# extraction of tree crowns and heights using lidar

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## OVERVIEW

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- background
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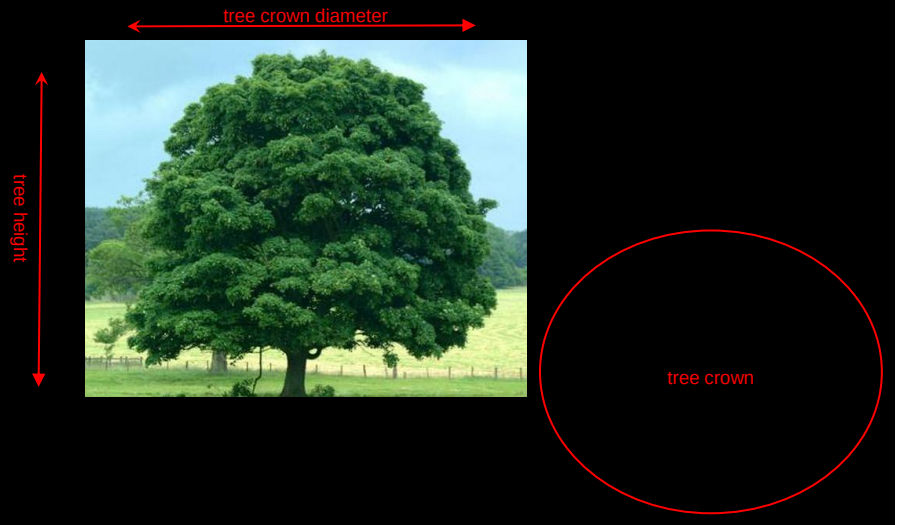
# introduction

**objective: extract tree crowns and heights from LiDAR**

**study area: Mt Tabor park**

**purpose: tree crowns & heights can be used to extract species, estimate forest age**

# tree structure



# study area - Mt Tabor

**reasons:**

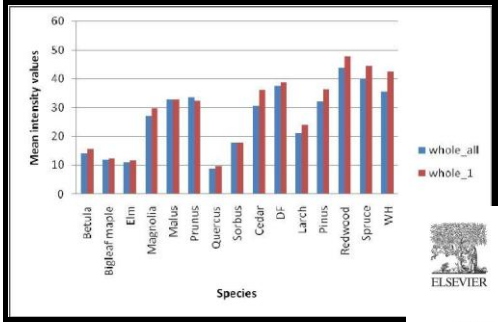
- **ground survey for species**
- **urban area**

**problems:**

- **buildings**
- **reservoirs**
- **low lying vegetation**
- **roads**

# background - previous studies

- **tree crowns & heights:**
  - **species determination**




Kim, Sooyoung (2007) Individual tree species identification using LIDAR- derived crown structures and intensity data, *University of Washington*

## previous work with tree crowns

- other reasons:
  - biomass estimation
  - forest age and health
  - reduce fieldwork for:
    - forest inventory
    - fire damage assessment
    - monitoring forest regeneration

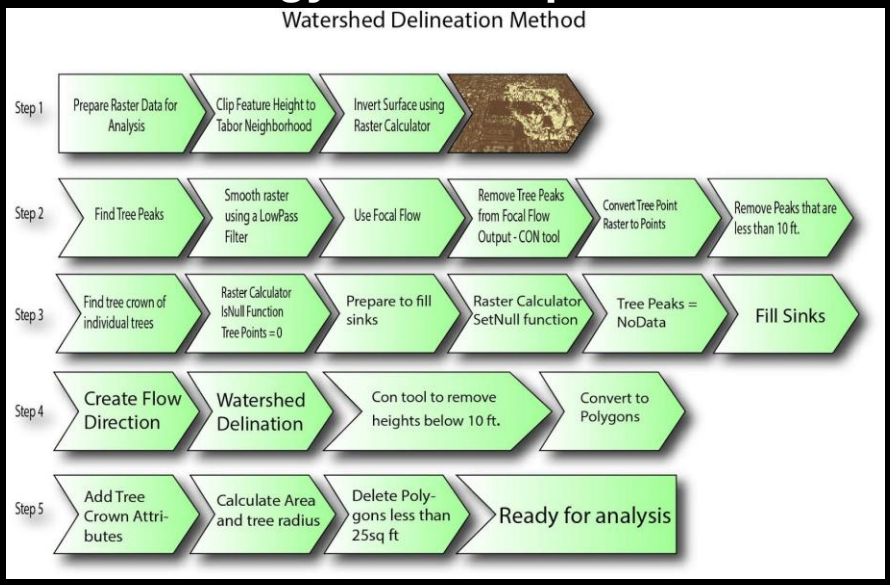
## data

- PSU's geography server
  - FeatureHeight - raster of Tabor area features
- Watershed Sciences
  - points.las - point cloud of Tabor area all returns
  - DEM - bare earth raster based on point cloud
- RLIS
  - TaborPark.shp - Mt Tabor outline
  - TaborHood.shp - Tabor neighborhood
- Parks and Recreation
  - TaborVeg.shp - areas on Mt Tabor used for vegetation surveys, i.e. areas covered with vegetation

