New tools for old problems
Irrigation Management Using Soil Moisture Sensors

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Our New Tools and Methods

1. Sensor Networks – ground and cloud-based systems

2. "Our Toolbox"

3. Software Development – Translating Information into Decisions

   - *Automated Irrigation Control*

   - *Model Integration*

   - *Alert Capabilities*

4. Economic Impacts – Multiple and Synergistic
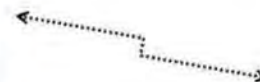
Sensor Networks

Local Irrigation Control

Production Area / Irrigation Zone

Sensors   Solenoid

DATA STATION

Global Irrigation Control
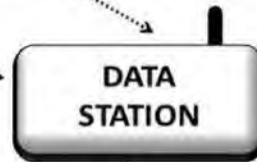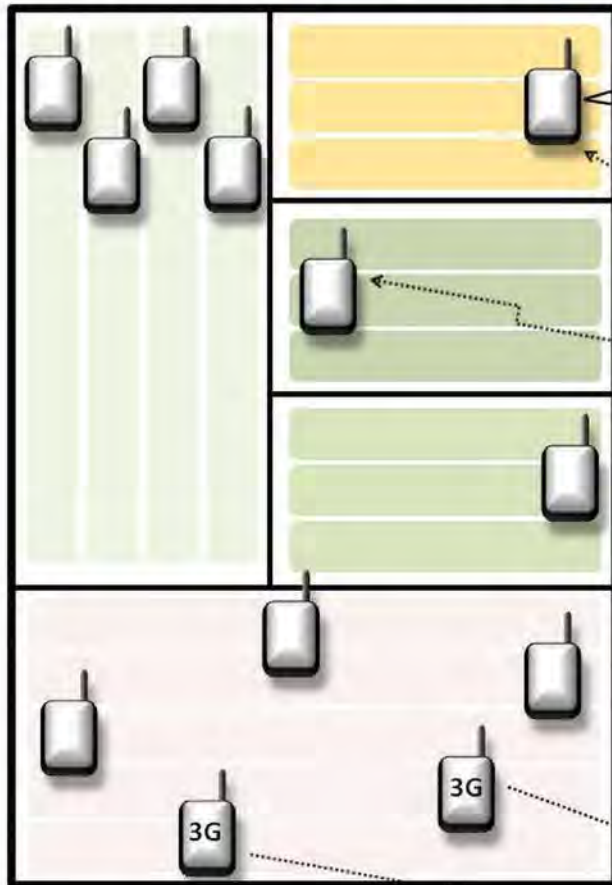
Local Computer

Grower Input

Crop Models | Irrigation Scheduler

Graphic User Interface

Database

3G

3G

(Via Secure Internet Connection)

Remote Server

Smartphone or Handheld Device

Smart-Farms.net — Managing Irrigation and Nutrition via Distributed Sensing
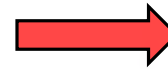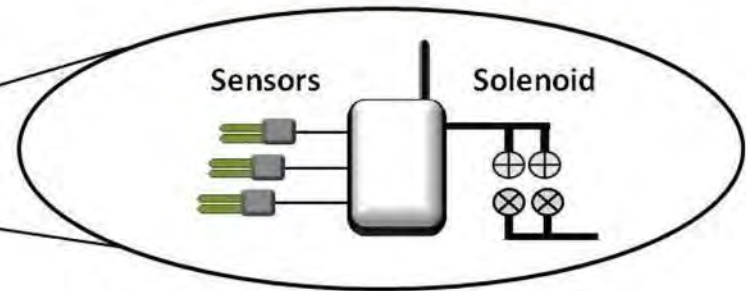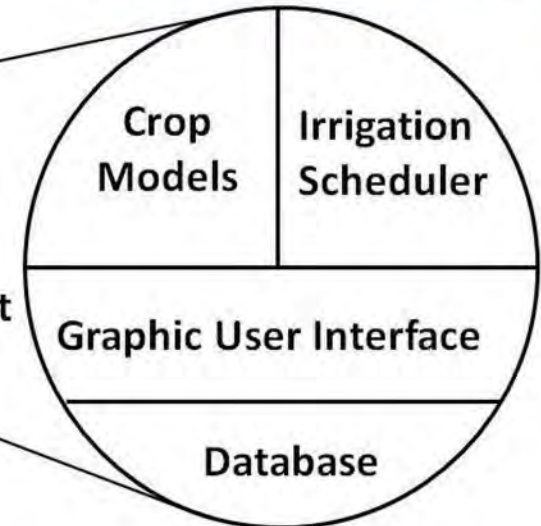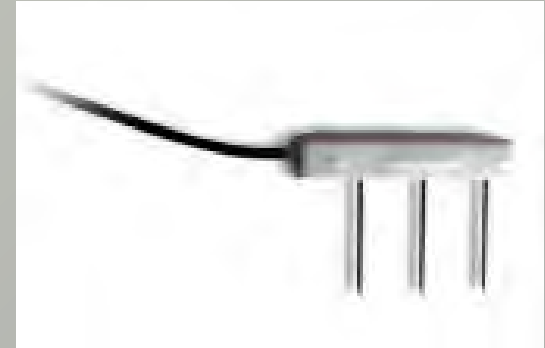
Smart Toolbox

