PORTLAND PARKS & RECREATION

Healthy Parks, Healthy Portland

Tree Canopy Monitoring:

Protocol and Monitoring from 2000-2020

February 2022

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Cover Photo: A tulip tree shades Alberta Park on a summer afternoon

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Summary

To monitor trends in Portland's urban forest canopy cover, Portland Parks & Recreation established a protocol for measuring canopy change using point interpretation of aerial photos. Tree canopy cover was measured in 2000, 2005, 2010, 2015, and 2020 citywide and in commercial, industrial, open space and residential zoning classes.

20-year findings

- From 2000 to 2020, statistically significant increases in tree canopy cover were found citywide and in commercial, industrial, and residential zones
- Increases over the 20-year period represent an addition of 2,289 acres of tree canopy

2015-2020 reporting period

- Tree canopy covers 29.8% of Portland's area in 2020, down from 30.7% in 2015
- Tree canopy loss occurred in all zoning classes between 2015–2020, totaling 823 acres. Losses during this period are as follows:
    - *Commercial*: 13.3% to 13.0% (-15 acres)
    - *Industrial*: 9.5% to 8.7% (-164 acres)
    - *Open space*: 54.9% to 54.2% (-121 acres)
    - *Residential*: 34.0% to 32.9% (-523 acres)
- Tree canopy losses found across all zoning classes and citywide during this study period are within the margin of error, and not statistically significant
- Future updates of this study will show whether losses found during this period continue, representing a reversal in the long-term trend of tree canopy expansion in Portland. The next measurement will be taken in 2025.

Introduction

Tree canopy cover is identified as an important measure of urban forest health by the City of Portland. Tree canopy cover is a measure of Portland Parks & Recreation bureau-wide performance and is also cited as an important indicator in the *Portland Urban Forest Management Plan* (2004), *Urban Forest Action Plan* (2007), the *Climate Action Plan* (2015), and the *2035 Comprehensive Plan* (2016). Monitoring Portland's tree canopy is important in order to understand how canopy coverage may be changing, and understanding these trends will allow managers to make important decisions regarding management strategies.

Tree canopy cover has been measured in a variety of ways within the city of Portland. Past studies have varied in methodology and time frame, and citywide canopy estimates from 1972 to 2014 range from 25% – 31% (Metro 2008 and 2016, Nowak & Greenfield 2012, Poracsky & Lackner 2004, PP&R 2007). These studies have provided important estimates of tree canopy cover, but differences in methodology preclude direct comparison of results for the purpose of detecting change.

Accurately detecting change requires establishing and using a replicable protocol with a low error rate. Canopy change, especially growth, occurs slowly and in order to detect a change, the same method must be used over a period of time long enough for change to be evident. A successful monitoring protocol will use the same type and resolution of imagery, minimize and measure error, set thresholds for determining whether or not change has occurred, define a statistical method for comparing results, and be repeated at a regular time interval. This is vital to ensure that change reported is due to actual change, and is not a result of measurements being taken using different methods. If weighing tree canopy measurements against targets, progress towards targets will be measured using the same protocol.

To monitor trends in Portland's urban forest canopy, PP&R established a protocol for measuring tree canopy change according to the guidelines above, using point interpretation of aerial photos across four zoning classes and citywide, over five-year time increments. This report documents the adopted protocol and reports results for the study period from 2000-2020.

Monitoring Protocol

CHOOSING A METHODOLOGY

The goal of this canopy monitoring protocol is to determine how canopy is distributed among land use classes and citywide, and to determine how canopy is changing over time. Available methods for quantifying canopy were evaluated for their ability to answer these questions, including classification of remotely sensed data, ground sampling, and point interpretation of aerial photos. The benefits and drawbacks of each method were carefully weighed using the guidelines below.