# Methods

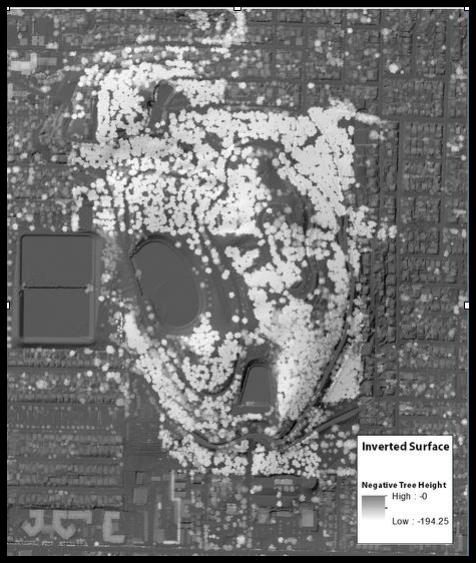
- ArcMap
  - treat raster like a watershed
    - focal flow to determine local maxima (tree heights)
    - watershed delineation (tree crowns)
- FUSION
  - US Forest Service program to analyze LiDAR data and derive canopy models, tree metrics, and other
  - find canopy maxima of LiDAR point cloud, derive crown sizes and tree heights

# methodology in arcmap



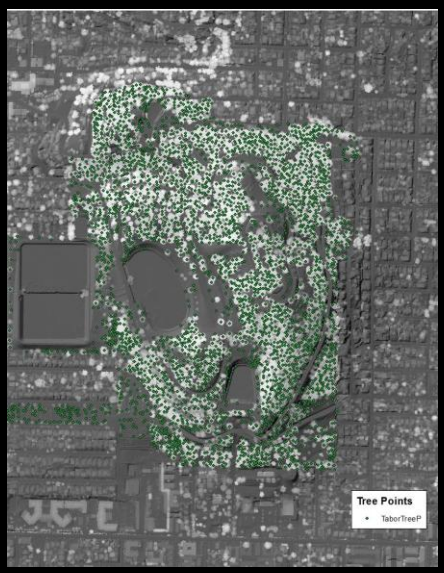
# step 1 - prepare feature height raster

- make data size manageable
  - clip to tabor neighborhood
- imitate a watershed
  - invert surface
  - tree peaks become "ponds"
  - tree branches/crowns become watersheds
  - raster calculator: FeatureHeight * -1



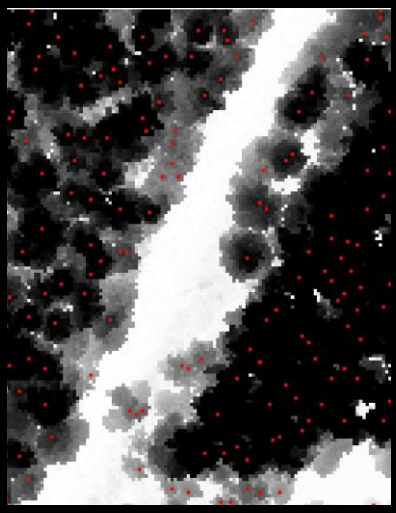

# step 2 - find tree peaks

smooth inverted raster
  - low filter
- determine local minima
  - focal flow
- extract tree peaks
  - con tool
    VALUE = "255"
  - if true, return
    InvertSurface - negative elevation of the tree peaks
- remove low lying vegetation
  - con tool
  - VALUE <= -10
- clip to vegetation layer



# step 3 - find tree crowns

- create mask to make tree peaks null data
  - tool: RasterCalculator
  - IsNull("ConTree10")
  - 1 means NoData, 0 values are where the tree peaks are
- mask the inverted raster to prepare to fill sinks
  - RasterCalculator
  - SetNull("contreemask"==0, "InvertSurface")
  - inv_null now has noData where there are tree peaks



# step 3 - find tree crowns (cont.)

- fill sinks to prepare for watershed delineation
- create flow direction surface
  - Flow Direction
- create watersheds
  - input Flow Direction: NullDirection
  - input pour points: TreeP10

# step 3 - find tree crowns (cont.)

- remove low lying watersheds
  - con tool
  - VALUE >= 10
- convert to polygons
- clip to vegetated area, include trees that overhang roads


