>
<tr>
<td>Annual savings</td>
<td>$20,288</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td>Annualized sensor system cost</td>
<td>$14,205</td>
</tr>
<tr>
<td>Annual maintenance</td>
<td>$1,000</td>
</tr>
<tr>
<td>Total sensor system cost</td>
<td>$15,205</td>
</tr>
<tr>
<td>Annual net savings</td>
<td>$5,263</td>
</tr>
</tbody>
</table>

*Corresponding water prices = $55, $226, $652, and $978 per acre-foot; $1/acre-foot = $8.1071/hecacre-meter.

Belayneh et al., 2013. HortTechnology 23:760-769
Dearing, Georgia
• National market scope
• Mid-size containers

Large grower

Focus on “troublesome crops”

Show me the $$$

Comparative Water Use Study

Gardenia ‘radicans’ (an industry problem crop!)

High shrinkage due to crop death/unmarketable final product.
McCorkle Nurseries, Neals Mill Farm

Office with basestation, computer

300 meters

2 acre greenhouse

Preliminary Study (2010)

Cumulative irrigation volume (gallons)

Date

Control plots

Weekend
(Plants not watered)

Moisture Clik-controlled irrigation
Preliminary Study – Controlled Plot Results

Water Use
• Control: 13,350 gallons applied
• Moisture Clik: 2,327 gallons applied (83% less)

Substrate Solution EC
• Control: 0.94 mS/cm
• Moisture Clik: 1.51 mS/cm – Less Leaching?

Plant Growth and Quality
• Similar and marketable

Follow-up Studies – Comparative Water Use
Sensor Network Production Impacts

- Better uniformity
- Reduced losses due to disease, overwatering
- Greatly reduced production times
  - 14 to 9 months (1st study)
  - 9 to 5 months (2nd study)
- Compressed Marketing Window

Chappell et al., 2013 HortTechnology 23:770-776

Gardenia Studies: Profitability Summary

Return on Investment in sensor network was < 1 month

<table>
<thead>
<tr>
<th></th>
<th>No Sensors</th>
<th>Sensor-Based Irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annualized Revenue</td>
<td>$66,297.36</td>
<td>$145,505.64</td>
</tr>
<tr>
<td>Annualized Production Expenditures</td>
<td>$30,539.11</td>
<td>$50,039.93</td>
</tr>
<tr>
<td>Annualized Sensor System Cost (3-year Lifetime, 6% Interest)</td>
<td>$0.00</td>
<td>$3,755.24</td>
</tr>
<tr>
<td>Annualized Profit</td>
<td>$35,758.24</td>
<td>$91,710.47</td>
</tr>
<tr>
<td>Annualized Profit per Square Foot</td>
<td>$1.79</td>
<td>$4.59</td>
</tr>
<tr>
<td>Percent Change from Base Case</td>
<td></td>
<td>+156%</td>
</tr>
</tbody>
</table>

Lichtenberg et al., 2013 HortTechnology 23:770-776
Flowers By Bauers Greenhouse

20,000 square foot greenhouse production
- Produces 475,000 stems of Snapdragons per annum
- Hydroponic culture using recirculating water and nutrients
- Perlite substrate in bags, monitored with EC-5, GS3-EC sensors; Tank with EC, pH
- Canopy environment monitored with air Temp / RH (VPD) and light (PAR) sensors
Using Sensors in Greenhouse Management

1. Identify stress areas within the greenhouse.
2. Establish and adjust irrigation schedules.
3. Improve floral quality; shorten production times.
4. Proactive approach to disease by reducing substrate moisture, using control set-points.
5. Identify equipment failures.
6. Improved resource use-efficiency; reduced labor cost

The Perlite Grow Bag System (pre-2012):

- 6’ NFT tube filled with 2.2 cubic feet of perlite.
- The tube was white/black.
- Bare rooted seedlings were transplanted when plants were 15-20 days old.
- The plant was ready for harvest within 7-17 weeks depending on the season.
- The perlite bag was used for 20 crops (6 years) with no sterilization. After 6 years the perlite loss its properties for hydroponics (organics buildup, worn, pests)
Tray Production System (2013)

- 30 plants per tray.
- \( \frac{1}{4} \) substrate volume per plant compared to bag system
- Requires 2 drip tapes to uniformly disperse the nutrient solution.
- Reliant on sensor-based irrigation management
- Benefit: more precise VWC control in root zone

Bauer’s Sensorweb Homepage
Node and Sensor Placement in the Bench

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
</table>

28 m

3% slope

WETTER DRIER WETTER DRIER

Macro-Irrigation Schedule

First Irrigation at 6:00 AM
Last Irrigation at 6:00 PM
Enough Time to Dry Down Before Sunset

Macro-Irrigation Scheduler

15 March 2015
Micro-Pulse Irrigation Schedule

Set-Point (180/120 Pulse) Irrigation
Economic Analysis: Total Stems

Lichtenberg, Majsztrik and Saavedra, 2014 (submitted, Irr. Sci.)

Economic Analysis: $ /stem

Lichtenberg, Majsztrik and Saavedra, 2014 (submitted, Irr. Sci.)
### Economic Analysis: Annual Profitability

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops/ year</td>
<td>37</td>
<td>38</td>
<td>1</td>
<td>1 %</td>
</tr>
<tr>
<td>Stems/ year</td>
<td>106,308</td>
<td>139,382</td>
<td>33,074</td>
<td>31 %</td>
</tr>
<tr>
<td>Price/ stem</td>
<td>$0.59</td>
<td>$0.62</td>
<td>$0.03</td>
<td>5 %</td>
</tr>
<tr>
<td>Labor costs</td>
<td>$15,905</td>
<td>$17,893</td>
<td>$1,988</td>
<td>12 %</td>
</tr>
<tr>
<td>Electricity</td>
<td>$4,109</td>
<td>$2,923</td>
<td>$1,186</td>
<td>-29 %</td>
</tr>
<tr>
<td>Sensor system</td>
<td>$0</td>
<td>$7,147</td>
<td>$7,147</td>
<td>----</td>
</tr>
<tr>
<td>Revenue</td>
<td>$63,094</td>
<td>$85,679</td>
<td>22,585</td>
<td>36 %</td>
</tr>
<tr>
<td>Profit</td>
<td>$43,080</td>
<td>$57,716</td>
<td>$14,636</td>
<td>34 %</td>
</tr>
</tbody>
</table>

Payback period on upfront costs <16 months

Lichtenberg, Majsztrik and Saavedra, 2014 (submitted, Irr. Sci.)

### Project Information at [http://smart-farms.net](http://smart-farms.net)
Network Cost

Starter Sensor Network Cost:
• Approximately $10,000 depending on configuration (with custom installation)

Relational Cost:
• 50lb bag (22.7 Kg) slow-release fertilizer cost $80
• Medium application rate is about 57g (2oz) / 3 gal container
• Single application SRF costs $0.25 / 3 gal

15,000 plants per acre (spaced) x 0.25 = $3,750 / acre for SRF

Network Cost

Starter Sensor Network Cost:
• Approximately $10,000 depending on configuration (with custom installation)

Relational Cost:
• Reduce nutrient leaching by 30% (reduce application rate)
  Reduce fertilizer application to 38g/plant = $1,125 per acre

$10,000/ $1,125 equates to saving 1/3 fertilizer applied to less than 9 acres
Thank You

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