- Canopy change methodology requirements:
- Low error rate
- Use imagery and technology that will continue to be available in future years
- Cost effective
- Replicable
- Peer reviewed with a recognized protocol
- Ability to subject results to quality assurance testing
- Ability to determine canopy cover for pre-defined strata and citywide
- Produce results that can be statistically compared for significance

Point interpretation of aerial imagery was selected, as it best met the above requirements. The primary drawback of point interpretation is the inability to produce cover maps. Point interpretation also cannot analyze canopy by categories not established at the beginning of the study (for example, neighborhood boundaries), as each strata requires a large number of sample points. However, the key goal of this project was to monitor canopy in predetermined strata and citywide, and cover maps and additional analysis are not required for this effort.

DEFINING STRATA

Recognizing that the city has different land use areas with varying characteristics and goals, strata were determined according to zoning classifications. Zoning classes are good proxies for the city's different land use types and best represent development intensity. Zoning classes also have some connection to the Urban Land Environments outlined in the 2004 *Portland Urban Forest Management Plan*. Four strata were established corresponding to zoning code: commercial, industrial, open space, and residential (Table 1). All areas within the city's boundary were assigned to one of the zoning classes.

Table 1: Zoning Class Descriptions				
Zoning Class	**Zoning Code**	**Zoning Class Description**	**Acres**	**% of City**
Commercial	CO1, CN1, CO2, CN2, CG, CS, CM, CX	Storefronts, neighborhood and office commercial areas, and mixed residential commercial areas	6,237	6.7%
Industrial	EG1, EG2, IG2, IG1, IH, EX	Manufacturing and warehousing areas, industrial and wholesales sales, and industrial parks	21,507	23.2%
Open Space	OS	Natural areas, developed parks, and schools	16,819	18.1%
Residential	RF, R20, R10, R7, R5, R3, R2.5, R2, R1, RH, RX, IR	Single and multifamily residential homes	48,149	51.9%
			92,712	100.0%

Note that some zoning boundaries and designations were updated in 2018 (Bureau of Planning and Sustainability 2018). Table 1 reflects zoning classes prior to this update. For the purposes of the 2015 – 2020 reporting period, the prior zoning designations were kept in place. Future updates of this report will reflect the new zoning map.

APPLYING THE MONITORING PROTOCOL

PP&R contracted with Davey Resource Group, an experienced urban forestry consultant agency, to assist in establishing a protocol in 2012. The complete monitoring protocol is described in Appendix A.

Point interpretation was conducted by first establishing randomly located points across each zoning class. To keep standard error low, a minimum of 1,000 points were used for each zoning class for a total of 4,521 points. High resolution imagery was available back to 2000, thus years 2000, 2005, and 2010 became the first study years, and Davey Resource Group conducted point interpretation for these years. Subsequent point interpretation was conducted by Urban Forestry staff for years 2015 and 2020.

For each study year, points were laid in the same geographic location on aerial images and a trained photo interpreter examined the points to determine whether the points coincided with tree canopy or not. To ensure that the photo interpretation process was completed with the highest degree of accuracy, a second photo interpreter performed quality assurance inspections on 10% of the work performed to verify the interpretations, with a 95% agreement threshold.

A percent tree canopy cover was determined for each zoning class, and the number of acres of tree canopy was calculated by multiplying the percentage of tree canopy by the total acres within the zoning class. Citywide tree canopy levels and acreages were calculated as weighted averages of the zoning classes. Standard error and 95% confidence intervals were calculated, and change over time was tested for significant difference using a Chi-squared test (McNemar's test) and significant differences were found if $p < 0.05$.

