



Municipal Tree Inventories Using Remote Sensing, Biometrics & Photogrammetry The Vaughan Experience

Presented by:

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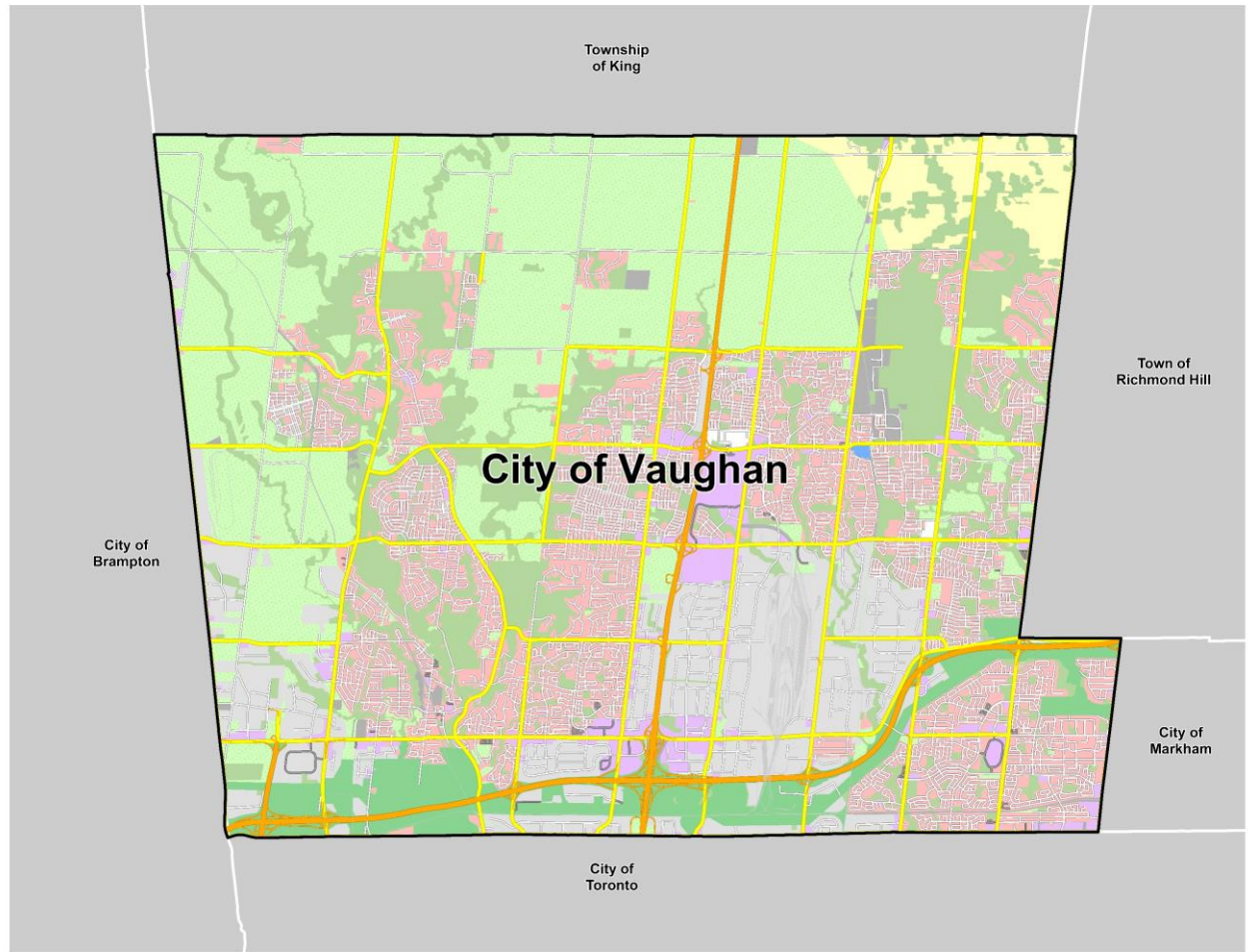