# step 4 - tree crown attributes

- calculate area
- remove polygons less than 25 sq feet
- calculate radii

# tree crowns

Table

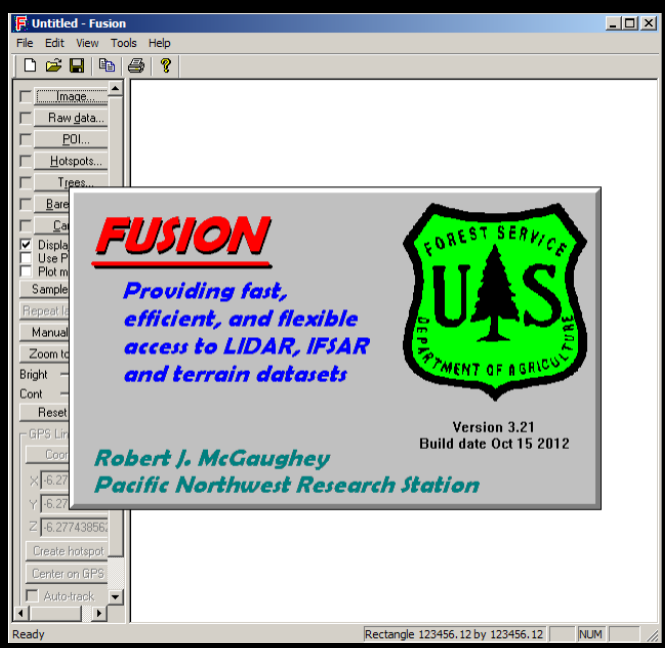
TaborTreeCrown25

| FID | Shape * | ID | GRIDCODE | Area | Radius | Height |
|---|---|---|---|---|---|---|
| 0 | Polygon | 1931 | -107 | 832.495 | 16.2827 | 107 |
| 1 | Polygon | 1931 | -35 | 213.273 | 8.24144 | 35 |
| 2 | Polygon | 1938 | -118 | 1152.16 | 19.1554 | 118 |
| 3 | Polygon | 1938 | -38 | 201.866 | 8.01801 | 38 |
| 4 | Polygon | 1943 | -44 | 506.952 | 12.7063 | 44 |
| 5 | Polygon | 1945 | -110 | 1578.59 | 22.4218 | 110 |
| 6 | Polygon | 1945 | -36 | 241.779 | 8.77495 | 36 |
| 7 | Polygon | 1948 | -25 | 227.928 | 8.51989 | 25 |
| 8 | Polygon | 1948 | -72 | 92.4157 | 5.4251 | 72 |
| 9 | Polygon | 1948 | -94 | 461.541 | 12.1238 | 94 |
| 10 | Polygon | 1952 | -138 | 1933.17 | 24.8125 | 138 |
| 11 | Polygon | 1952 | -133 | 3719.26 | 34.4162 | 133 |
| 12 | Polygon | 1952 | -99 | 1892.5 | 24.5501 | 99 |
| 13 | Polygon | 1952 | -121 | 577.651 | 13.5634 | 121 |
| 14 | Polygon | 1955 | -131 | 571.432 | 13.4902 | 131 |
| 15 | Polygon | 1960 | -18 | 138.119 | 6.63227 | 18 |
| 16 | Polygon | 1962 | -123 | 523.376 | 12.9105 | 123 |
| 17 | Polygon | 1963 | -131 | 1359.53 | 20.808 | 131 |
| 18 | Polygon | 1964 | -119 | 1260.42 | 20.0352 | 119 |
| 19 | Polygon | 1964 | -97 | 1000.26 | 17.8481 | 97 |
| 20 | Polygon | 1967 | -122 | 1363.84 | 20.8409 | 122 |
| 21 | Polygon | 1968 | -98 | 198 | 7.94086 | 98 |
| 22 | Polygon | 1968 | -134 | 893.31 | 16.8669 | 134 |
| 23 | Polygon | 1968 | -122 | 745.54 | 15.4089 | 122 |
| 24 | Polygon | 1969 | -125 | 478.795 | 12.3484 | 125 |
| 25 | Polygon | 1972 | -123 | 1108.14 | 18.7859 | 123 |
| 26 | Polygon | 1972 | -119 | 595.209 | 13.768 | 119 |
| 27 | Polygon | 1972 | -131 | 1700.75 | 23.2732 | 131 |
| 28 | Polygon | 1972 | -112 | 343.049 | 10.4523 | 112 |
| 29 | Polygon | 1975 | -113 | 2436.03 | 27.8533 | 113 |
| 30 | Polygon | 1975 | -129 | 738.237 | 15.3332 | 129 |
| 31 | Polygon | 1975 | -123 | 398.072 | 11.2594 | 123 |
| 32 | Polygon | 1977 | -151 | 1166.02 | 19.2703 | 151 |

