A watershed perspective of the implication of the drought for crop production

Hosted by:
2014 Vegetable Crops Program Team Meeting
University of California, Agriculture and Natural Resources

Samuel Sandoval Solis, PhD
Assistant Professor
C.E. Specialist in Water Resources
Outline

Water Cycle

Case Study of Pajaro Valley

• Municipal Recycled Water
• Agriculture Water Use Efficiency & Water Conservation
• Conjunctive Management & Groundwater
Main Players

- Inland v. Coastal Users
- Farmers v. Municipal
- Landowners V. Tenants

### The System: Pajaro Valley

#### Land Use Type

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Agricultural Acreage</td>
<td>30,448</td>
<td>33,409</td>
<td>31,516</td>
<td>34,463</td>
<td>34,650</td>
<td>28,299</td>
<td>28,264</td>
<td>28,367</td>
</tr>
<tr>
<td>Urban Acreage</td>
<td>4,757</td>
<td>6,688</td>
<td>8,018</td>
<td>8,384</td>
<td>12,860</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Native Vegetation</td>
<td>61,301</td>
<td>56,409</td>
<td>56,972</td>
<td>53,659</td>
<td>48,996</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Values from 1966-1997 are for the model area; acreages from 2009-2012 are for PVWMA service area.

Source: PVWMA 2002, and PVWMA data, 2012
Seawater Intrusion
Sea Water Intrusion Historic Trend - 1951 -

Inland extent of SWI: 1951
~ 0.9 miles

Legend:
- Cities & Towns
- Streets
- Highway 1
- Pajaro River
- SWI_1951
- PVWMA Boundary
Sea Water Intrusion Historic Trend - 1966 -

Inland extent of SWI: 1966

~ 1.4 miles
~ 2.2 miles

Legend:
- Cities & Towns
- Streets
- Highway 1
- Pajaro River
- SWI_1951
- SWI_1966
- PVWMA Boundary
Sea Water Intrusion Historic Trend - 1998 -

Inland extent of SWI: 1998

~ 1.8 miles

~ 3.0 miles
Sea Water Intrusion Historic Trend - 2005 -

Inland extent of SWI: 2005

~ 2.0 miles

~ 3.2 miles
Composite Groundwater Map
Fall 2012

Explanation
- Red: San Andreas Fault
- Black: PVWMA Boundary
- Groundwater Contours (ft-msl)
  - Blue: Above Sea Level
  - Sea Level
  - Red: Below Sea Level

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STRATEGY:

RECYCLED MUNICIPAL WATER
Treatment Plants
By the numbers

Recycled Water Used (AF)

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>1,000</td>
<td>1,500</td>
<td>2,000</td>
<td>2,500</td>
</tr>
</tbody>
</table>
STRATEGY:

CONJUNCTIVE MANAGEMENT & GROUNDWATER STORAGE
Harkins Slough Project: Aquifer Storage & Recovery
By the numbers

![Graph showing the cumulative diversion and recovery of water from 2001 to 2012.](image)
STRATEGY:

AGRICULTURAL WATER USE EFFICIENCY
Conceptual Model

Well Production (AF) \[ \div \] Land Use (acres) = Applied Water (AF/acre) = Evapotranspiration (AF/acre)

Growers interview (AF/acre & $$$)

* AF = Acre-Feet

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### Applied Water

<table>
<thead>
<tr>
<th>Crop</th>
<th>ET (AFY/acre)</th>
<th>Appl. Water (AFY/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Fallow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables Row Crops (lettuce, Celery,</td>
<td>2.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Zucchini, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strawberries</td>
<td>1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Raspberries</td>
<td>1.8</td>
<td>2.1</td>
</tr>
<tr>
<td>Blackberries</td>
<td>1.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Blueberries</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Vines / Grapes</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Artichokes</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Deciduous (Apple Orchards)</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Nurseries / Flower / Subtropical Plants</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Unknown Ag. Use</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>