2019 Educational Forum and Trade Show

#PROForum19

The City of Vaughan

- Population: 325,000
- Land Area: 27,000 Ha
- 130,000 Street Trees
- 202 Parks 680 Ha
- Open Spaces 2600 Ha
- Woodlots 195.3 Ha



New Municipal Approach to Collect & Manage Tree Data

Remote Mapping and Photogrammetry – *R-MAP*

Inventory Method	Ground Survey	<i>R-MAP</i> 3D Aerial Analysis	Lidar
Time	Two Growing Seasons	One Growing Season	One Growing Season
Accuracy*	Med	High	High
Data Storage & Requirements	Low	Med	High
Cost (\$ Per Tree)	2.75-5.00	0.80-1.50	9.00+
Crown Map & M ²	N/A	Applicable	Applicable

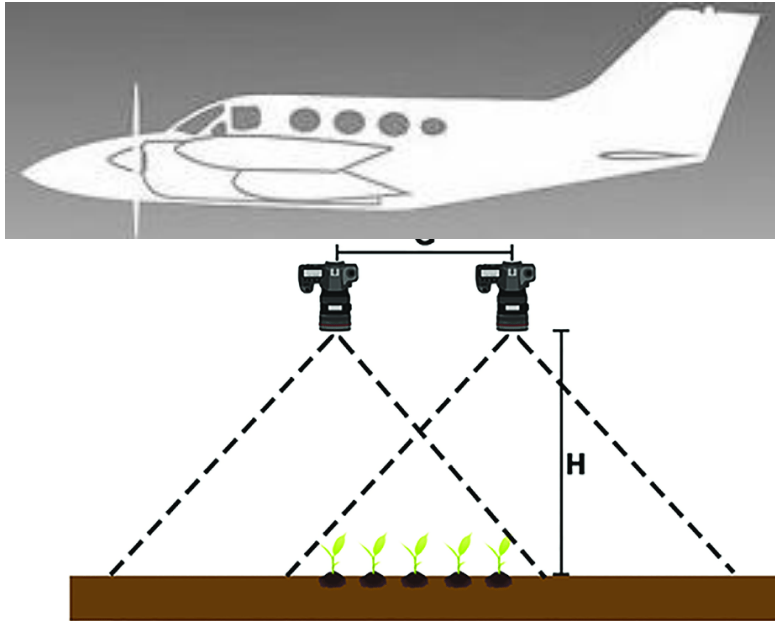
What is *R-MAP* & How Does It Work?

Originally developed to minimize field costs - the most expensive part of tree inventories

Step 1: Large Scale 5cm Stereo Leaf On Aerial Imagery Capture & File Enhancements



Step 2: 1-2% Precision Field & D-GPS Photos & Individual Tree Sampling



What is *R-MAP* & How Does It Work?

Create Base Inventory of Street Tree Crowns by Species & Health Attributes

Step 3: Develop Local Tree Crown Shape + Height to Tree Diameter Biometric Regressions



Step 4: *R-MAP* Base Inventory
3D GPS Tree Crowns, Species, Health Observations & Heights as GIS Data Layers
Created by Seasoned Forest Technicians

