PORTLAND PARKS & RECREATION

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Tree Canopy and Potential in Portland, Oregon

February 2018

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Cover Photo: A single family lot in Portland's Powellhurst-Gilbert neighborhood shows room for tree planting

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Summary

As part of ongoing efforts to monitor and manage Portland's urban forest, Portland Parks & Recreation identified and mapped the distribution of tree planting opportunity in the city. Potential for expansion of the city's current tree canopy and the services it provides is extensive but uneven across Portland's geography, zoning, and property ownership. This analysis of the distribution of Portland's tree canopy and potential provides critical baseline information for updating the 2004 *Urban Forest Management Plan* and revising canopy goals according to the most current available data.

KEY FINDINGS

- Areas of potential tree canopy make up 20,886 acres, or 23%, of the city, representing space for an estimated 1.3 million additional trees.
- Potential tree canopy is not evenly distributed across zoning types. Residential zones contain 54% of the city's canopy potential, industrial zones 25%, open space zones 14%, and commercial zones 7%.
- Distribution of potential canopy is geographically uneven, with areas east of the Willamette River containing 82% of the city's potential tree canopy, compared to 18% west of the river.
- Nearly two-thirds of Portland's canopy potential (62%) is located on private lands, with the remaining divided between public lands (21%) and rights-of-way (16%).
- To meet the city's goal of 33.3% canopy cover by 2035, canopy cover in Portland would have to expand by approximately 3,200 acres, or 15% of total canopy potential identified in this analysis. To meet *Urban Forest Management Plan* goals for an equitable distribution of the services provided by the urban forest, tree planting will need to be focused in areas where it is currently lacking.
- Meeting some or all of Portland's canopy potential would yield substantial returns in environmental services and other benefits. If realized, canopy potential identified in this report represents $197 million in annual services, totaling $3.9 billion over 20 years.
- This study does not attempt to predict changes to Portland's canopy potential due to expected population growth and associated development; however, over 80% of all potential canopy identified in this study lies outside areas projected by the City to experience development in the next 20 years. Further study, including detailed site analysis based on zoning requirements, is needed prior to further adjusting estimates presented in this report.

Background

Portland's urban forest is integral to the environmental, economic, and social health of the city. Trees on public and private lands benefit residents by protecting air and water quality, improving public health, increasing public safety, and making the city more livable for both humans and wildlife. In recognition of the importance of the urban forest, canopy cover is cited as an important indicator in the *Portland Urban Forest Management Plan* (2004), *Urban Forest Action Plan* (2007), *Portland Plan* (2012), *Climate Action Plan* (2015), and the *2035 Comprehensive Plan* (2016) and the city has set a goal of expanding canopy cover from its current 29.9% to at least 33.3% by 2035 (Bureau of Planning and Sustainability (BPS 2012a).

Portland Parks & Recreation (PP&R) regularly monitors urban forest canopy cover in order to assess forest health, track program progress, and inform management of this natural resource (PP&R 2007b, 2017). In recent years, Portland has been successful in increasing canopy cover across the city despite population growth and urban development, adding over 3,000 acres of canopy from 2000-2015—a time period in which population grew by approximately 100,000 people. Building on this short-term success will be a challenge, as Portland's population is expected to grow by an additional 260,000 people by 2035 (BPS 2016). Continuing to expand tree canopy in the face of this growth and associated land development will take planning and investment, and this report provides important baseline information for those efforts.

This analysis provides detail on the distribution of tree canopy in Portland, identifies areas of the city that offer tree planting opportunities, and estimates the monetary value of planting to fulfill canopy potential across the city. Mapping canopy potential will help guide efforts to continue Portland's success in expanding the urban forest and aid in developing canopy targets that meet multiple tree-related and other goals, including equity in distribution of forest canopy and the services it provides and mitigating and adapting to climate change.

While this report focuses on areas of opportunity for tree planting, meeting and exceeding one-third canopy cover across the city requires the preservation of existing trees whenever possible. Planting a tree is an investment that takes decades to realize—akin to putting a dime in the bank and waiting for the interest to turn it into a dollar. Portland's "bank account" of tree canopy cannot grow by pulling out dollars and replacing them with dimes.

Data and Methods

CATEGORIZING LAND COVER

This analysis is based on existing land cover classifications, including a map of tree canopy cover derived from the 2014 Metro Regional Land Information System (RLIS) land cover classification (Metro 2016) as well as other land cover datasets maintained by the City of Portland (Table 1). Using these data within a geographic information system (GIS), land cover across the city was grouped into four categories: 1) water, 2) existing tree canopy cover, 3) impervious surfaces, 4) pervious surfaces, including non-tree vegetation. Impervious surfaces were further divided into buildings, streets, sidewalks, and parking lots in order to capture differences in their ability to support tree canopy.