AFY = Acre-Feet per Year

* Data estimated through interviews

75% Acreage
Water Savings

Michael Cahn

inches = 31.0
feet = 2.6

ET

<table>
<thead>
<tr>
<th>Inches</th>
<th>Feet</th>
<th>Frequency</th>
<th>Frequency(%)</th>
<th>Acreage</th>
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<tbody>
<tr>
<td>25</td>
<td>2.08</td>
<td>3</td>
<td>25%</td>
<td>1805</td>
</tr>
<tr>
<td>26</td>
<td>2.17</td>
<td>1</td>
<td>8%</td>
<td>602</td>
</tr>
<tr>
<td>28</td>
<td>2.33</td>
<td>2</td>
<td>17%</td>
<td>1203</td>
</tr>
<tr>
<td>30</td>
<td>2.50</td>
<td>1</td>
<td>8%</td>
<td>602</td>
</tr>
<tr>
<td>32</td>
<td>2.67</td>
<td>0</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>34</td>
<td>2.83</td>
<td>0</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>36</td>
<td>3.00</td>
<td>1</td>
<td>8%</td>
<td>602</td>
</tr>
<tr>
<td>38</td>
<td>3.17</td>
<td>2</td>
<td>17%</td>
<td>1203</td>
</tr>
<tr>
<td>40</td>
<td>3.33</td>
<td>1</td>
<td>8%</td>
<td>602</td>
</tr>
<tr>
<td>42</td>
<td>3.50</td>
<td>0</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>44</td>
<td>3.67</td>
<td>0</td>
<td>0%</td>
<td>0</td>
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<tr>
<td>46</td>
<td>3.83</td>
<td>1</td>
<td>8%</td>
<td>602</td>
</tr>
</tbody>
</table>

Crop Polygon Area = 7219

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### Potential Water Savings

**Total**

- **≈ 4.6 – 5.1 TAF per year**
- **Coastal**
  - **≈ 1.6 – 1.8 TAF per year**
- **Inland**
  - **≈ 3.0 – 3.3 TAF per year**

**Lost in Revenue**

- **Wat. Agency:** $862 - $951K per year

---

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Acres</th>
<th>(%)</th>
<th>Irrigation Method</th>
<th>Acreage Factor</th>
<th>Wat. Use (AF/acre)</th>
<th>Applied Water (acre-feet)</th>
<th>Wat. Savings (acre-feet)</th>
<th>Wat. Use Effic. (%)</th>
<th>Wat. Savings Coastal (acre-feet)</th>
<th>Wat. Savings Inland (acre-feet)</th>
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</thead>
<tbody>
<tr>
<td>Fallow</td>
<td>2,767</td>
<td>10%</td>
<td>Sprinkler/Drip</td>
<td>0.80</td>
<td>2.67</td>
<td>15,441</td>
<td>1,725</td>
<td>89%</td>
<td>636</td>
<td>1,089</td>
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<tr>
<td>Vegetables Row Crops</td>
<td>7,219</td>
<td>26%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.36</td>
<td>15,242</td>
<td>2,063</td>
<td>86%</td>
<td>948</td>
<td>1,114</td>
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<tr>
<td>Strawberries</td>
<td>8,076</td>
<td>29%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.34</td>
<td>7,796</td>
<td>596</td>
<td>92%</td>
<td></td>
<td>596</td>
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<tr>
<td>Raspberries, Blackberries</td>
<td>4,171</td>
<td>15%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.34</td>
<td>7,796</td>
<td>596</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blueberries</td>
<td>0</td>
<td>0%</td>
<td>Sprinkler/Drip</td>
<td>0.80</td>
<td>3.96</td>
<td>86</td>
<td>86</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vines / Grapes</td>
<td>27</td>
<td>0%</td>
<td>Drip</td>
<td>0.80</td>
<td>3.96</td>
<td>86</td>
<td>86</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artichokes</td>
<td>180</td>
<td>1%</td>
<td>Sprinkler/Drip</td>
<td>0.80</td>
<td>1.50</td>
<td>215</td>
<td>215</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deciduous (Apple Orchards)</td>
<td>2,129</td>
<td>8%</td>
<td>Sprinklers</td>
<td>0.80</td>
<td>0.52</td>
<td>889</td>
<td>189</td>
<td>79%</td>
<td></td>
<td>189</td>
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<tr>
<td>Nurseries / Flower / Subtropical Plants</td>
<td>1,463</td>
<td>5%</td>
<td>Sprinklers</td>
<td>0.13</td>
<td>4.21</td>
<td>480</td>
<td>54</td>
<td>93%</td>
<td>13</td>
<td>42</td>
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<tr>
<td>Other</td>
<td>788</td>
<td>3%</td>
<td>---</td>
<td>0.80</td>
<td>1.93</td>
<td>1,215</td>
<td>1,215</td>
<td>100%</td>
<td></td>
<td></td>
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<tr>
<td>Unknown Ag. Use</td>
<td>1,480</td>
<td>5%</td>
<td>---</td>
<td>0.80</td>
<td>3.96</td>
<td>4,684</td>
<td>468</td>
<td>100%</td>
<td>196</td>
<td>272</td>
</tr>
</tbody>
</table>