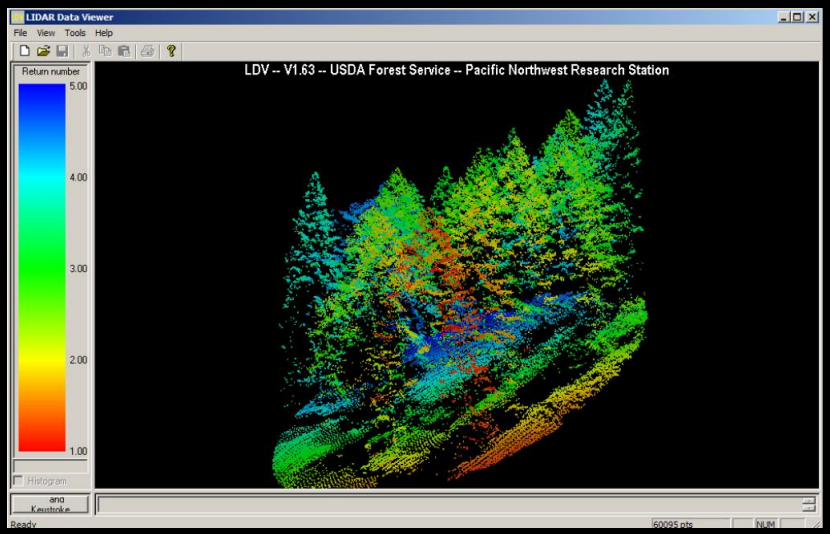
1 (0 out of 4343 Selected)

TaborTreeCrown25

# FUSION

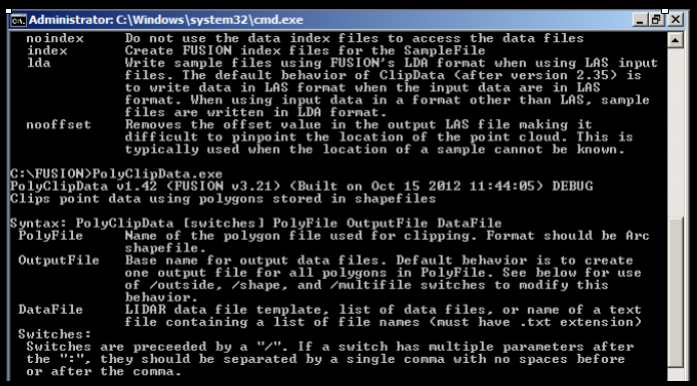


# viewer




# command line for tools

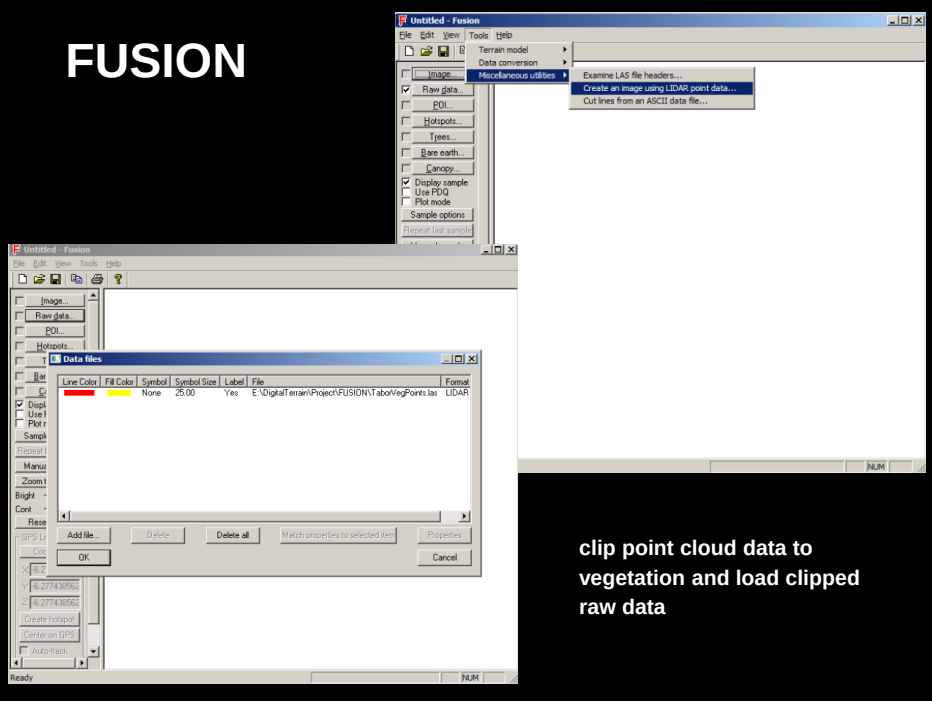
- polyclipdata.exe
- canopymodel.exe
- canopymaxima.exe
- dtm2xyz.exe
- ...



