Tree Canopy Change Detection in Phoenix, Arizona (2014-2020)

Cameron T. Dougal, Mary K. Wright, and David M. Hondula

HeatReady PHX
OFFICE OF HEAT RESPONSE AND MITIGATION

Massachusetts Institute of Technology

School of Geographical Sciences and Urban Planning
Arizona State University

Introduction

The City of Phoenix, Arizona, United States, is one of many cities across the globe that have made major investments in increasing tree canopy for pedestrian thermal comfort, urban heat reduction, and aesthetic rejuvenation of the City.

To understand the return on investment of past and future tree planting across the City and identify areas where tree canopy has changed, it is vital to have a longitudinal assessment of tree canopy coverage at a high spatial resolution using methods that are comparable across time scales.

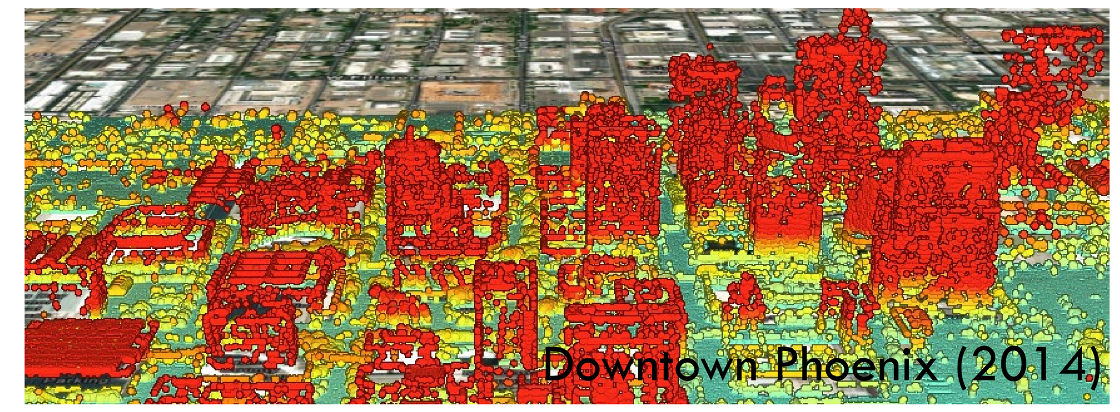
To this end, we applied identical methodologies using lidar and high-resolution imagery to compare tree canopy change in Phoenix between 2014 and 2020. After significant investments in tree planting that are currently ongoing in the City of Phoenix, the process we used will allow for direct comparison of tree canopy across time.

Methods

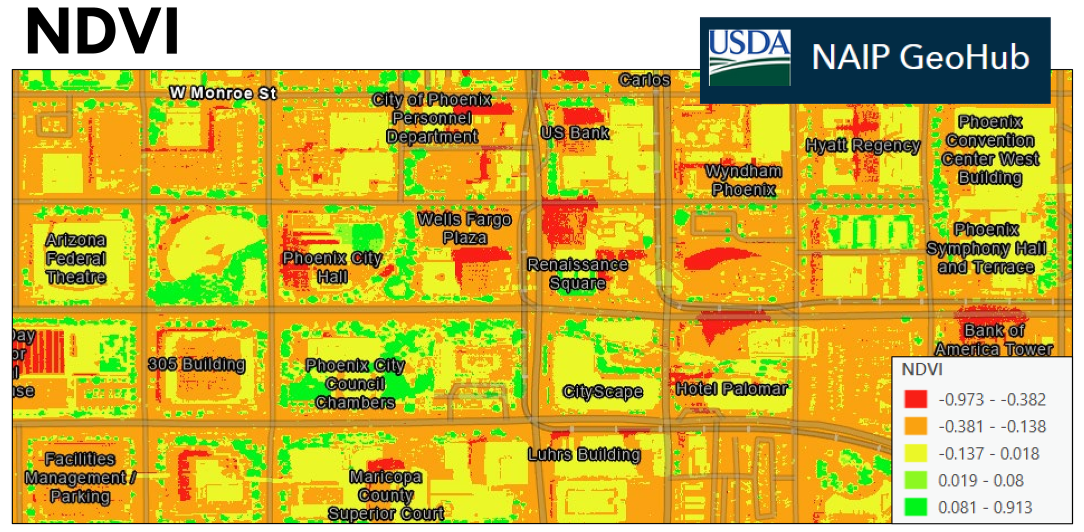
Step 1. Data processing

- Generate Canopy Height Model (CHM) from lidar for all of Phoenix with lidar coverage
  - Generate Digital Surface Model (DSM)
  - Generate Digital Elevation Model (DEM)
  - CHM = DSM – DEM
- Calculate NDVI from NAIP aerial imagery