Soil Moisture, EC Sensors

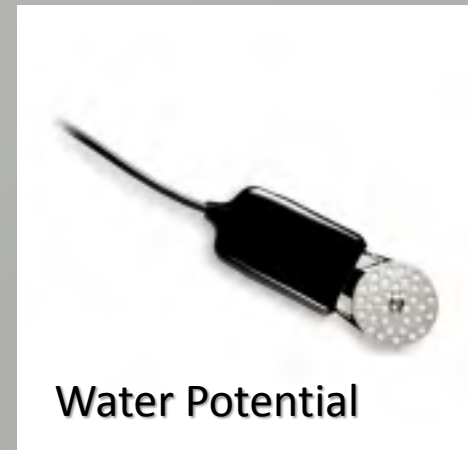Various soil moisture sensors

GS3: EC, soil moisture, soil temperature

Line pressure

In-line/Tank EC

Water Potential

Environmental Sensors

Photosynthetic
and Total radiation

Wind speed
and direction

Precipitation

temperature, RH
and VPD

Sonic anemometer

Leaf wetness, Dew and Ice

Radio Dataloggers

Monitoring
Node

Control
Node

Cellular (3G)
Monitoring Node

Automated Control Capability

- Developed an advanced node, capable of controlling irrigation and reading multiple sensors

- Data is used by growers in real-time to make decisions and monitor crop/field conditions

- Plant irrigation can be determined automatically based on set-points or using plant water use models