## FUSION methodology

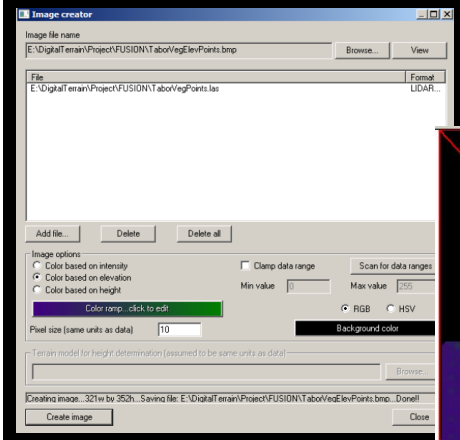
- load raw point data
- create image from LiDAR
- run canopymodel.exe to derive canopy.dtm
- run canopymaxima.exe to extract tree heights and tree crown diameters
  - output - xy point table
- export to ArcMap
- buffer points with tree crown radius for visual display

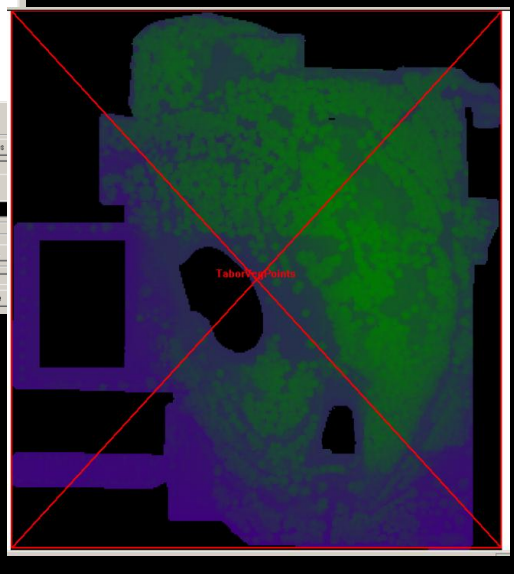
## FUSION




clip point cloud data to vegetation and load clipped raw data

# FUSION

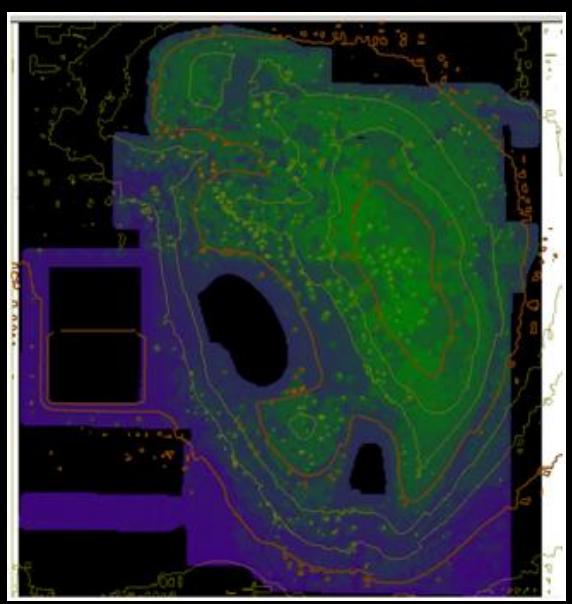


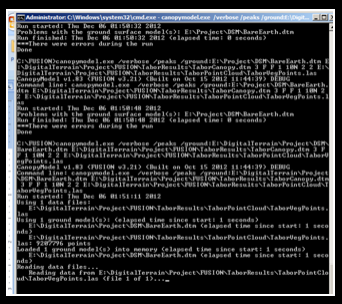
create image of points

# FUSION

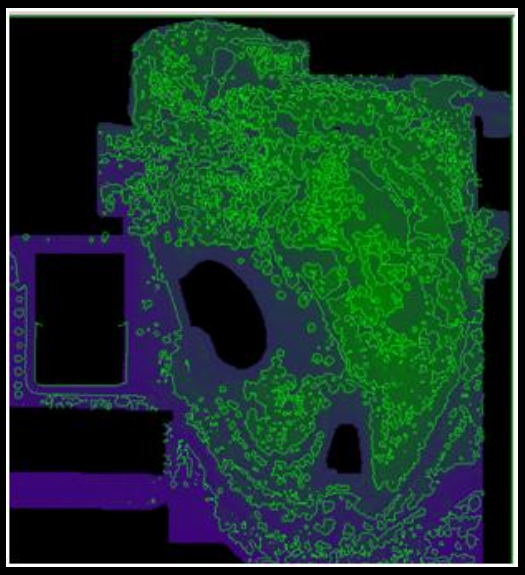
insert bare earth surface (derived from point cloud by Watershed Sciences)