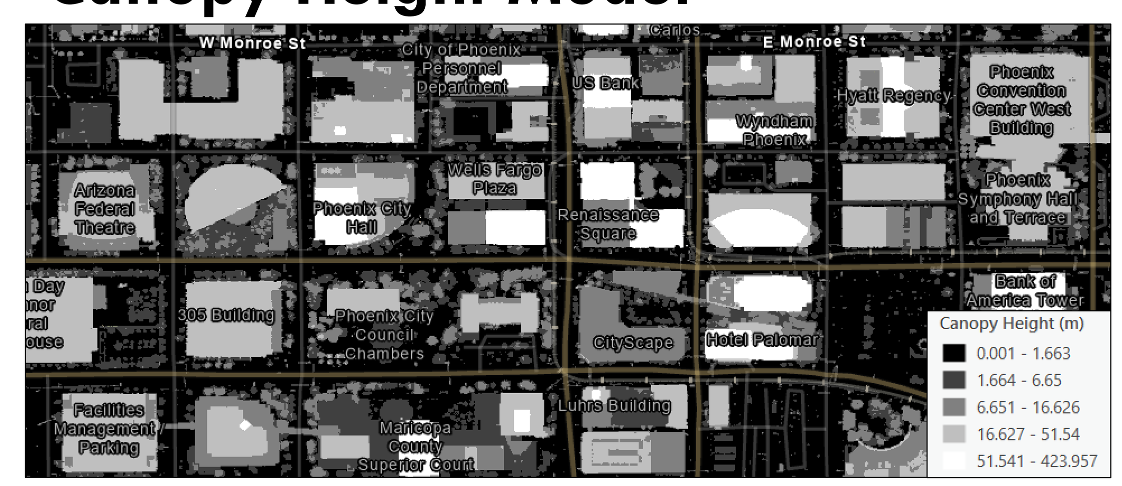
Lidar 3-D Point Cloud



NDVI



Canopy Height Model



Step 2. Data filtering

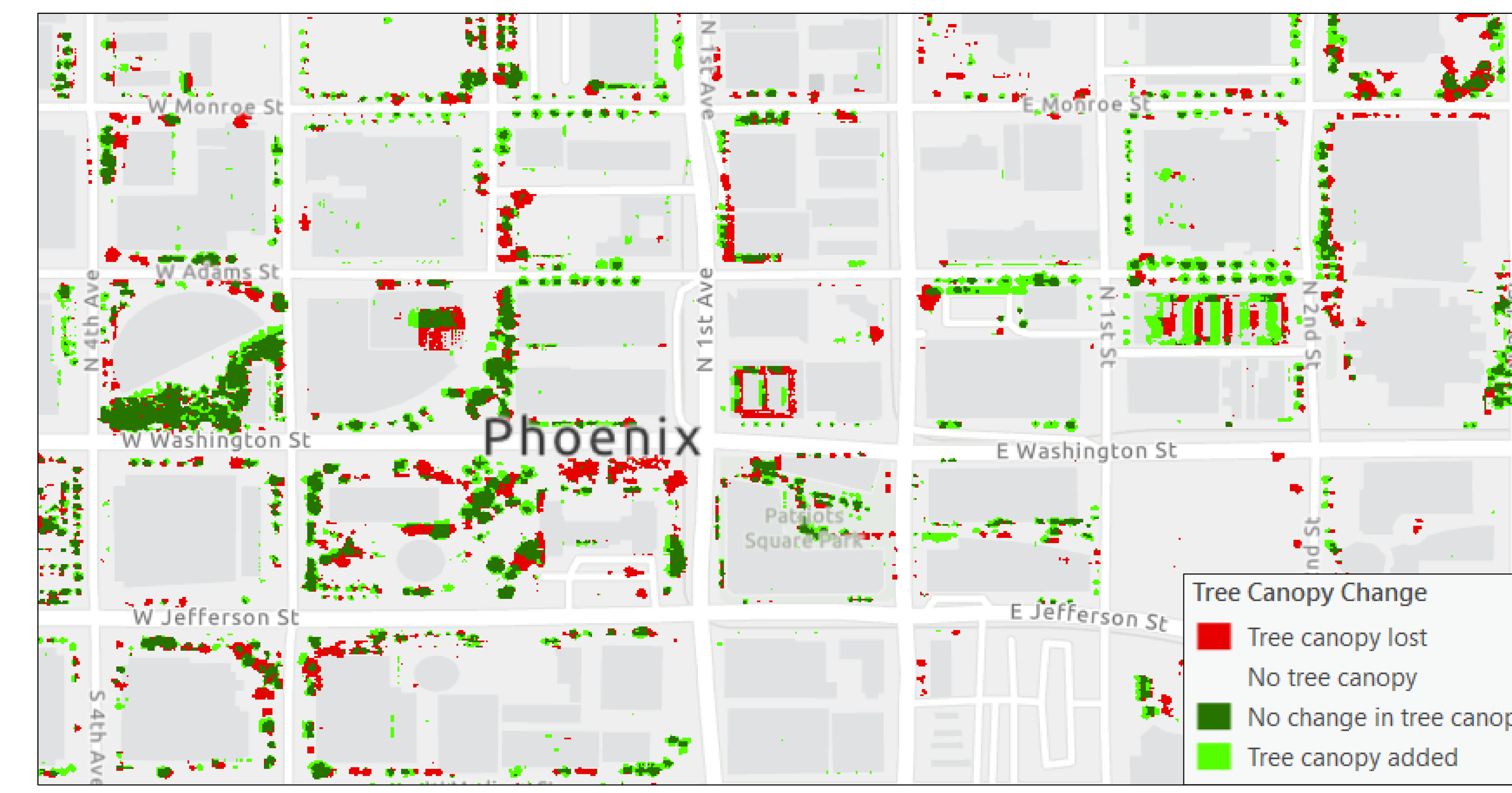
- Classify raster pixels as trees if:
  - Height ≥ 1.5 m
  - Height ≤ 40 m
  - NDVI ≥ 0.08

*These values were selected to limit to plausible tree heights and NDVI values low enough to detect desert trees.