Findings

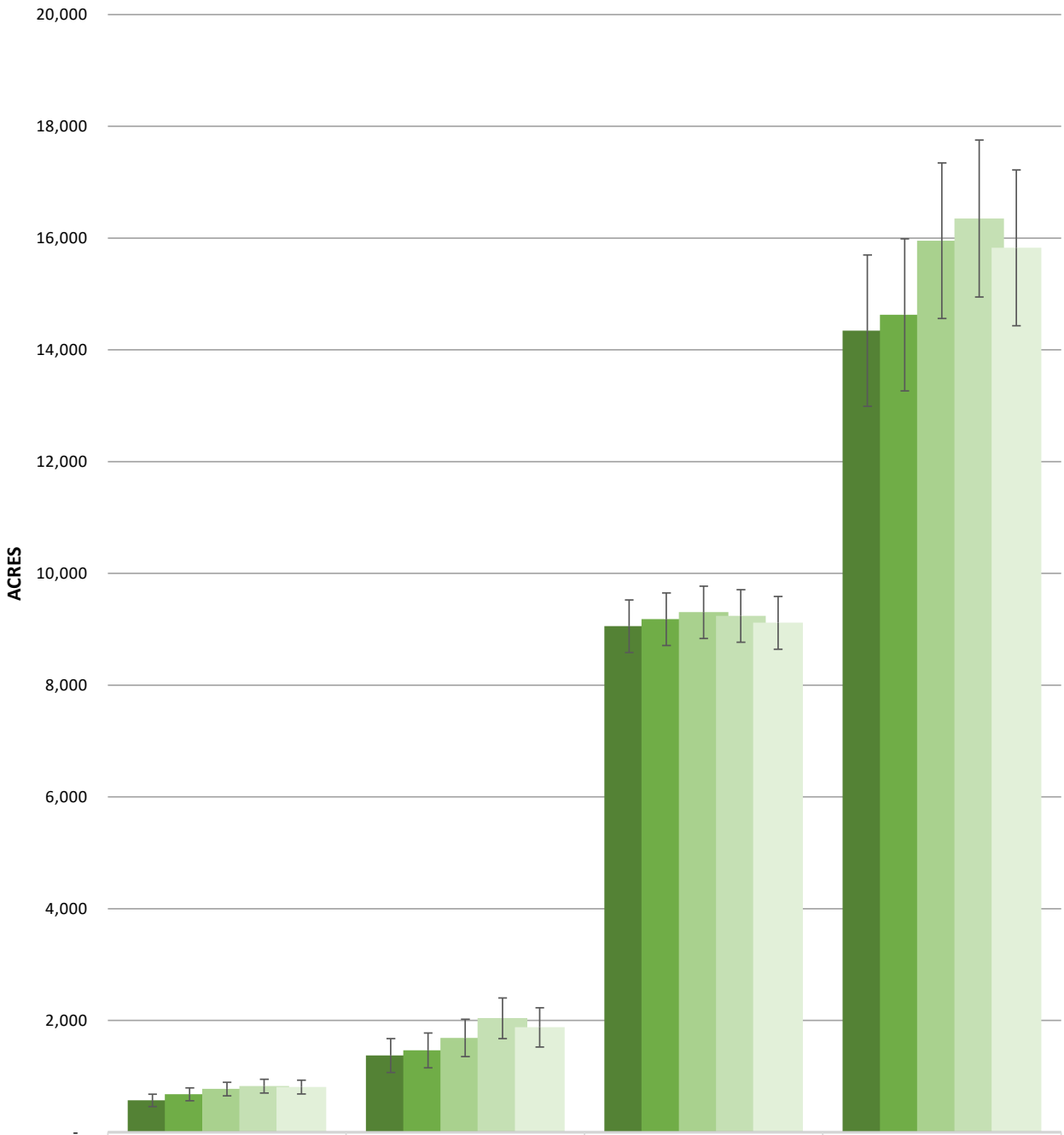
TREE CANOPY COVER AND ACRES OF CANOPY

Overall tree canopy cover ranged from 27.3% in 2000 to 30.7% in 2015, falling to 29.8% in 2020 (Table 2). Total tree canopy acres found in the city ranged from 25,348 in 2000 to 28,460 in 2015, falling to 27,637 in 2020. Tree canopy cover was found to be unevenly distributed among the four zoning classes (Figure 1).