**Total**

- **28,300**
- **91%**
- **2.47**
- **46,370**
- **5,095**
- **89%**
- **1,793**
- **3,302**
## Economic Impact

![Graph showing the cost of water as a percentage of total investment for different crops.](image.png)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Investment ($)</th>
<th>Applied Water (AF/acre)</th>
<th>$210</th>
<th>$315</th>
<th>$368</th>
<th>$420</th>
<th>$525</th>
<th>$578</th>
<th>$630</th>
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</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>$6,090</td>
<td>2.6</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
</tr>
<tr>
<td>Strawberries</td>
<td>$27,583</td>
<td>2.4</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
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<td></td>
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<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
</tr>
<tr>
<td>Raspberries</td>
<td>$23,182</td>
<td>2.3</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
<td>IIC</td>
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<td>DV</td>
<td>DV</td>
<td>DV</td>
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<tr>
<td>Blackberries</td>
<td>$25,082</td>
<td>2.3</td>
<td>IIC</td>
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<td>DV</td>
<td>DV</td>
<td>DV</td>
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<tr>
<td>Nurseries</td>
<td>$75,647</td>
<td>4.2</td>
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<td>IIC</td>
<td>IIC</td>
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<td>IIC</td>
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<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
<td>DV</td>
</tr>
</tbody>
</table>

* IIC – Increase in cost as a percentage of the total crop investment
**DV – Dollar value of the increase in investment costs
STRATEGY:

OUTREACH AND ENGAGEMENT
Precipitation Mechanism

Prevailing winds rich in moisture blow landward from the ocean. As moist air rises over the coastal mountains, it expands and cools. If enough moisture is present, condensation and precipitation will occur.

As the air rises over the higher mountains, additional cooling causes more condensation and precipitation. Sinking air warms and becomes drier. With depleted moisture, sinking air warms and becomes even drier.

Evaporation in isolated desert basins causes salts to precipitate on dry lakebeds.

Groundwater flow and stream runoff carry dissolved salts to the ocean. Over time, the continuous process of evaporation concentrates salts in seawater.

Transpiration is the process where plants absorb moisture through their roots and release it to the air from their foliage.

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Analysis:

IMPLICATION OF THE DROUGHT FOR CROP PRODUCTION
Increase in water use 2014?

06-10: 55 TAF (Ag. 46 TAF)
2014: 64 TAF (Ag. 54 TAF)
Increase of 16%!!!
Water Uses

Reasonable Uses

Beneficial Uses
- Crop evapotranspiration ($ET_c$)
- Water harvested in the crop
- Salt removal
- Microclimate Control
- Seed or weed germination
- ET of beneficial crop plants

Non-Beneficial Uses
- Reservoir evaporation
- Soil Evaporation
- Sprinkler Evaporation
- Water needed to maintain water quality standards
- Some deep percolation due to non-uniformity

Unreasonable Uses
- Excessive deep percolation
- Excessive tailwater

Non-Beneficial Uses
Water Management and Water Cycle
Air Temperature

Air Temp (F) vs. Month

- Avg. 2006-2010

Map of the region

University of California
Agriculture and Natural Resources
Reference Evapotranspiration ($ET_0$)

- **Map of the area**
- **Graph showing monthly $ET_0$ values from January to December**
- **Table showing comparison between average $ET_0$ for 2006-2010 and 2014 for Watsonville and Pajaro**

<table>
<thead>
<tr>
<th>Location</th>
<th>Avg. 06-10 (in/y)</th>
<th>2014 (in/y)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watsonville</td>
<td>41.2</td>
<td>48.4</td>
<td>17%</td>
</tr>
<tr>
<td>Pajaro</td>
<td>37.9</td>
<td>42.1</td>
<td>11%</td>
</tr>
</tbody>
</table>
Soil Temperature