Tree Canopy

Step 3. Longitudinal analysis

- Compare 2014 and 2020
  - Tree canopy gained
  - Tree canopy lost
  - Tree canopy unchanged
  - No tree canopy



Data descriptions

Lidar data were obtained for 2014 and 2020 from the United States Geological Survey.

The Normalized-Difference Vegetation Index (NDVI) was derived from the United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) for 2015 and 2019.

All data were processed in the R software program ver. 4.2.2. Lidar data were processed into raster heigh models using the 'LAScatalog' processing engine of the 'lidR' package (Roussel 2023)—this engine allows for resolution of edge effects across lidar tiles. Raster data were processed using the terra package (Hijmans et al. 2023).

Results

Key takeaways

→ The citywide tree canopy in both 2014 and 2020 is about 9%.

→ The longitudinal analysis shows that between 2014 and 2020:

→ The City of Phoenix tree canopy slightly decreased by 0.25%.

→ Roughly the same amount of tree canopy lost was also gained (3.23% gained vs. 3.49% lost).

Table 1. Citywide tree canopy coverage in Phoenix, Arizona

Citywide canopy	%
Tree canopy in 2014	9.14
Tree canopy in 2020	8.89
Tree canopy gained	3.23
Tree canopy lost	3.49
Tree canopy unchanged	5.65
No tree canopy in either year	87.62

Key takeaways

→ Tree canopy coverage varies across City Council Districts and by parcel type (residential vs. commercial).

→ The largest increase in canopy overall, and in both residential and commercial parcels, occurred in District 7 (0.9% overall, 1.2% residential, 0.4% comm.).

→ Overall, residential parcels have the highest tree canopy, however, residential parcels saw a larger decrease between 2014 and 2020 (13.7% vs. 12.88%), than commercial parcels.

Table 2. Tree canopy percentage by City of Phoenix Council District and parcel type

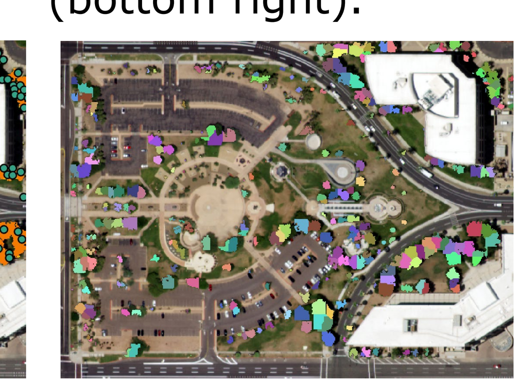
	Overall			City Parcel Average: Residential			City Parcel Average: Commercial		
District	2014	2020	Change	2014	2020	Change	2014	2020	Change
1	10.06	9.45	-0.62	12.35	11.20	-1.16	9.21	8.71	-0.50
2	10.39	9.78	-0.60	13.95	12.80	-1.15	14.48	14.10	-0.38
3	11.02	10.39	-0.63	14.43	13.60	-0.83	11.86	11.50	-0.35
4	9.92	9.74	-0.18	14.64	14.79	0.15	8.06	7.73	-0.32
5	9.64	9.71	0.07	12.30	12.59	0.29	10.88	10.82	-0.05
6	9.26	8.77	-0.49	15.48	14.00	-1.48	17.44	16.09	-1.36
7	6.15	7.05	0.90	8.76	9.95	1.19	7.32	7.75	0.43
8	6.40	6.42	0.03	10.63	10.05	-0.58	7.53	7.59	0.06
Overall	9.14	8.89	-0.26	13.70	12.88	-0.81	10.11	9.88	-0.23

*Note that lidar coverage is incomplete in Districts 1 & 2

Next Steps

- Conduct a formal accuracy assessment
  - optimize NDVI cutoff for accuracy
- Tree top detection
  - Calculate tree heights
- Tree crown segmentation
  - Calculate crown widths





Demonstration of tree canopy classification (left), tree top detection (bottom left), and tree segmentation (bottom right).

Acknowledgements

This work was funded in part by a Massachusetts Institute of Technology Social Impact Internship grant.

Contact: mary.wright@phoenix.gov

References

Roussel J, Auty D (2023). Airborne LiDAR Data Manipulation and Visualization for Forestry Applications. R package version 4.0.3, https://cran.r-project.org/package=lidR.

Hijmans, Robert J., Roger Bivand, Edzer Pebesma, and Michael D. Sumner (2023). terra: Spatial Data Analysis. R package version 1.7-29, https://cran.r-project.org/package=terra.