Table 2: Percent tree canopy cover and acres of tree canopy from 2000–2020

	2000 Tree Canopy Cover		2005 Tree Canopy Cover		2010 Tree Canopy Cover		2015 Tree Canopy Cover		2020 Tree Canopy Cover	
Zoning Class	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**
Commercial	9.1	571	11.0	687	12.5	781	13.3	827	13.0	812
Industrial	6.4	1,374	6.8	1,467	7.9	1,690	9.5	2,043	8.7	1,879
Open Space	53.9	9,057	54.6	9,182	55.3	9,306	54.9	9,239	54.2	9,118
Residential	29.8	14,345	30.4	14,629	33.1	15,955	34.0	16,351	32.9	15,827
City Total	**27.3**	**25,348**	**28.0**	**25,965**	**29.9**	**27,732**	**30.7**	**28,460**	**29.8**	**27,637**

Figure 1: Acres of canopy in zone classes from 2000–2020. Error bars represent 95% confidence intervals.



	Commercial	Industrial	Open Space	Residential
Year 2000	571	1,374	9,057	14,345
Year 2005	681	1,467	9,182	14,629
Year 2010	775	1,690	9,306	15,955
Year 2015	827	2,043	9,239	16,351
Year 2020	812	1,879	9,118	15,827

In commercial zones, tree canopy rose from 571 acres to 827 acres between 2000-2015, falling to 812 acres in 2020. This represents total tree canopy cover ranging from 9.1% in 2000 to 13.3% in 2015, falling to 13.0% in 2020. Commercially zoned lands contain approximately 3% of the city's total tree canopy.

In industrial zones, tree canopy rose from 1,374 acres to 2,043 acres between 2000-2015, falling to 1,879 acres in 2020. This represents total canopy cover ranging from 6.4% in 2000 to 9.5% in 2015, falling to 8.7% in 2020 – the lowest of any zoning class. Industrial zoned lands contain approximately 7% of the city's total tree canopy.

In the open space zone, tree canopy rose from 9,057 acres to 9,306 acres between 2000-2010, falling between 2010-2020, to 9,118 acres. Open space zones have the highest rate of canopy cover found in any zoning class, at 54.2% in 2020, down from 55.3% in 2010. Land zoned open space contains approximately 33% of the city's tree canopy.

In residential zones, which make up the largest portion of the city's land base, tree canopy rose from 14,345 acres to 16,351 acres between 2000-2015, falling to 15,827 acres in 2020. This represents total tree canopy cover ranging from 29.8% in 2000 to 34.0% in 2015, falling to 32.9% in 2020. Residential zones contain the majority (57%) of the city's tree canopy.

CHANGE OVER TIME

From 2000 to 2005, increases in tree canopy cover were found citywide and in all zoning classes (Table 3), however only changes in commercial zones were statistically significant (McNemar's test, $p < 0.05$), where tree canopy cover rose from 9.1% to 11.0% during the time period.

Table 3: Change in tree canopy cover in five-year intervals, 2000 – 2020

	2000-2005		2005-2010		2010-2015		2015-2020	
Zoning Class	**Percent Change**	**Change in Acres**	**Percent Change**	**Change in Acres**	**Percent Change**	**Change in Acres**	**Percent Change**	**Change in Acres**
Commercial	+1.9*	+116*	+1.5*	+94*	+0.7	+46	-0.3	-15
Industrial	+0.4	+93	+1.0*	+223*	+1.6*	+353*	-0.8	-164
Open Space	+0.7	+124	+0.7	+124	-0.4	-66	-0.7	-121
Residential	+0.6	+284	+2.8*	+1,326*	+0.8	+395	-1.1	-523
City Total	**+0.7**	**+617**	**+1.9***	**+1,767***	**+0.8**	**+728**	-0.9	**-823**

* Change significantly different with $p < 0.05$ (McNemar's test)

From 2005 to 2010, significant increases in tree canopy cover were found citywide and in all zoning classes except open space. Citywide tree canopy cover increased by 1.9%, commercial by 1.5%, industrial by 1.0%, and residential by 2.8%.

From 2010 to 2015, increases in tree canopy were found in all zoning classes except open space, however the only significant change was seen in industrial zones, which increased by 1.6%, from 7.9% to 9.5% tree canopy cover.