- Sensor data and irrigation control can be accessed remotely

- System is fault-tolerant and reliable

Kohanbash, Kantor, Martin and Crawford, 2013
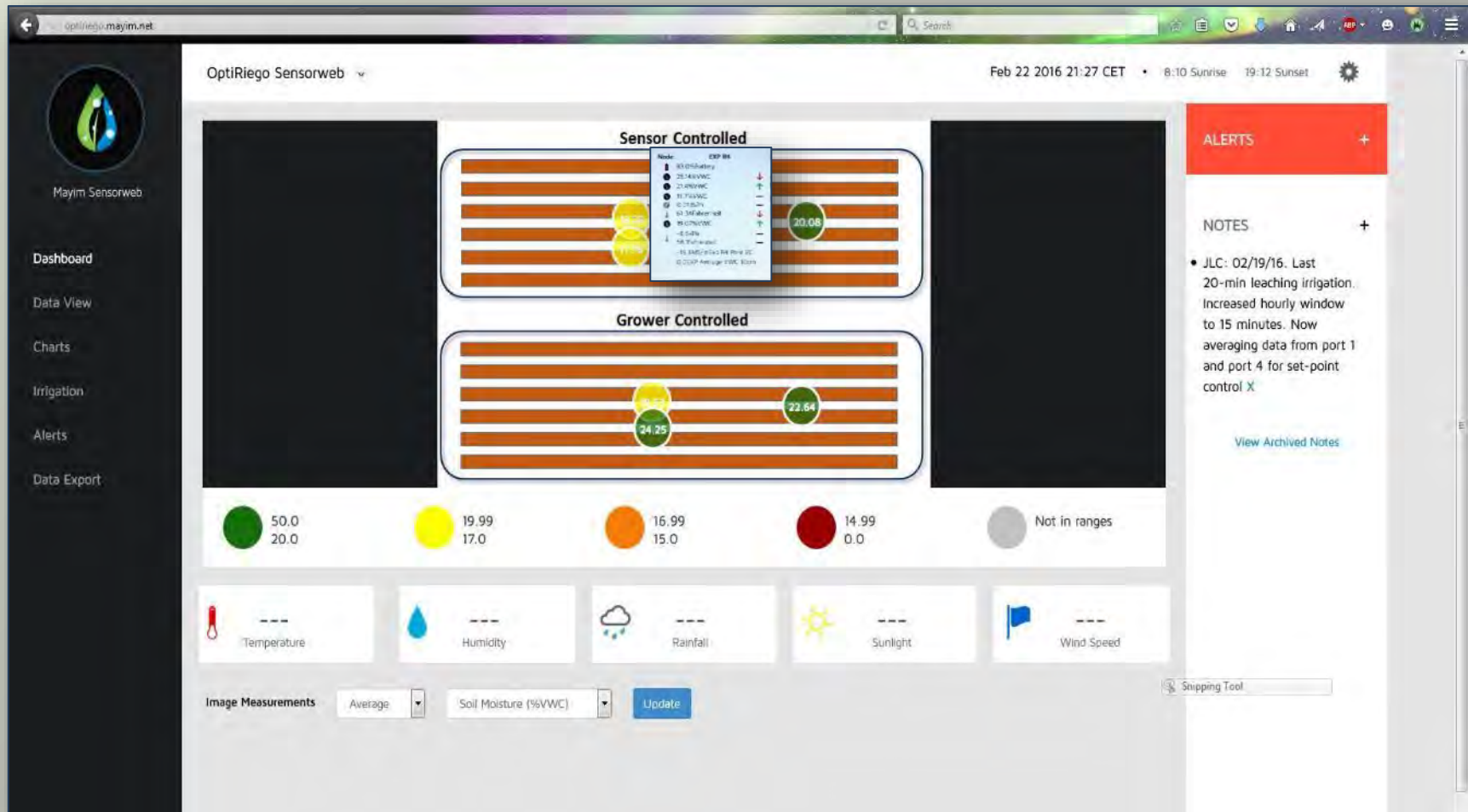*HortTechnology 23: 725-734*

Set-Point Irrigation Scheduling

nR5-DC Node

- ✓ Prototype nR5-DC Node – Integrated with a flow meter and controls a 12V latching solenoid

- ✓ **Allows us to control and measure water applications in remote locations where there is *NO* electrical power**

Flow meter

12V DC latching solenoid + 1" valve

Bleed valve
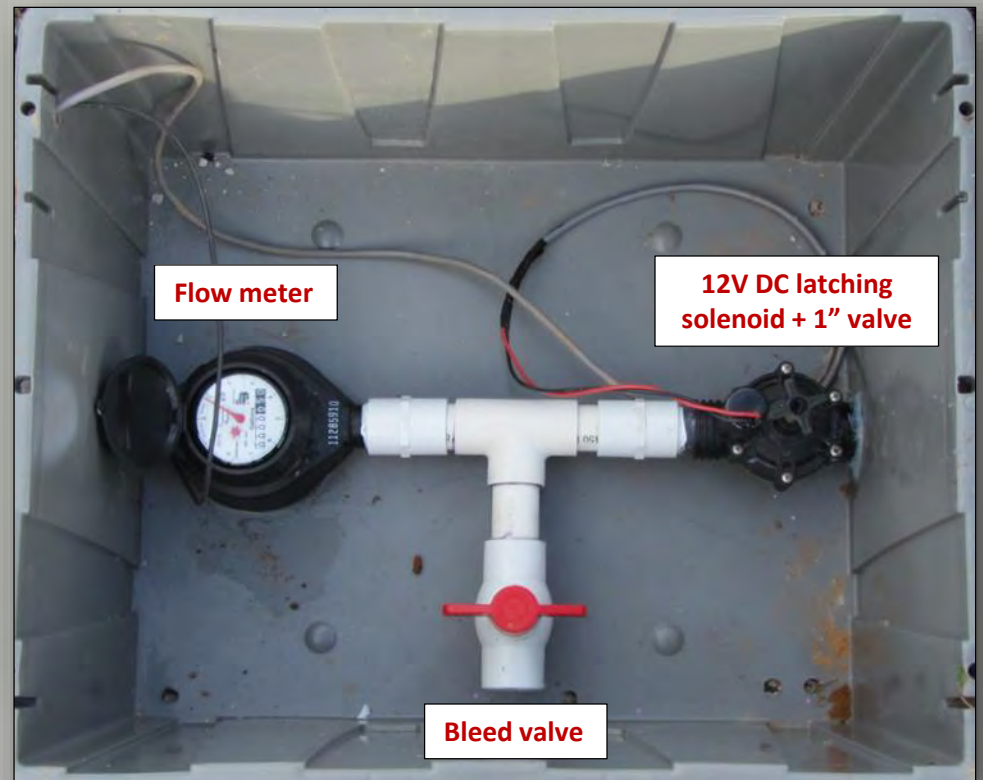
SensorWeb™ Software Interface