Table 1 : Data and sources

Data	Time Period	Source
Canopy	2014	Metro RLIS
Waterbodies	2014	Metro RLIS
Zoning	2017	City of Portland, Bureau of Planning and Sustainability
Impervious surfaces (buildings, streets, sidewalks, parking lots)	2014	City of Portland, Bureau of Environmental Services, Bureau of Transportation
PDX primary zone	2014	Port of Portland
Buildable Lands Inventory	2012	Bureau of Planning and Sustainability

Those land covers not able to support tree canopy—streets, buildings, and waterbodies—were then removed from analysis. While exceptions exist, these areas cannot be planted without significant expense or redesign. Because of federal regulation of vegetation around airports, the "primary zone" around Portland International Airport (PDX) was also excluded from analysis, as it is exempt from some tree planting and removal regulations and therefore does not constitute a viable planting opportunity.

Finally, areas of existing canopy were removed from analysis as they do not represent areas of potential. While future tree planting efforts could take place in some of these spaces, planting would not result in a notable net gain of tree cover over time.

All remaining areas, including all pervious surfaces, non-tree vegetation, sidewalks, and parking lots were preliminarily classified as areas of canopy potential (Figure 1), able to support tree canopy and adding to the city's existing tree canopy cover. Note that areas of potential identified in this

analysis are areas where it is assumed that there is enough planting opportunity nearby to support 100% tree canopy coverage —not that a tree can be planted anywhere in this space. For example, while tree planting space is limited in sidewalks, there is enough planting opportunity both within the sidewalk and on adjacent lands that trees planted may be able to create a continuous canopy over these areas. While this is also true to a lesser extent with streets (canopy currently covers 10-15% of Portland's streets), to be conservative, streets were excluded as areas of potential with no canopy assumed to be added over these spaces from additional tree plantings. See Table 2 for a summary of areas classified as canopy potential.

Figure 1: Areas not covered by water, buildings, streets, or existing canopy are classified as canopy potential prior to the application of adjustment factors.

Table 2: Land covers and canopy potential	
Potential	**No Potential**
Pervious surfaces	Areas under tree canopy cover
Parking lots	Buildings
Sidewalks	Water
	Streets
	PDX Primary Zone

ADJUSTMENT FACTORS

Some limitations not easily identified from aerial images preclude planting in potential canopy areas. Gross canopy potential over pervious areas was reduced by an adjustment factor in order to account for sports fields, vegetable gardens, underground utilities, and other physical limitations to planting. Developing this adjustment factor for Portland would require a separate field study which is outside the scope of this report. However, this work has been done in San Jose, CA (McPherson et al. 2013), which has a similar population density to Portland and can be used as a model for this report. That study found 64% of unirrigated, bare soil to be free of such limitations; therefore, an adjustment factor of 0.64 was applied to pervious areas of potential canopy.

Surface parking lots are included as potential in this study because of the opportunity for trees to mitigate the increased stormwater runoff and urban heating associated with these areas. Portland city code requires tree planting with the development of new parking lots. Although there is no set canopy goal associated with these requirements, it is estimated that current standards would lead to 35% canopy coverage of parking lots at maturity (Bureau of Development Services 2017). Therefore, an adjustment factor of 0.35 was applied to all areas of potential canopy over surface parking lots.

TARGET GEOGRAPHIES

Geography, land use, and property ownership can each help to explain the presence or absence of tree canopy in an urban environment, as well as the limitations to the planting and preservation of trees. Using a classified map of tree canopy makes it relatively easy to analyze the data by a number of categories and determine the extent to which each is related to tree canopy and potential. This study reports canopy and potential according to geography (east or west of the Willamette River), zoning (commercial, industrial, open space, or residential), and ownership (public, private, right-of-way). Neighborhood data is included in Appendix A, and zoning categories are explained in Appendix B.

SERVICES PROVIDED BY INCREASED CANOPY COVER

Urban trees provide numerous services to city residents including improved environmental and human health, public safety, and livability. Expanding Portland's urban forest to meet some or all of its canopy potential would also increase the tree-related services that residents currently enjoy.