In the latest reporting period, from 2015-2020, decreases in tree canopy cover were found citywide, and across all zoning classes. None, however, were statistically significant.

Over the twenty-year period, from 2000 to 2020, tree canopy cover increased significantly citywide and in all zoning classes with the exception of open space (Table 4). Citywide tree canopy cover increased by 2.5%, commercial by 3.9%, industrial by 2.3%, and residential by 3.1%. Citywide, these increases represent an estimated addition of 2,289 acres of tree canopy.

Table 4: Change in canopy cover from 2000 to 2020

Zoning Class	Percent Change	Change in Acres
Commercial	+3.9*	+241*
Industrial	+2.3*	+505*
Open Space	+0.3	+61
Residential	+3.1*	+1,482*
City Total	**+2.5***	**+2,289***

* Change significantly different with $p < 0.05$ (McNemar's test)

Discussion

CANOPY DISTRIBUTION AND TRENDS

From 2000-2020, tree canopy cover significantly increased citywide and across commercial, industrial, and residential zones. For the first 10 years of the study period, tree canopy cover increased significantly citywide and across all zones, with tree canopy in commercial, industrial, and residential zones continuing to grow between 2010-2015. In the latest reporting period, 2015-2020, some of these gains were lost as tree canopy cover declined across all zones, although not at statistically significant levels.

Twenty years is a relatively short period of time, but clear trends are revealing changes in the urban forest. While Portland's tree canopy cover is greater today than 20 years ago, canopy growth has slowed or reversed in the past 5 years. Interestingly, this time period coincides with the 2015 adoption of improved regulations for tree preservation and removal with Portland's tree code, Title 11. Despite these new rules resulting in the preservation of thousands more trees than would have been preserved in previous years, the city was still not able to realize the gains in tree canopy cover seen in the early periods of this study.

Tree canopy cover varies greatly between zoning classes, reflecting land use and development intensity. Land use also explains the likelihood for changes in tree canopy cover during each reporting period. For example, the open space zone has the highest level of tree canopy cover, but changes over the study period were statistically insignificant. Open space lands include natural areas and developed parks, where land use patterns are largely set. In contrast, residential, commercial, and industrial zones are more likely to undergo development and, with less overall tree canopy, may have more opportunities for planting new trees, making them more likely to experience changes in canopy cover over short 5-year increments.

COMPARISON TO CANOPY COVER TARGETS

PP&R's 2004 *Portland Urban Forest Management Plan* (UFMP) set aspirational tree canopy cover targets for Urban Land Environments (ULEs) (Table 5). Targets were established by reviewing recommendations for tree canopy cover in scientific literature. ULEs were derived from Metro's Regional Land Information System, and have some connection to the zoning code categories used in this study. Note that ULEs are now outdated and may include up to 20% classification error (PP&R 2009). The two ULEs that correspond best with zoning categories are the residential ULE and the commercial/ industrial/ institutional ULE. The UFMP recommends targets of 35-40% tree

Table 5: Existing canopy cover targets within the City of Portland		
Category	**Canopy cover targets in UFMP (2004)**	**Canopy goals in PP&R Canopy Report (2007) and Climate Action Plan (2015)**
Residential ULE	35-40%	n/a
Commercial/Industrial/Institutional ULE	15%	n/a
Natural Areas and Stream Corridors ULE	Targets set by City Framework Plan	n/a
Transportation Corridors and Rights of Way ULE	35%	n/a
Developed Parks and Open Spaces ULE	30%	n/a
Citywide	No target set	33.3%

canopy cover for the residential ULE and 15% for the commercial/industrial/institutional ULE. In 2020, tree canopy cover did not meet these goals, having declined across every zone: in the residential zone tree canopy cover is 32.9%, the commercial zone is 13.1%, and the industrial zone is 8.7%.