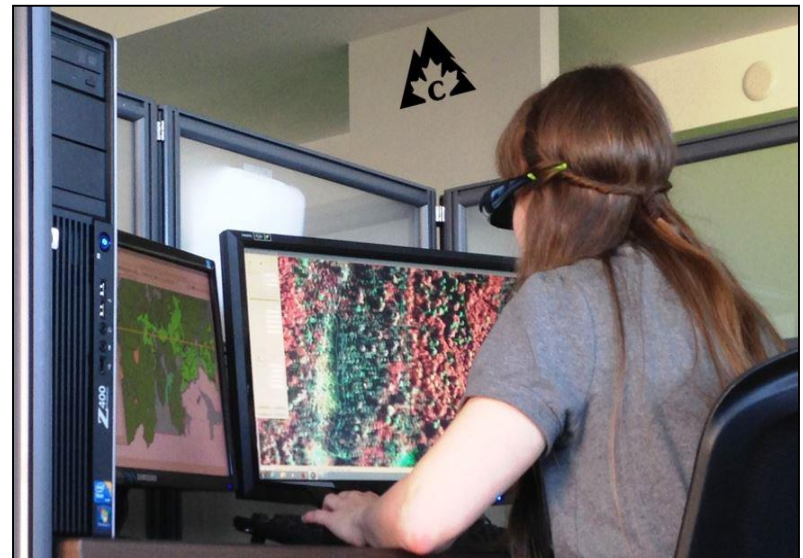
$$\text{DBH} = X + Y * \text{Hgt} + \text{XX} * \text{CA}$$

($R^2 = 0.81$ $\text{RMSE} = 8.341$)

$$\text{DSH} = X + Y * \text{Hgt} + \text{XX} * \text{CA}$$

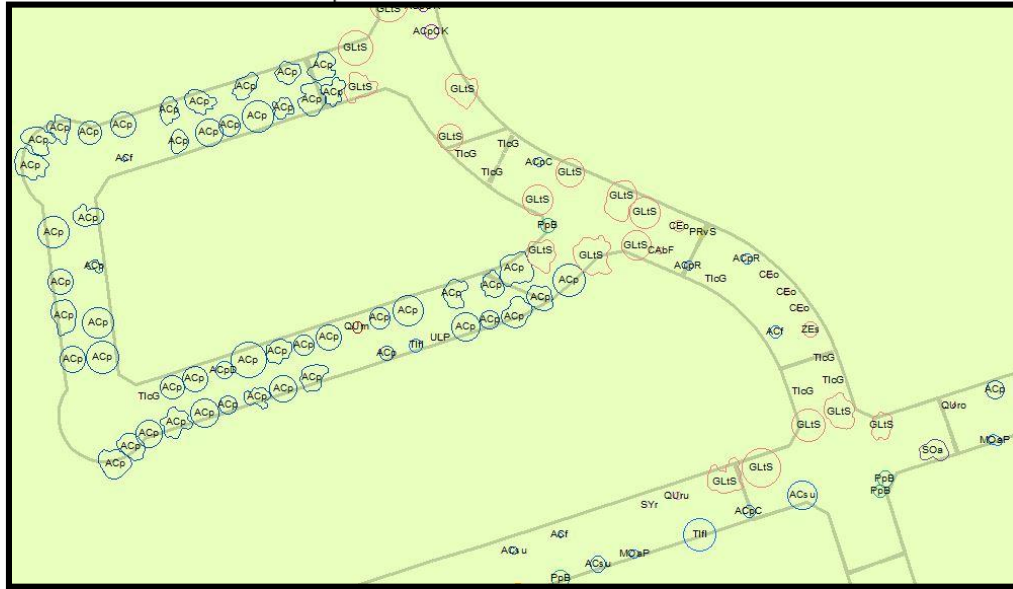
($R^2 = 0.77$ $\text{RMSE} = 9.575$)

DBH = Diameter Breast Height
DSH = Diameter at Ground Surface
Hgt = Height
CA = Crown Area
 R^2 = Linear Regression
RMSE = Root Mean Square Error



Vaughan's Street Tree Inventory Overlaid on City GIS Map:

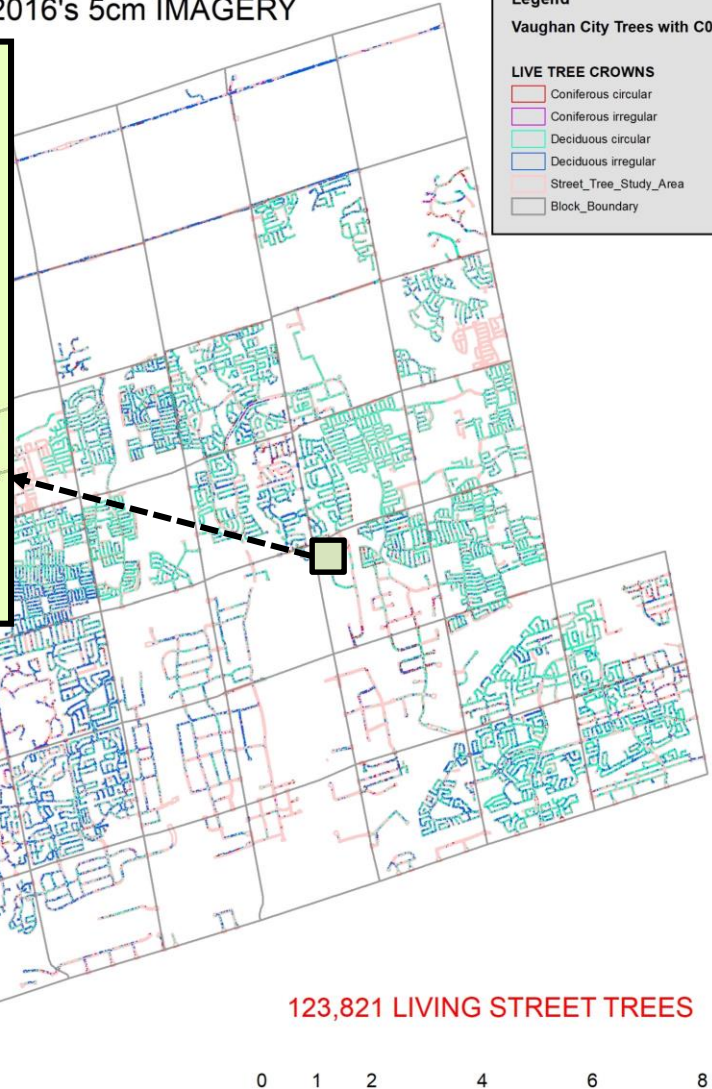
VAUGHAN TREE INVENTORY - SUMMER 2016's 5cm IMAGERY



Legend
Vaughan City Trees with C02e Values

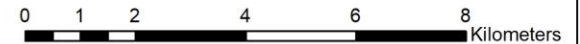
LIVE TREE CROWNS

- Coniferous circular
- Coniferous irregular
- Deciduous circular
- Deciduous irregular
- Street_Tree_Study_Area
- Block_Boundary