Farm (website) Homepage – "Management at a Glance"

SensorWeb Micro-Pulse Irrigation Scheduling Capability

- ➢ Sensor-based irrigation control scheduled for 15 minutes every hour
- ➢ Within each 15 minute period, able to irrigate up to three, 4-minute pulses (i.e. 240s on, 60s off)
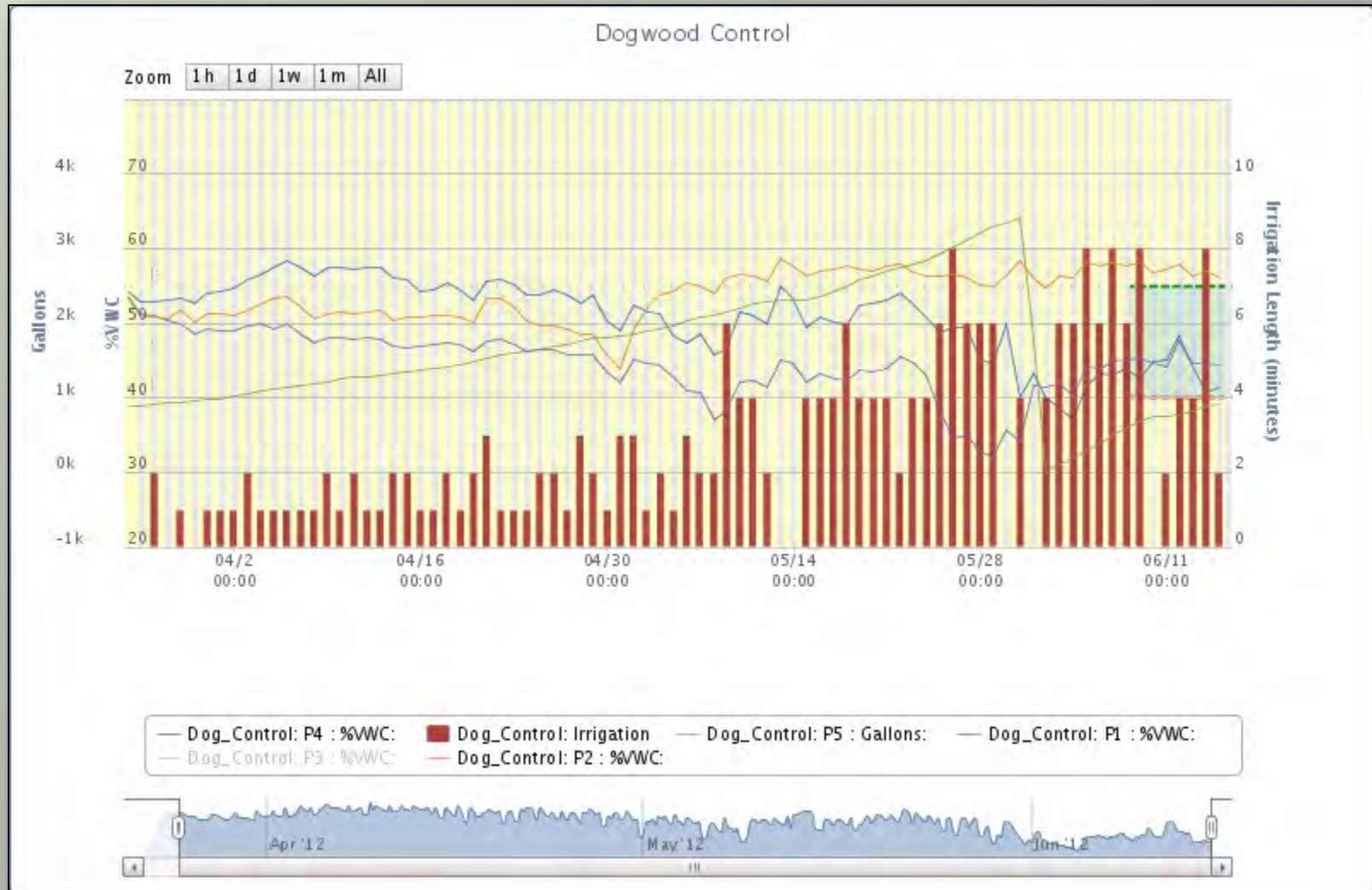- ➢ *Only irrigates* if the minimum soil VWC is reached (currently set at 19% VWC)