PP&R's *Canopy Report* (2007) and City of Portland's *Climate Action Plan* (2009 and 2015) set a goal of expanding urban forest canopy to cover one-third of the city's area. The 33.3% citywide goal was established from tree canopy cover data produced using a different method than that used in this report, and direct comparison of results is not recommended.

This report provides baseline data that can be used to establish and refine canopy targets. The *Portland Urban Forest Management Plan* is scheduled to be updated in coming years, providing an excellent opportunity for revising tree canopy goals, using new information on areas of potential growth to set realistic targets (PP&R 2018). Well-developed tree canopy targets will provide the opportunity to make deliberate and clear decisions for planning and goal setting for the future of the urban forest.

In addition to a citywide tree canopy goal, goals for each zoning class are recommended due to the fundamental differences between zones in land use characteristics, existing tree canopy, and capacity to accommodate tree canopy in the future. Zone class targets will assist managers in developing effective strategies for increasing tree canopy, and may also assist the City in reaching its other tree goals, such as more equitable distribution of trees.

OPPORTUNITIES FOR FUTURE STUDY

Establishing and applying a monitoring protocol has been an important step in a long-term commitment to tracking tree canopy trends. The protocol outlined in this study will continue to serve as guide for PP&R in future years and the next tree canopy measurement will occur using 2025 aerial images.

This monitoring study reports trends in tree canopy cover, but does not provide information on why changes are occurring. Canopy increases may be attributed to growth of existing trees and planting of new trees. Tree removal for development, tree loss from pests and diseases, natural mortality, and weather events may negatively affect tree canopy cover. Examination of the reasons behind tree canopy

trends requires additional study and would allow for more informed strategies for meeting tree canopy goals.

Additionally, this study does not provide information on tree canopy cover levels or change in areal units other than zoning classes or citywide. Other boundaries of interest may be useful, such as at the neighborhood level or across private versus public property. Maps of Portland's tree canopy have been developed for the years 2014 and 2019 (Metro 2016 and 2022) providing an opportunity to pursue these questions. While not strictly comparable to data presented in this report, these maps of Portland's tree canopy are complementary and will aid understanding of recent changes in the distribution of tree canopy in Portland.

References

Bureau of Planning and Sustainability. 2018. **City of Portland Zoning App**. https://www.portlandmaps.com/bps/zoning/#/map/

Bureau of Planning and Sustainability. 2016. ***2035 Comprehensive Plan***. https://www.portland.gov/bps/comp-plan/2035-comprehensive-plan-and-supporting-documents

Bureau of Planning and Sustainability. 2015. ***Climate Action Plan***. https://www.portland.gov/bps/climate-action/history-and-key-documents

Lindren, B.W. and G.W. McElrath. 1969. ***Introduction to Probability and Statistics***. Macmillan, London.

Metro. 2008. ***State of the Watersheds Monitoring Report***. http://www.oregonmetro.gov/index.cfm/go/by.web/id=27579

Metro. 2016. ***Canopy 2014***. http://rlisdiscovery.oregonmetro.gov/?action=viewDetail&layerID=3552

Metro. 2022. ***Canopy 2019***. Still pending at time of publishing.

Nowak, D. J. and E.J. Greenfield. 2012. ***Tree and impervious cover change in US cities***. Urban Forestry & Urban Greening. 11: 21-30.

Poracsky, J. and M. Lackner. 2004. ***Urban Forest Canopy Cover in Portland, Oregon: 1972 - 2002***. Final Project Report prepared for Portland General Electric and City of Portland Urban Forestry Commission.