129 - Pajaro

Avg. 2006-2010

2014

209 - Watsonville

Avg. 2006-2010

2014
### Rainfall

#### Avg. 2006-2010

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>Avg. 06-10 (in/year)</th>
<th>2014 (in/year)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watsonville</td>
<td>18.2</td>
<td>13.9</td>
<td>-23%</td>
</tr>
<tr>
<td>Pajaro</td>
<td>13.3</td>
<td>8.0</td>
<td>-40%</td>
</tr>
</tbody>
</table>
STRATEGY:

OUTREACH AND ENGAGEMENT
STRAWBERRIES

Club Price 6.99 ea

3 LB

3 LB

3 LB

3 LB

3 LB

3 LB

3 LB

3 LB

3 LB
Thanks!
samsandoval@ucdavis.edu
http://watermanagement.ucdavis.edu
Cooperative Extension – California Water Virtual Tour
Insights: Water & Drought
Online Seminar Series

For further resources, visit us at ciwr.ucanr.edu

Contributing partners:

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Agriculture and Natural Resources
Strategic Water Initiative
web: ucanr.edu/waterinitiative

California Institute for Water Resources
University of California
Agriculture and Natural Resources
web: ciwr.ucanr.edu
Twitter: @ucanrwater

California Department of Water Resources
web: www.dwr.ca.gov
Twitter: @CA_DWR
\[
\frac{\text{Well Prod (2009)}}{\text{LU (2009)}} = \text{Applied Water 2009 Normal Year (AFY/acre)}
\]

\[
\frac{\text{Well Prod (2011)}}{\text{LU (2011)}} = \text{Applied Water 2011 Wet Year (AFY/acre)}
\]

Well Production (AF) ÷ Land Use (acres) = Applied Water (AF/acre)  

*AF = Acre-Feet*
## Normal Water Year: 2009

### Calendar Year: 2009

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>Acres</th>
<th>(%)</th>
<th>Irrigation Method</th>
<th>Acreage Factor</th>
<th>Wat. Use (AF/acre)</th>
<th>Applied Water (acre-feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow</td>
<td>2,767</td>
<td>10%</td>
<td></td>
<td>0.80</td>
<td>2.67</td>
<td>13,513</td>
</tr>
<tr>
<td>Vegetables Row Crops</td>
<td>6,318</td>
<td>22%</td>
<td>Sprinkler/Drip</td>
<td>0.80</td>
<td>2.67</td>
<td>13,513</td>
</tr>
<tr>
<td>Strawberries</td>
<td>7,068</td>
<td>25%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.36</td>
<td>13,338</td>
</tr>
<tr>
<td>Raspberries, Blackberries</td>
<td>3,655</td>
<td>13%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.34</td>
<td>6,832</td>
</tr>
<tr>
<td>Blueberries</td>
<td>0</td>
<td>0%</td>
<td></td>
<td>0.80</td>
<td>2.68</td>
<td>58</td>
</tr>
<tr>
<td>Vines / Grapes</td>
<td>27</td>
<td>0%</td>
<td>Drip</td>
<td>0.80</td>
<td>2.68</td>
<td>58</td>
</tr>
<tr>
<td>Artichokes</td>
<td>180</td>
<td>1%</td>
<td></td>
<td>0.80</td>
<td>1.50</td>
<td>215</td>
</tr>
<tr>
<td>Deciduous (Apple Orchards)</td>
<td>1,530</td>
<td>5%</td>
<td>Sprinklers</td>
<td>0.80</td>
<td>0.52</td>
<td>639</td>
</tr>
<tr>
<td>Nurseries / Flower / Subtropical Plants</td>
<td>1,397</td>
<td>5%</td>
<td></td>
<td>0.13</td>
<td>4.21</td>
<td>765</td>
</tr>
<tr>
<td>Other</td>
<td>788</td>
<td>3%</td>
<td></td>
<td>0.80</td>
<td>1.93</td>
<td>1,215</td>
</tr>
<tr>
<td>Unknown Ag. Use</td>
<td>4,569</td>
<td>16%</td>
<td></td>
<td>0.80</td>
<td>2.68</td>
<td>9,794</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>28,299</td>
<td>100%</td>
<td></td>
<td>0.80</td>
<td>2.05</td>
<td><strong>46,370</strong></td>
</tr>
</tbody>
</table>

2009 Water Pumping = 46,370 AF  
5-year Average (2006-2010) Pumping = 46,178 AF