Statewide, tree-scale mortality monitoring for improved forest management

David Marvin & Christopher Anderson
What we did
What we did

Created statewide maps of tree mortality from high resolution satellite imagery for 2016.
What we did

Created statewide maps of tree mortality from high resolution satellite imagery for 2016.
How we did it

1. Semi-supervised object-based image analysis
2. Deep-learning classification
3. Deep-learning regression
Bass lake & Sierra National Forest
Our goal

Create statewide maps of tree mortality from high resolution satellite imagery

Our methods

1. Semi-supervised object-based image analysis
2. Deep-learning classification
3. Deep-learning regression
### Field data evaluation

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead tree crowns</td>
<td>4,820</td>
</tr>
<tr>
<td>Area covered</td>
<td>70 ha</td>
</tr>
<tr>
<td>Elevation range</td>
<td>1346 - 2371 m</td>
</tr>
<tr>
<td>Year collected</td>
<td>Sept 2018</td>
</tr>
</tbody>
</table>
1. **Semi-supervised object-based image analysis**
   - Input data: NAIP
   - Resolution: 1 m²
   - Output: [ground, live tree, dead tree] classes

2. **Deep-learning classification**
   - Input data: Planet
   - Resolution: 9 m²
   - Output: [ground, live tree, dead tree] classes

3. **Deep-learning regression**
   - Input data: Sentinel-1, Sentinel-2
   - Resolution: 100 m²
   - Output: % mortality (0-100)
1. **Semi-supervised object-based image analysis**
   - Input data: NAIP
   - Resolution: $1 \text{ m}^2$
   - Output: [ground, live tree, dead tree] classes

2. **Deep-learning classification**
   - Input data: Planet
   - Resolution: $9 \text{ m}^2$
   - Output: [ground, live tree, dead tree] classes

3. **Deep-learning regression**
   - Input data: Sentinel-1, Sentinel-2
   - Resolution: $100 \text{ m}^2$
   - Output: % mortality (0-100)
1. Semi-supervised object-based image analysis
   ○ Input data: NAIP
   ○ Resolution: 1 m²
   ○ Output: [ground, live tree, dead tree] classes

2. Deep-learning classification
   ○ Input data: Planet
   ○ Resolution: 9 m²
   ○ Output: [ground, live tree, dead tree] classes

3. Deep-learning regression
   ○ Input data: Sentinel-1, Sentinel-2
   ○ Resolution: 100 m²
   ○ Output: % mortality (0-100)
Confusion matrix
Percentiles

<table>
<thead>
<tr>
<th></th>
<th>Observed</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ground</td>
<td>Live tree</td>
<td>Dead tree</td>
</tr>
<tr>
<td>Ground</td>
<td>0.75</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>Live tree</td>
<td>0.09</td>
<td>0.66</td>
<td>0.25</td>
</tr>
<tr>
<td>Dead tree</td>
<td>0.06</td>
<td>0.23</td>
<td>0.72</td>
</tr>
</tbody>
</table>
Confusion matrix
Counts

<table>
<thead>
<tr>
<th></th>
<th>Live tree</th>
<th>Dead tree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>62115</td>
<td>11951</td>
</tr>
<tr>
<td>Observed Live tree</td>
<td>193427</td>
<td>73576</td>
</tr>
<tr>
<td>Observed Dead tree</td>
<td>27763</td>
<td>1808</td>
</tr>
<tr>
<td>Predicted Ground</td>
<td>7169</td>
<td>22542</td>
</tr>
</tbody>
</table>
Classes
- Ground
- Live trees
- Dead trees
- Fire

Lake
# Field data evaluation

<table>
<thead>
<tr>
<th></th>
<th>from NAIP predictions</th>
<th></th>
<th>from Planet predictions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy score</td>
<td>0.619</td>
<td>Accuracy score</td>
<td>0.687</td>
<td></td>
</tr>
<tr>
<td>AUC score</td>
<td>0.602</td>
<td>AUC score</td>
<td>0.636</td>
<td></td>
</tr>
<tr>
<td>Precision</td>
<td>0.482</td>
<td>Precision</td>
<td>0.595</td>
<td></td>
</tr>
<tr>
<td>Recall</td>
<td>0.536</td>
<td>Recall</td>
<td>0.447</td>
<td></td>
</tr>
</tbody>
</table>
1. Semi-supervised object-based image analysis
   ○ Input data: NAIP
   ○ Resolution: 1 m²
   ○ Output: [ground, live tree, dead tree] classes

2. Deep-learning classification
   ○ Input data: Planet
   ○ Resolution: 9 m²
   ○ Output: [ground, live tree, dead tree] classes

3. Deep-learning regression
   ○ Input data: Sentinel-1, Sentinel-2
   ○ Resolution: 100 m²
   ○ Output: % mortality (0-100)
1. Semi-supervised object-based image analysis
   ○ Input data: NAIP
   ○ Resolution: 1 m²
   ○ Output: [ground, live tree, dead tree] classes

2. Deep-learning classification
   ○ Input data: Planet
   ○ Resolution: 9 m²
   ○ Output: [ground, live tree, dead tree] classes

3. Deep-learning regression
   ○ Input data: Sentinel-1, Sentinel-2
   ○ Resolution: 100 m²
   ○ Output: % mortality (0-100)
Model performance
RMSE - 0.124
$r^2$ - 0.547
A statewide map of tree mortality from high resolution satellite imagery.
But...

How many trees died?
Estimated Tree Mortality

USFS
2015: 29 million
2016: 62 million

Salo
2015-2016: 70.5 million
Thank you!

David Marvin
dave@salo.ai@dmarvs

Christopher Anderson
cba@salo.ai@earth_chris