# FUSION



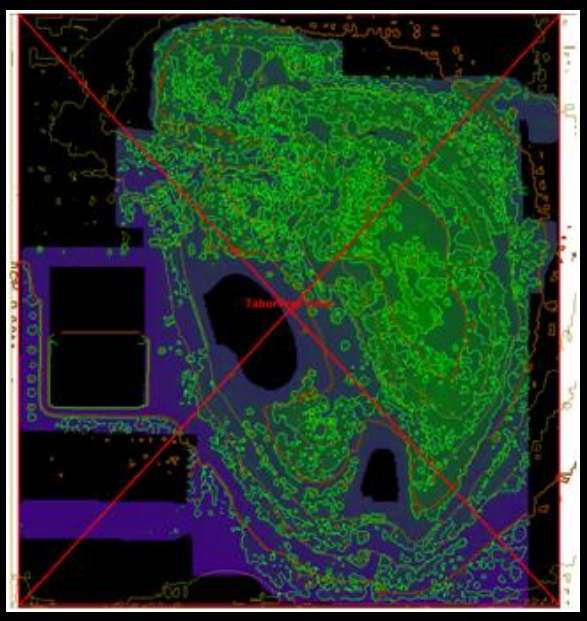
create canopy model
& normalize
heights using bare
earth DTM



# FUSION

derive canopy
maxima

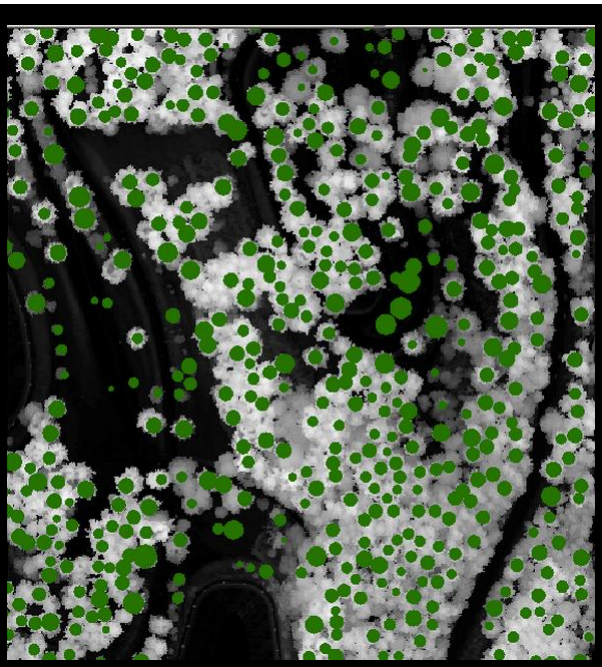
tree list that
includes crown
information
and height