This study uses algorithms developed by the US Forest Service to quantify the value of air quality improvement, stormwater reduction,

and carbon sequestration that meeting some or all of Portland's canopy potential would generate (www.itreetools.org). Additionally, aesthetic and other benefits are estimated based on local and national research on the sales prices of properties with and without trees, which is a proxy for the price that the public is willing to pay to live near trees and enjoy their harder-to-quantify services, including beautification, noise reduction, privacy, wildlife habitat, and psychological well-being. Details on each of the calculations are included in Appendix B.

LIMITATIONS

This large-scale study is not meant to map specific sites for tree planting in Portland; rather, it highlights the overall pattern of planting opportunity across the city and its various zones of land use and ownership. Suitability assessment for actual planting of trees requires site inspection, which is outside the scope of this analysis.

The numbers presented in this report are meant to reflect canopy potential based on current land use, accounting for physical obstacles to planting through adjustment factors and the exclusion of Portland International Airport. This is an assessment of physical capacity for tree canopy, providing a baseline for what land is currently available for planting. A preliminary analysis of lands that are expected to experience some level of development in coming decades is included in this report's findings, however further study is required to assess how development on these lands would impact overall tree canopy and potential in Portland.

Findings

CITYWIDE CANOPY POTENTIAL

Given current land use and development, Portland could support an additional 20,886 acres of tree canopy, comprising 22.5% of Portland's total area (92,680 acres). Combined with existing canopy, total canopy potential is 52.4% (Figure 2). Canopy potential is unequally distributed across geography, zoning class, and ownership.

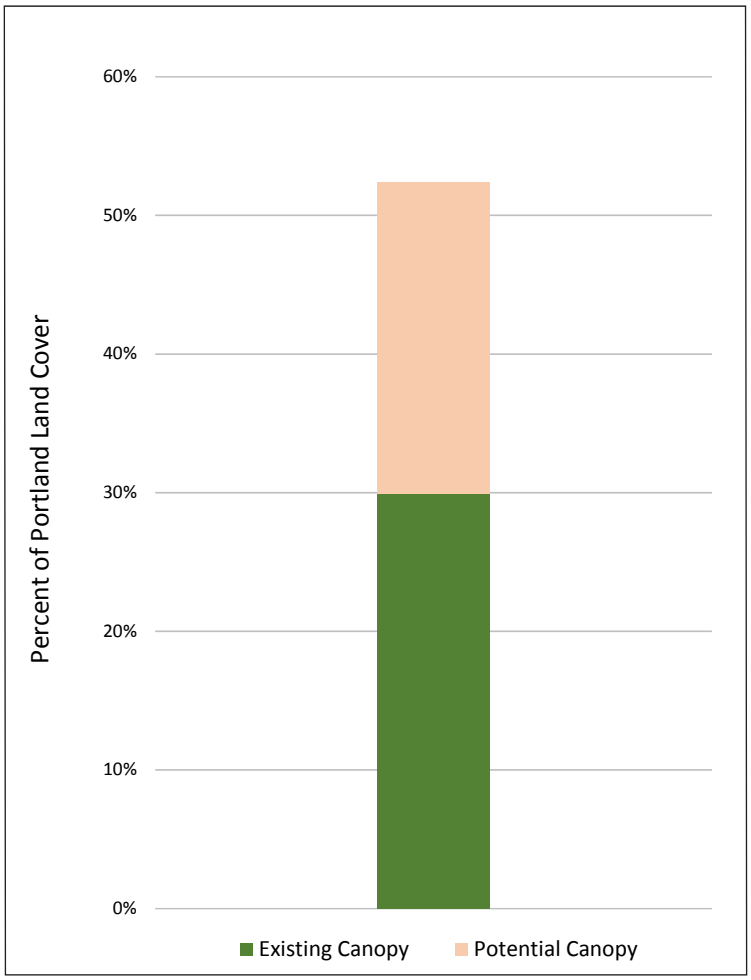

Figure 2: Existing canopy and potential total 52.4% of Portland land cover.

GEOGRAPHY

Lands east of the Willamette River in Portland contain 17,205 acres of tree canopy potential, comprising 82.4% of the city's overall potential canopy cover. Portland's west side contains 3,681 acres of tree canopy potential, comprising 17.6% of the city's overall potential canopy cover (Table 3).