Software Capability: Micro-Precision Irrigation

- *Turning Data into Information*

- *Measuring Variability:* – *Averaging Capability (any sensor, any node)*

- *Acting on that Information:* – *Automated Micro-pulse Irrigation*

Enables remote and/or automatic control of irrigation schedules, via a customizable web-based interface

Kohanbash, Kantor, Martin and Crawford, 2013 HortTechnology 23: 725-734

Sensor-Controlled Irrigation Scheduling

Belayneh, Lea-Cox and Lichtenberg, 2013. HortTechnology 23:760-769

Real-time EC Monitoring: Integrating Data
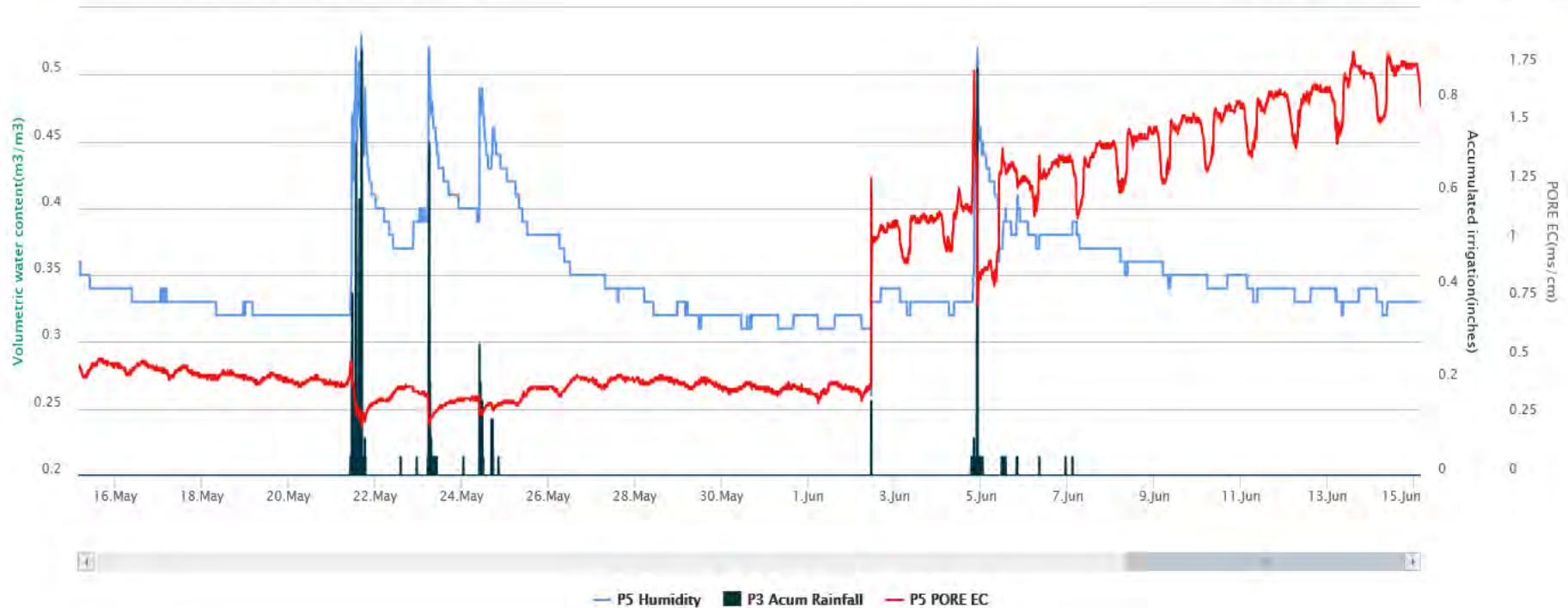
SensorWeb Alert Capability

➤ Alerts can be set for any node or sensor, at a specified time or set-point threshold value

➤ Alerts can be texted or emailed to any user

The Process

Data ➡ Information ➡ Knowledge ➡ Action

The System

Sensors ➡ Software ➡ 'Analyst' ➡ Decision-Maker

Intelligence   Intelligence   Intelligence

Irrigation Efficiency – Return on Investment

Table 4. Water price comparisons and returns from changing timed cyclic irrigation into sensor-controlled irrigation.