Portland Parks & Recreation. 2004. ***Portland Urban Forestry Management Plan***. https://www.portland.gov/trees/urban-forest-management-plan

Portland Parks & Recreation. 2007. ***Portland's Urban Forest Canopy: Assessment and Public Tree Evaluation***. https://www.portland.gov/sites/default/files/2020-08/urban-canopy-report-10-07.pdf

Portland Parks & Recreation. 2007. ***Urban Forest Action Plan***. https:// https://www.portland.gov/sites/default/files/2020/urban-forest-action-plan-02-07.pdf

Portland Parks & Recreation. 2009. ***A Standardized Methodology to Track Urban Forestry Canopy Cover Change***. White paper

Portland Parks & Recreation. 2018. ***Tree Canopy and Potential in Portland, Oregon***. https://www.portland.gov/sites/default/files/2020-08/tree-canopy-and-potential-2018.pdf

Sokol, R.R. and F.J. Rohlf. 2003. ***Biometry: The Principles and Practices of Statistics in Biological Research***. WH Freeman and Company, New York, NY.

Thompson, S. K. 2002. ***Sampling***, second edition. John Wiley and Sons, Inc., New York, New York.

Appendix A: Canopy Monitoring Protocol

Method: Point interpretation of aerial photos

Measurement frequency: 5 years

Image standards: Color digital orthorectified photos at 6" resolution taken during leaf on season

Strata: Commercial, industrial, open space, and residential according to zoning code

Points: A minimum of 1,000 randomly selected points are established within each zoning class. The high sample number is needed to minimize standard error. A standard error threshold of 2% is established. If standard error for any zone exceeds 2%, additional sample points should be established until the standard error threshold is reached. Future analyses use the same established points.

Interpreting points: Points are interpreted as tree, non-tree, or unreadable. Unreadable points are removed from the sample.

Photo interpretation guidelines:

- Photo interpreters should have extensive experience interpreting aerial photography and relating photos to locations on the ground. Interpreters should have a high degree of confidence that they can differentiate between trees, lawn, buildings, roads, and other ground surfaces. This is a strategy to reduce errors that would occur when the interpreter records a tree when there is no tree, or fails to see the tree as occupying the point.
- The same photo interpreter should be used throughout the study, except for quality assurance testing.
- A second photo interpreter performs quality assurance testing on 10% of the data points. A 95% agreement must be reached for the data interpretation to be considered valid.
- Dead trees are considered "not tree." Because photos are analyzed in leaf-on season, trees devoid of leaves are considered dead or "not tree."
- Non-tree vegetation (e.g., hedges, low shrubs, green roofs, lawn) is considered "not tree."
- Points falling on water are included and are recorded as "not tree."
- In cases where the point falls on the edge of a tree, the interpreter will need to zoom in and carefully consider the image. Changes over time may be due to canopies growing into the location of the point, and it is important to spend the time to carefully analyze and capture these borderline changes.

- Images that are too difficult to interpret due to large dark shadows from buildings or very large trees are considered "unreadable" and are excluded from the study.
- Due to the nature of aerial photography, minor displacement occurs due to horizontal and parallax variation from year to year. To minimize bias, these changes are ignored and each photo is assumed to be correct. Although this may introduced error in some borderline cases, it is assumed that error is equally randomly distributed between tree and non-tree points.

DATA ANALYSIS

Zoning class tree canopy cover percentage (p): The number of sample points (N) interpreted as "tree" divided by the total number of sample points (n) within the zone (p=N/n).

Zoning class tree canopy acres: The percentage of tree canopy cover (p) multiplied by the total acres of land within that zone.

Citywide tree canopy acreage: The sum of tree canopy acreages in each zone.

Citywide tree canopy cover percentage: The total acres of tree canopy divided by the total acres of land in the city.

Standard error (SE): $\sqrt{((p \times (1-p)/n)}$ (Lindren and McElrath 1969)

Confidence interval: A 95% confidence interval is set and is calculated as: SE x 1.96 (Thompson 2002).

Significance testing: For each zone and citywide, McNemar's test is used to determine whether changes observed in canopy coverage are statistically significant (Sokal and Rohlf, 2003). McNemar's test is a non-parametric method used on nominal data. The test provides a chi-squared value, which is compared against a p-value for statistical significance. Canopy cover between years and across zones is considered significantly different if $p < 0.05$. A weighted total is used to calculate citywide chi-squared using McNemar's test. Each number of sample points (N) was multiplied by the portion of the city covered by each zone to calculate the total.