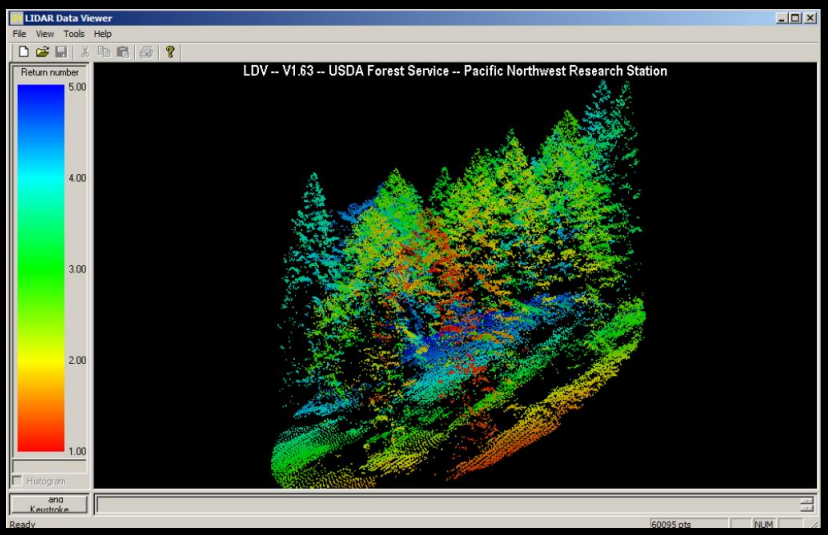
# FUSION

load CanopyMaxima xy data into ArcMap and export as multipoints

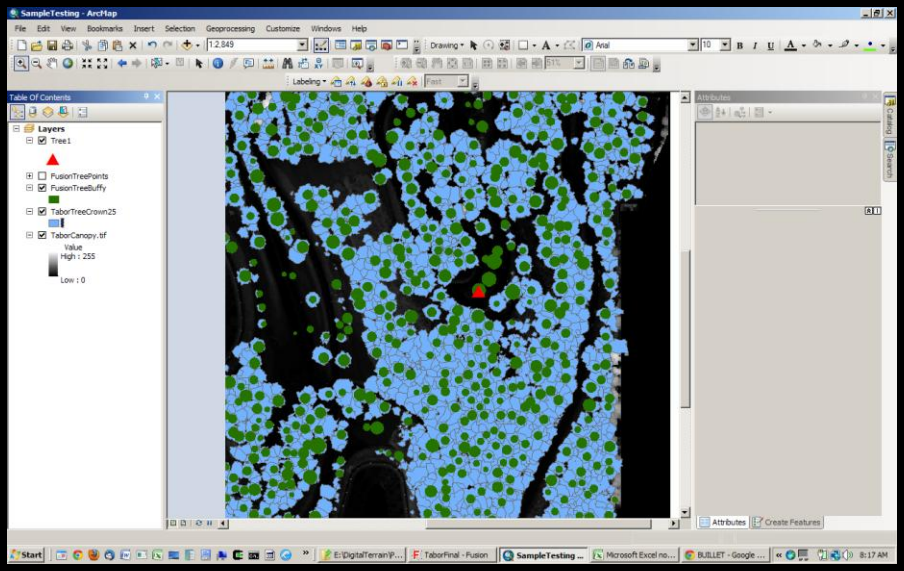
buffer points to create illusion of tree crowns



