Implementing Scientific Irrigation Scheduling to Improve the On-Farm Water Use Efficiency

Marie-Hélène Bernier
M.Sc. Student, Department of Bioresource Engineering
June 9th, 2008
Overview

- Water Situation in Ontario
- Research Problem & Solution Explored
- Irrigation Scheduling
- Study Area
- Data Collection
- Results
- Conclusions
“Apparent” Water Wealth

- 20% of the world’s freshwater surface supply is stored in the Great Lakes!

- The agricultural sector is highly drought-susceptible & frequently suffers from water shortages

- But why is it so?

- Only 1% is renewable; the remaining part being left from the last ice age

- Southern part of the province ⇒ Competition & localized conflicts

Sources: Gabriel & Kreutzwiser (1993) & Dolan et al. (2001)
Farm Cash Revenues for 2001

Farming is Ontario’s second largest economic sector with Gross Annual Sales of $6.8 billion.

The province with largest land area under fruit (25 780 ha) and vegetables (62 967 ha) production.

Ontario's Total Water Withdrawals

- Industrial Thermal Power: 81.3%
- Industrial Manufacturing: 0.5%
- Municipal Water Supply: 0.3%
- Agriculture: 11.1%
- Rural Residential: 0.5%
- Aquaculture: 0.6%
- Industrial Mining: 0.3%
- Golf Courses: 0.1%

Ontario's Total Water Consumption

- Municipal Water Supply: 37.7%
- Industrial Manufacturing: 28.3%
- Agriculture: 20.2%
- Golf Courses: 3.9%
- Industrial Mining: 3.4%
- Industrial Thermal Power: 3.4%
- Rural Residential: 3.2%

Relatively high rate of consumption (79%) compared to other sectors, agriculture is the 3rd largest water consumer.

In Southern Ontario, horticultural production faces competition especially during summer. Exacerbating Factors

- Expansion of the agricultural sector
- Increasing urban development & tourism
- Potential climate change impacts

Water conservation strategies for horticultural irrigation are high priority.

Research Problem

- Assessing Irrigation Performance
  - Current irrigation water consumption patterns
  - Crop water needs
  - Irrigation Water use efficiency

- Improving Current Irrigation Practices
  - Soil moisture monitoring
  - Limit guesswork
  - Realize water savings

Solutions Explored
Irrigation Scheduling

“Determining accurately **WHEN** and **HOW MUCH** water to apply to a field.”

“To **MAXIMIZE** irrigation efficiency”

- **Subjective**
  - “By the seat of their pants”

- **Scientific**
  - Soil moisture monitoring

*Source: Broner (2005)*
When and How Much Water to Apply?

Soil Moisture Profile

- Saturated
- Field Capacity
- Permanent Wilting Point
- Excess water
- 100% available
- Management Allowable Depletion (MAD)
- 0% available
- No water available

### Management Allowable Depletion

- **Crop grown**
  - Tomatoes: 25%
  - Peppers: 25%
  - Strawberries: 25%
  - Peaches: 50%

- **Irrigation System**

- **Crop Development Stage**

---

**Sources:** Sanders (1993) & Werner (1993); Ley et al. (1994); Nyvall (1998); Nyvall (2002); Planner (2003); Hanson et al. (2004); OMAFRA (2004); Bierman (2005); Broner (2005); Nyvall & Tam (2005); AgriMet (2007) & LeBoeuf et al. (2007)
Southern Ontario High Value Horticultural Production

Source: Mehdi et al., (2007)

**Soil Water Content**
- Volumetric Water Content (%)-
  - Time Domain Reflectometry (TDR)

**Soil Water Potential**
- Tension or Suction (cbars)-
  - Tensiometry

**Electrical Conductivity & Capacitance Devices**

**Electrical Resistance Blocks**
Assessing Irrigation performance

- **Survey**
  - Current IS practices & perceived water needs
  - Individual interviews
  - Collected data (e.g.: Irrigated acreage, irrigation system type, ...)

- **Climate Data**
  - Weather Incorporated Innovated (WIN)

- **Soil Moisture Monitoring Data**
  - 8 different devices
Water Budget Method

\[ \Delta S = \text{Effective Precipitation (EP)} + \text{Irrigation Water (IW)} - \text{Crop Water Use (CWU)} - \text{Deep Percolation (DP)} \]
Effective Precipitation

\[ EP = (R - 5) \times 0.75 \]
## Crop Coefficient (Kc)

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Growth Stage</th>
<th>Kc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peaches</td>
<td>April</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>June (1-15)</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>June (16-30)</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>0.95</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>From seeding to 1st flower</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>From 1st flower to maximum row fill</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Remainder of crop</td>
<td>1</td>
</tr>
<tr>
<td>Peppers</td>
<td>From seeding to 1st flower</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>From 1st flower to maximum row fill</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Remainder of crop</td>
<td>1</td>
</tr>
<tr>
<td>Strawberries</td>
<td>Initial*</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Mid season*</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>Late season*</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Source: Peaches, tomatoes and peppers crop coefficients data are taken from OMAFRA (2004) while strawberries data are taken from Van der Gulik (2001)
Deep Percolation