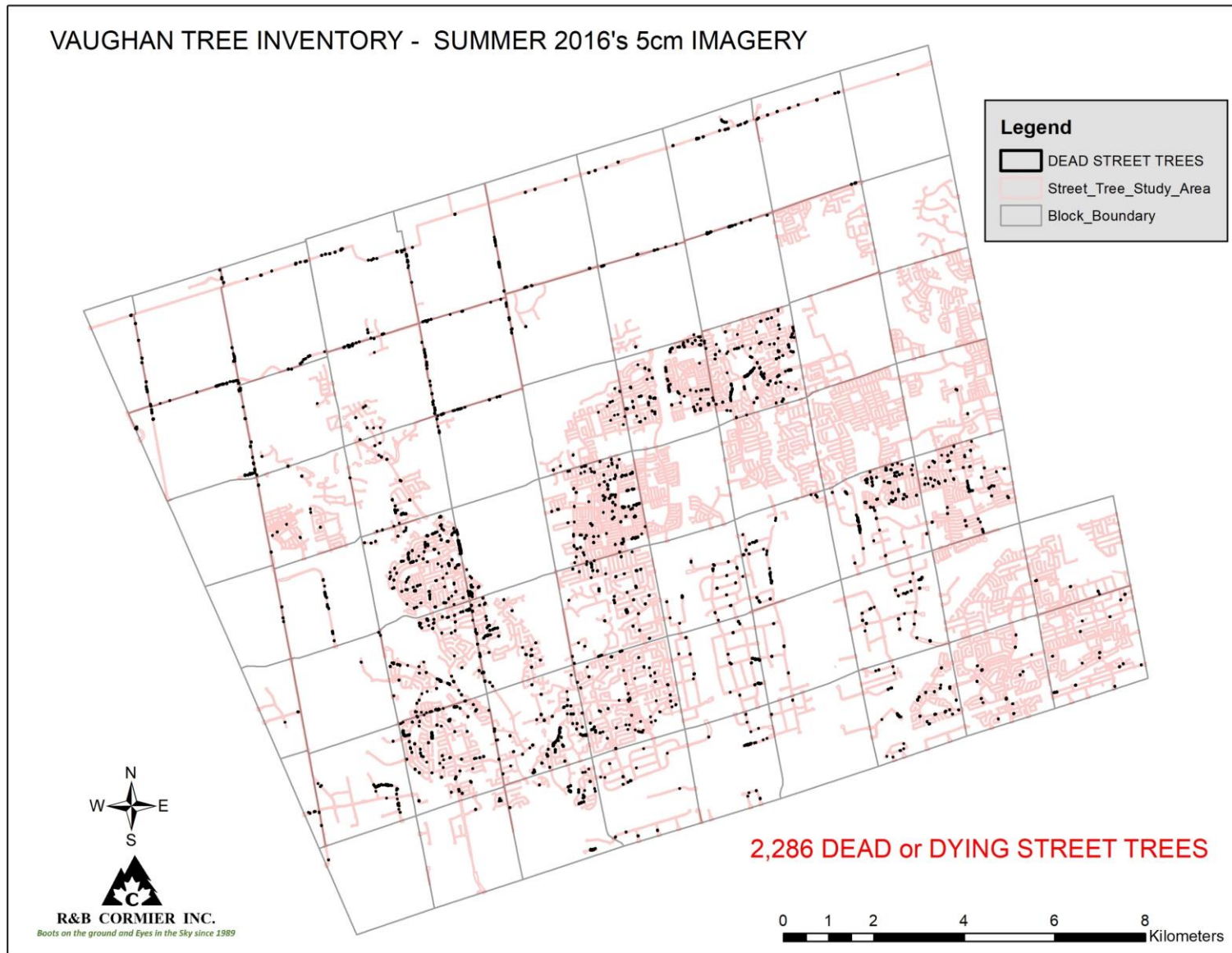


R&B CORMIER INC.
Boots on the ground and Eyes in the Sky since 1989

123,821 LIVING STREET TREES



Vaughan's Street Tree Inventory Overlaid on City GIS Map:



Vaughan's Single Tree Inventory Outputs Overlaid on Ortho Photo in ArcGIS:



Forested Areas & Parks Inventory Outputs Overlaid on Ortho Photo in ArcGIS:

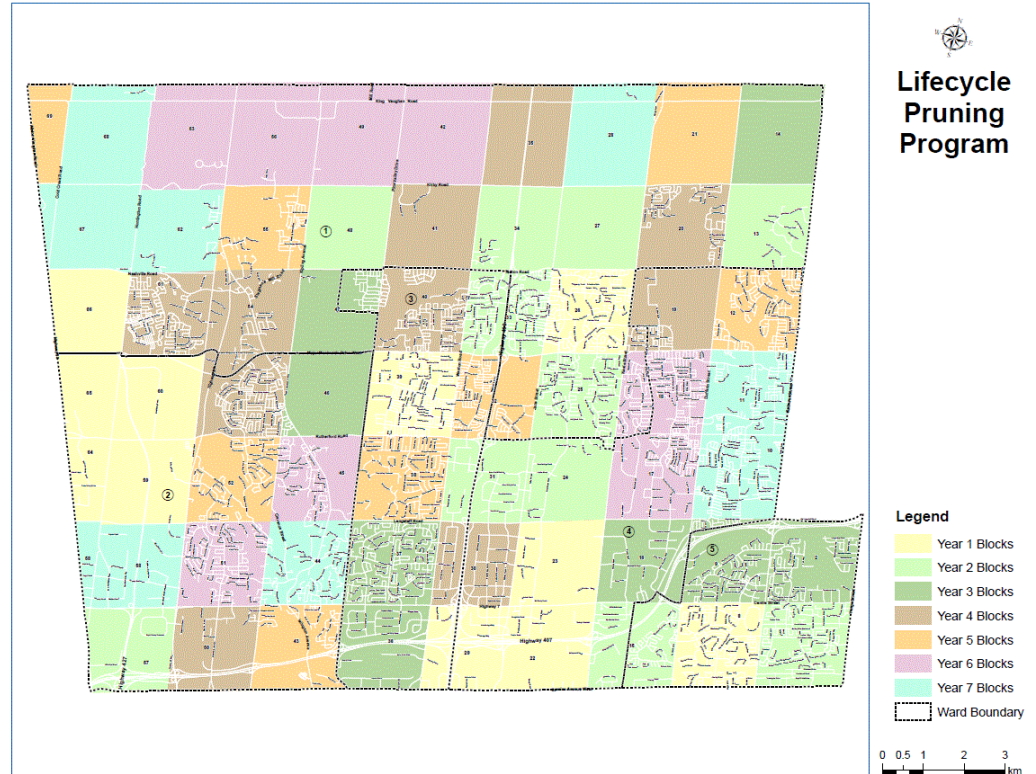


Forested Areas & Parks Inventory Outputs Overlaid on Ortho Photo in ArcGIS:



How the Tree Inventory data is being used?

- **Tree health & growth forecasting**
 - Tree Removal Program
- **Risk management**
 - Storm Triage
 - Highlighting Risk Areas
- **Efficient Planning, Enhanced Scheduling & Budgeting**
 - Lifecycle Pruning Program



Challenges Encountered & Lessons Learned

- Trees <15cm DBH were difficult in identifying the specific species
- Additional Attribute: Exact Street Number & Street
- Only 5cm leaf-on aerial photography is needed
- Understory Trees could not be captured
- Data Gap Issues
- Future Resources – Including Office and Field Equipment
- Training & Software within the Forestry Department

Options in the Future & What the Inventory Can Enabled

- **Tree Canopy Change Detection**
 - Checking on non-GPS inputted data
 - Identification of unauthorized removals
- **Digitized Asset Analysis**
- **Carbon and Environmental Monitoring**
- **Report Realistic Tree Values**
- **Unique Process**
 - The on-ground data collection approach delivers a point for each
 - Our technique illustrates the actual tree crown area and a location point

Future Uses for Forestry

- Continued Efficiencies within Forestry Management
 - Specialized Quires – e.g. Oak Wilt, age group analysis, invasive species
 - Development of a Structural Pruning Program
 - Work Route Optimization
- Direct Connection Between Tree Location and Work Order System
- Prediction Models: where to plant & focus manage trees & assets
- Open Data for Citizens of Vaughan
- Change Monitoring