Costs and benefits	Water price [per 1000 gal (3.785 m³)][z]			
	$0.17	$1.00	$2.00	$3.00
Benefits	2.7 year ROI			4-month ROI
Pumping cost savings	$ 8,137	$46,944	$94,189	$141,283
Management cost savings	$12,150	$12,150	$12,150	$12,150
Annual savings	$ 20,288	$59,094	$106,339	$153,433
Costs				
Annualized sensor system cost	$14,205	$14,205	$14,025	$14,025
Annual maintenance	$ 1,000	$1,000	$1,000	$ 1,000
Total sensor system cost	$15,205	$15,205	$15,025	$15,025
Annual net savings	$ 5,263	$44,069	$91,313	$138,408

[z]Corresponding water prices = $55, $326, $652, and $978 per acre-foot; $1/acre foot = $8.1071/hectare-meter.

Belayneh, Lea-Cox and Lichtenberg, 2013. HortTechnology 23:760-769

Fungal Disease Management

Gardenia 'radicans' - high shrinkage due to crop death/unmarketable final product.

Reduction in Production Times, Net Benefits

- ✓ 14-month production cycle collapsed to 8-month

- ✓ 30% loss to Disease reduced to virtually zero

- ✓ Economic Gain = $1.06 / ft^2
  (total net revenue = $20,700 for crop)

- ✓ ROI < 3 months for $6,000 network

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

Increase in Crop Quantity and Quality

35,000 square foot greenhouse production

- Produces 475,000 stems of Cut Snapdragons, Sunflowers 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

Economic Analysis: Annual Profitability

Pre-Sensor: (2007 – 2009)   **Post-Sensor: (2010 – 2012)**

	2007 -2009	2010- 2012	Difference	Change
Crops/ year	37	38	1	1 %
Stems/ year	106,308	139,382	33,074	31 %
Price/ stem	$ 0.59	$ 0.62	$ 0.03	5 %
Labor costs	$ 15,905	$ 17,893	$ 1,988	12 %
Electricity	$ 4,109	$2,923	$ 1,186	-29 %
Sensor system	$ 0	$7,147	$ 7,147	---
Revenue	$63,094	$ 85,679	22,585	36 %
Profit	$43,080	$57,716	$14,636	34 %

Payback period on upfront costs: <16 months

Lichtenberg et al., 2015 (Irr. Sci., In Review)

On-farm Weather Station

DS-2 Sonic Anemometer
Wind speed and direction

VP-4
Temp, RH, VPD,
Barometric Pressure

Pyranometer
Solar Radiation

QSO-S PAR
PAR (visible light)

ECRN-100 Rain gauge
Precipitation

**Em50G "cloud –based"
data logger**

Environmental Data Applications

Soil Temperature

- planting timing (seed/transplants)
- seed emergence
- nematode activity

Temperature

- foliar spray timing (leaf scorch/phytotoxicity)
- spray records
- plant stress/spray performance (esp. herbicides)

Relative Humidity

- general labor scheduling
- foliar spray timing
- spray records (performance)
- pruning timing (disease risk - i.e. Eutypa)

Leaf Wetness

- foliar spray timing
- spray records (performance)

Precipitation

- general labor scheduling
- spray timing
- spray records (performance)
- spray wash-off

Wind

- general labor scheduling
- spray timing
- spray records (drift injury/performance)
- plant injury/stress
- irrigation

Dashboard – Single Node Data

Checkboard – Aggregate Data

Geolocated 7-Day Weather Forecast

Impacts

Synergistic Capabilities:

1. Precision Water and Nutrient Management

2. Timeliness of Decisions; Opportunity Costs

3. Intelligent Alerts

4. Better Predictive Capabilities

Can translate into Multiple Benefits:

1. Reduced Risk and Crop Losses

2. Reduction in Production Times

3. Increased Crop Yield and Quality

Project Information at http://smart-farms.net

http://www.watereducationalliance.org