Field Capacity = 11.2%
## Water Budget Method - Results

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>Rooting Depth (mm)</th>
<th>FC (%)</th>
<th>MSWS (mm)</th>
<th>MSWD (mm)</th>
<th>AE (%)</th>
<th>IT (mm)</th>
<th>IRR (mm)</th>
<th>IWR (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dresden</td>
<td>Peppers</td>
<td>300</td>
<td>12.58</td>
<td>38</td>
<td>9</td>
<td>84</td>
<td>28</td>
<td>11</td>
<td>165</td>
</tr>
<tr>
<td>Simcoe - Outside</td>
<td>Strawberries</td>
<td>300</td>
<td>18.09</td>
<td>54</td>
<td>14</td>
<td>84</td>
<td>41</td>
<td>16</td>
<td>384</td>
</tr>
<tr>
<td>Simcoe - Tunnels</td>
<td>Strawberries</td>
<td>300</td>
<td>18.30</td>
<td>55</td>
<td>14</td>
<td>84</td>
<td>41</td>
<td>16</td>
<td>320</td>
</tr>
<tr>
<td>Leamington - Surface</td>
<td>Tomatoes</td>
<td>300</td>
<td>13.36</td>
<td>40</td>
<td>16</td>
<td>84</td>
<td>30</td>
<td>12</td>
<td>144</td>
</tr>
<tr>
<td>Leamington - Buried</td>
<td>Tomatoes</td>
<td>300</td>
<td>11.22</td>
<td>34</td>
<td>8</td>
<td>84</td>
<td>25</td>
<td>10</td>
<td>140</td>
</tr>
<tr>
<td>Niagara - on-the-Lake</td>
<td>Peaches</td>
<td>600</td>
<td>15.43</td>
<td>93</td>
<td>46</td>
<td>86</td>
<td>16</td>
<td>136</td>
<td></td>
</tr>
</tbody>
</table>

### Water Budget Method

\[
\text{PSWS} = \text{FC} \times \text{CRD} / 100
\]

\[
\text{MSWD} = \text{MSWS} \times \text{MAD}
\]

\[
\text{IT} = \text{MSWS} - \text{MSWD}
\]

\[
\text{IRR} = \text{MSWD} \times 100
\]

### Diagram

- **PSWS** (mm)
- **EP** (mm)
- **IRR** (mm)
- **DP** (mm)
- **CWU** (mm)
- **CSWS** (mm)

### Table

<table>
<thead>
<tr>
<th>Date</th>
<th>PSWS (mm)</th>
<th>EP (mm)</th>
<th>IRR (mm)</th>
<th>DP (mm)</th>
<th>CWU (mm)</th>
<th>CSWS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 30</td>
<td>38</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>36</td>
</tr>
<tr>
<td>May 31</td>
<td>36</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>2.3</td>
<td>34</td>
</tr>
<tr>
<td>June 1</td>
<td>34</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1.9</td>
<td>32</td>
</tr>
<tr>
<td>June 2</td>
<td>32</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1.7</td>
<td>30</td>
</tr>
<tr>
<td>June 3</td>
<td>30</td>
<td>1.1</td>
<td>0</td>
<td>0</td>
<td>0.6</td>
<td>31</td>
</tr>
<tr>
<td>June 4</td>
<td>31</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1.2</td>
<td>30</td>
</tr>
<tr>
<td>June 5</td>
<td>30</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
<td>28</td>
</tr>
<tr>
<td>June 6</td>
<td>29</td>
<td>0.0</td>
<td>0</td>
<td>1</td>
<td>0.3</td>
<td>38</td>
</tr>
<tr>
<td>June 7</td>
<td>38</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>2.8</td>
<td>36</td>
</tr>
<tr>
<td>June 8</td>
<td>36</td>
<td>6.9</td>
<td>0</td>
<td>0</td>
<td>2.2</td>
<td>40</td>
</tr>
</tbody>
</table>
## Water Savings?

<table>
<thead>
<tr>
<th>Site</th>
<th>Extra Depth (mm)</th>
<th>Area (m²)</th>
<th>Extra Volume (m³)</th>
<th>Volume Applied (m³)</th>
<th>Extra Water Spent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dresden</td>
<td>10</td>
<td>28 329</td>
<td>283</td>
<td>4 586</td>
<td>6</td>
</tr>
<tr>
<td>Simcoe-Outside</td>
<td>98</td>
<td>8 822</td>
<td>865</td>
<td>3 573</td>
<td>24</td>
</tr>
<tr>
<td>Simcoe-Tunnels</td>
<td>91</td>
<td>8 701</td>
<td>792</td>
<td>2 665</td>
<td>30</td>
</tr>
<tr>
<td>Leamington-Surface</td>
<td>50</td>
<td>12 141</td>
<td>607</td>
<td>1 341</td>
<td>45</td>
</tr>
<tr>
<td>Leamington-Buried</td>
<td>6</td>
<td>12 141</td>
<td>73</td>
<td>1 964</td>
<td>4</td>
</tr>
<tr>
<td>Niagara-on-the-Lake</td>
<td>-75</td>
<td>24 282</td>
<td>-1 821</td>
<td>-52</td>
<td>-35</td>
</tr>
</tbody>
</table>

\[
\Delta S = IWA + EP - CWU - DP
\]

\[
IWA = \Delta S - EP + CWU + DP
\]
Conclusions

- Ontario has water issues too; threaten horticultural production

- Solutions explored
  - Assessing Irrigation Performance
  - Improving Current Irrigation Scheduling Practices

- Improve irrigation water use efficiency & water savings

- In the end, these solutions have the potential to reduce the vulnerability of the industry to increasing competition and drought frequency
Any Questions?
References


References


References


References