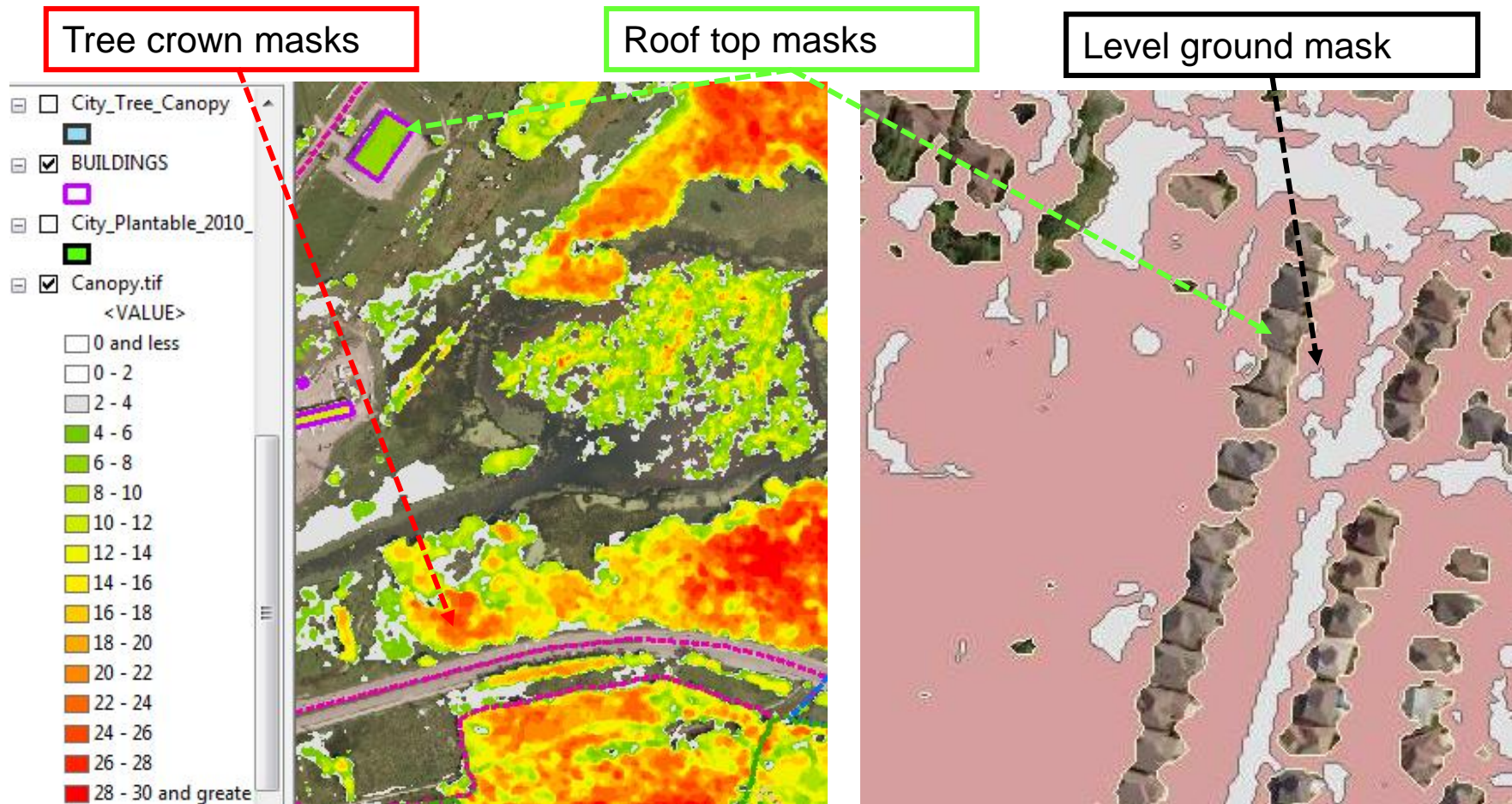
Future Uses within Asset Management

- **Monitoring progressions and deteriorations for a theoretical asset management system**
 - Not only for trees but for many other above ground assets that municipalities manage through various algorithms
- **The potential with this approach is larger than one may think**
 - This approach can be used to assess changes for:
 - Pavement & Sidewalks
 - Park Asset Surfacing
 - New installed Pools without Permits
 - Accuracies with Cemetery Lot Placement
 - Cost Reduction & Efficiencies for Operations & Condition Inspections

BEYOND THE BASE INVENTORY - 3D Change Detection

STEP 5: Create GIS Imagery Masks From 3D Tree or Asset Inventory Analysis

STEP 6: Focus Tree or Asset Analysis in Newer 3D Imagery Only on Changes in Height or Size



Thank-you

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