Progress on Precision Crop Load Management with Digital Tools

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Steps in Precision Crop Load Management

1. Count buds before pruning with computer vision
2. Calculate the target number of buds (bud load) (using Trunk Cross-sectional area, total branch length, total branch cross-sectional area or canopy volume)
3. Communicate actionable information to human worker to guide pruning
4. Count buds after pruning with computer vision
<table>
<thead>
<tr>
<th>Trunk Cross Sectional Area</th>
<th>Number of Buds</th>
<th>5 mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information of each single tree</td>
<td>Calibration (5 trees)</td>
<td></td>
</tr>
<tr>
<td>Trunk Cross Section Area</td>
<td>2023</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
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<td></td>
</tr>
<tr>
<td>‘NY1’, ‘Gala’ y ‘Fuji’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young trees (5 years) and Older trees (17 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orchard Robotics measurements and manual (30 cm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Computer vision estimates of Trunk Cross Sectional Area
Variability in dormant bud numbers along the row

![Graph showing variability in dormant bud numbers along a row.](image-url)
One concept of how to communicate pruning instructions to human workers.

- Remove 2 largest branches
- Remove 3 largest branches
- Remove 4 largest branches

iPad mounted on a pruning platform
Steps in Precision Crop Load Management

- Initial Floral Bud Number
- Precision Pruning
- Precision Chemical Thinning
- Precision Hand Thinning
- Final Target Fruit Number

**Initial Flower Load**

- Pollen Tube Growth Model
  - Bloom Thinning Spray
    - Smart Sprayer for bloom thinning
  - Carbon Balance Model
    - Petal Fall Spray
      - Smart Sprayer for petal fall thinning spray
      - 10-13mm Spray
        - Carbon Balance Model
          - Fruit Growth Rate Model
            - Use computer vision to measure fruitlet diameter (5-20mm)
  - Carbon Balance Model
    - 16-20mm Spray
      - Carbon Balance Model
        - Fruit Growth Rate Model
          - Use computer vision to measure fruitlet diameter (5-20mm)

**Final Target Fruit Number**

- Count Flower Clusters To Time Pollen Tube Growth Model
- Count fruitlet number after bloom thinning is done
- Count fruitlet number after all chemical thinning is done
Computer vision counting of Flowering

**Fuji**

```
R² = 0.53
```

**Gala**

```
R² = 0.6
```

**'NY1'** • **'Gala'**

```
R² = 0.78
```

```
R² = 0.95
```
With a flower density map it can be used to guide a variable rate sprayer. A variable rate sprayer can apply more chemical to trees with more flowers and less chemical to trees with fewer flowers and no chemical to trees with no flowers.

Aurea Imaging and Variable Rate Spraying

**TreeScout product and process**

- **Farmer drives with TreeScout in orchard**
- **Processing onboard and uploading to the cloud**
- **Client creates prescription map**
- **Prescription maps executed by machine**
Progress on Digital Methods of using the Fruit Growth Rate Model
Vision systems evaluated
Pometa- cell phone system

<table>
<thead>
<tr>
<th>Flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruitlets</td>
</tr>
<tr>
<td>(Chemical thinning prediction)</td>
</tr>
<tr>
<td>Yield Estimation</td>
</tr>
<tr>
<td>Walking and video recording the trees</td>
</tr>
<tr>
<td>Information at level of orchard</td>
</tr>
</tbody>
</table>
Computer vision estimates of fruit set vs Malusim manual method

\[ y = 1.2545x + 26.005 \]
\[ R^2 = 0.8069 \]

\[ y = 1.3459x - 18.022 \]
\[ R^2 = 0.7805 \]
Progress on Precision Hand Thinning for Individual Tree Optimization-2023
Variability in fruitlet number along the row - Geneva

- Fruit number before hand thinning
- Target fruit number
- Fruit number after hand thinning

Number of fruit per tree varies significantly across the row, with peaks and troughs indicating variability in fruitlet number. The target fruit number line shows a more consistent pattern compared to the other two lines, suggesting a controlled intervention or management approach in the targeted fruit number across the row.
Variability in fruitlet number along the row – Hudson Valley

- Before hand thinning
- Target fruit number
- After hand thinning

Fruit number per tree vs. Tree number in the row
One concept of how to communicate pruning instructions to human workers:

- Remove 2 largest branches
- Remove 3 largest branches
- Remove 4 largest branches

iPad mounted on a pruning platform
Summary of what we can do in 2024 with digital technology to implement precision crop load management

• Counts of dormant buds per tree with geo-referencing each tree.
• Measurement of a trunk diameter.
• We cannot yet communicate pruning severity for each tree to human workers.
• Counts of flower number per tree at bloom to first start pollen tube growth model and second to guide smart sprayer for variable rate blossom spraying.
• Apply variable rate chemical thinning using a blossom density map.
• Counts of fruitlets after blossom thinning (5-10mm) to guide chemical thinning.
• Digital measurements of fruit size increase to run the fruit growth rate model after each thinning spray.
• Counts of fruitlets per tree before hand thinning.
• We cannot yet communicate hand thinning severity for each tree to human workers.
• Counts of fruits and measure fruit size to predict yield and size.
Yield Estimation-Pometa

\[ y = -0.0023x^2 + 1.18x - 0.98 \]

\[ R^2 = 0.66 \]

\[ P=0.01 \]