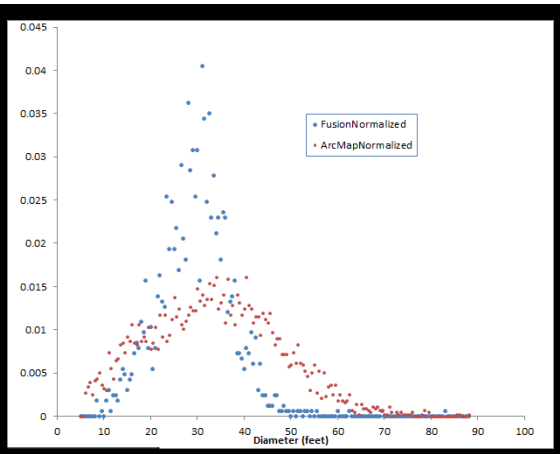
# FUSION



# visual results FUSION vs ArcMap

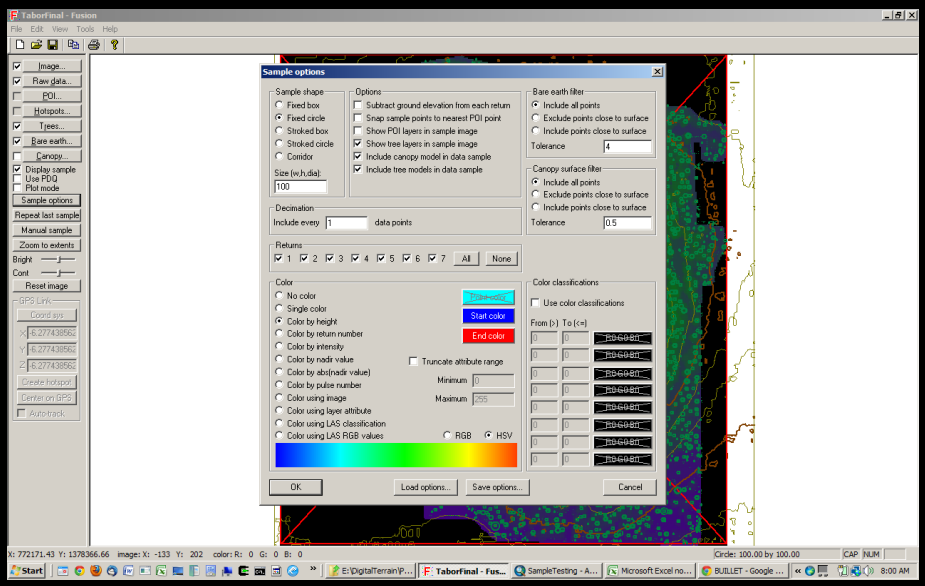



# statistical results

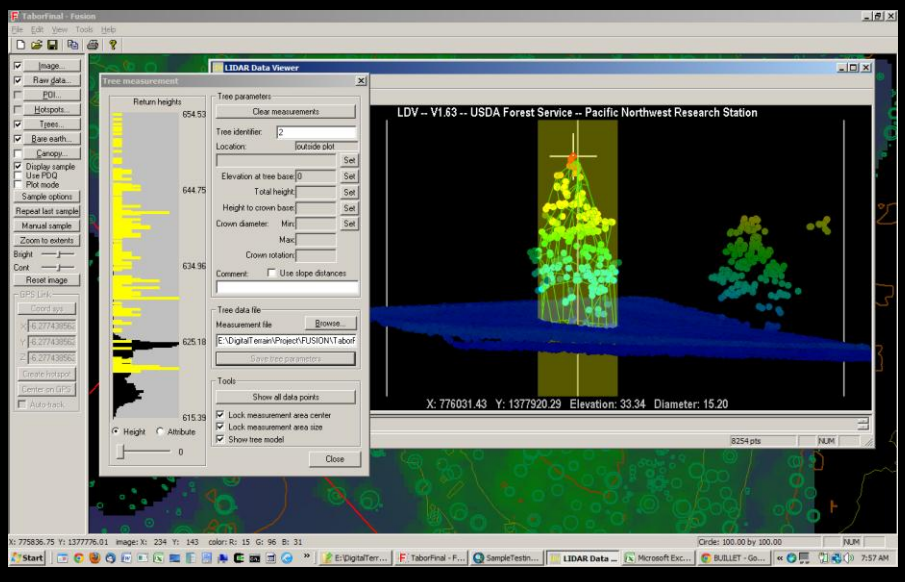



| | ArcMap | FUSION |
|---|---|---|
| **Mean** | 33.32 | 29.20 |
| **Median** | 33.08 | 29.39 |
| **Standard Deviation** | 13.79 | 7.56 |
| **Skewness** | 0.26 | 0.34 |
| **Minimum** | 5.72 | 8.16 |
| **Maximum** | 87.58 | 82.55 |

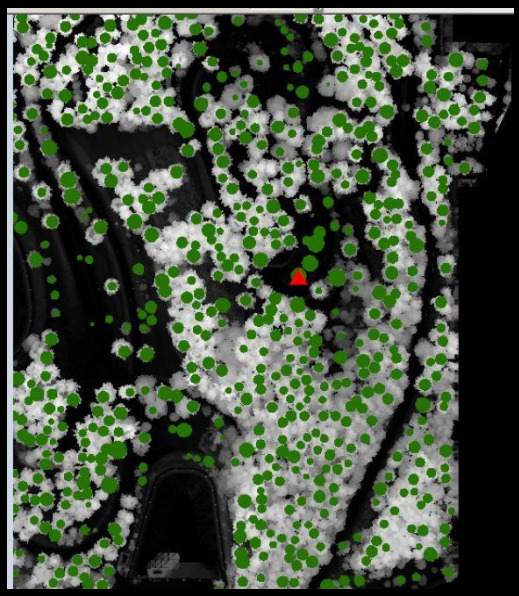
# FUSION - individual tree sample




# individual tree - manually measure



# FUSION results vs sample tree



# individual tree vs arcmap vs FUSION

Manual tree measure

| X | Y | Elevation | Total height | Ht_to_crown | Crown |
|---|---|---|---|---|---|
| 776031.43 | 1377920 | 621.19 | 33.34 | 4.5966 | 16.72 |

FUSION results

| X | Y | Elevation | Height | Ht_to_crown | Crown |
|---|---|---|---|---|---|
| 776031 | 1377924 | 0 | 654.53 | 327.27 | 47.81 |

ArcMap results

| X | Y | Elevation | Height | Ht_to_crown | Crown |
|---|---|---|---|---|---|
| | | | 30 | - | 17.21486 |

# individual vs. group comparisons

- ideally, this would be done to multiple random trees
- ArcMap results need x and y values appended
- FUSION results need to show feature height instead of just elevation + feature height

# conclusions

- methodology:
  - ArcMap - complicated, too many intermediate files
  - FUSION - simple once the interface and command line are understood
- results:
  - similar mean, median, skew, distribution
  - ArcMap
    - too many tree crowns
    - 4 times as many tree crowns
  - FUSION
    - smaller tree crowns
    - possibly too fewer trees
    - tighter distribution
- currently unknown:
  - accuracy of each model

# future research

- compare to manual analysis of sample plots
  - using point cloud data, randomly assign circular plots
  - manual delineate tree crowns and tree heights
  - within circular plots, compare ArcMap and FUSION tree crowns/heights to manual delineations
- combine LiDAR intensity or multispectral imagery with tree crown datasets to derive species