Table 3: Existing canopy and potential, east and west of the Willamette River					
	Percent of Total City Area	Percent Canopy Cover (acres)	Percent of Portland's Existing Canopy	Acres of Potential Canopy	Percent of Portland's Potential Canopy
East	72.0	20.5 (13,661)	49.3	17,205	82.4
West	28.0	54.2 (14,053)	50.7	3,681	17.6

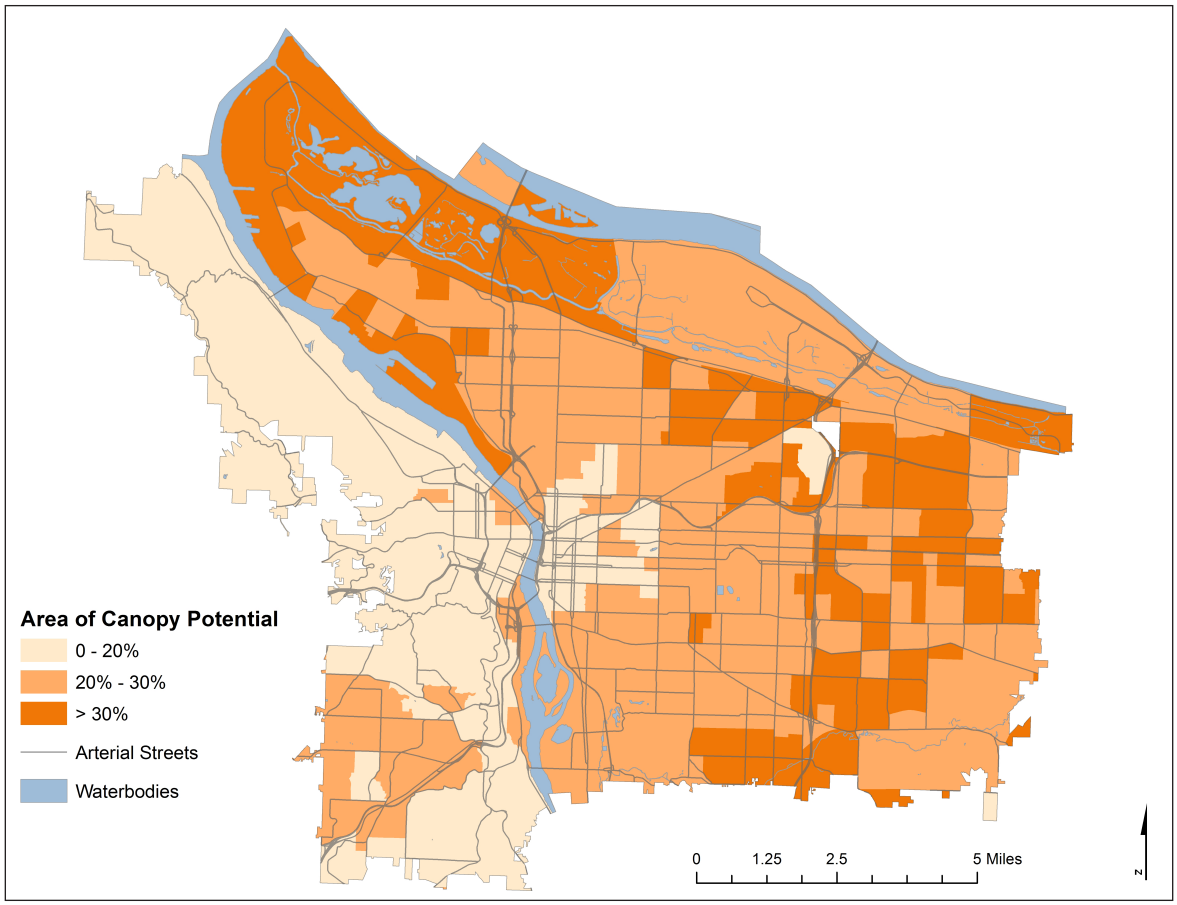

Figure 3: Canopy potential in Portland census block groups, as proportion of land area

ZONING

Residential areas contain the majority (53.9%) of Portland's canopy potential. Industrial areas contain 24.8% of Portland's canopy potential, and open space and commercial zones contain 13.8% and 7.3% of Portland's canopy potential, respectively (Table 4, Figure 4). See Appendix B for an explanation of zoning categories.

Table 4: Existing canopy and potential, by zoning class

Zoning Class	Percent of Total City Area	Percent Canopy Cover (acres)	Percent of Portland Canopy	Acres of Potential Canopy	Percent of Portland Potential Canopy
Commercial	7.9	13.0 (877)	3.2	1,534	7.3
Industrial	20.8	8.5 (1,516)	5.5	5,182	24.8
Open Space	18.3	63.7 (10,001)	36.1	2,888	13.8
Residential	53.1	33.5 (15,242)	55.0	11,267	53.9

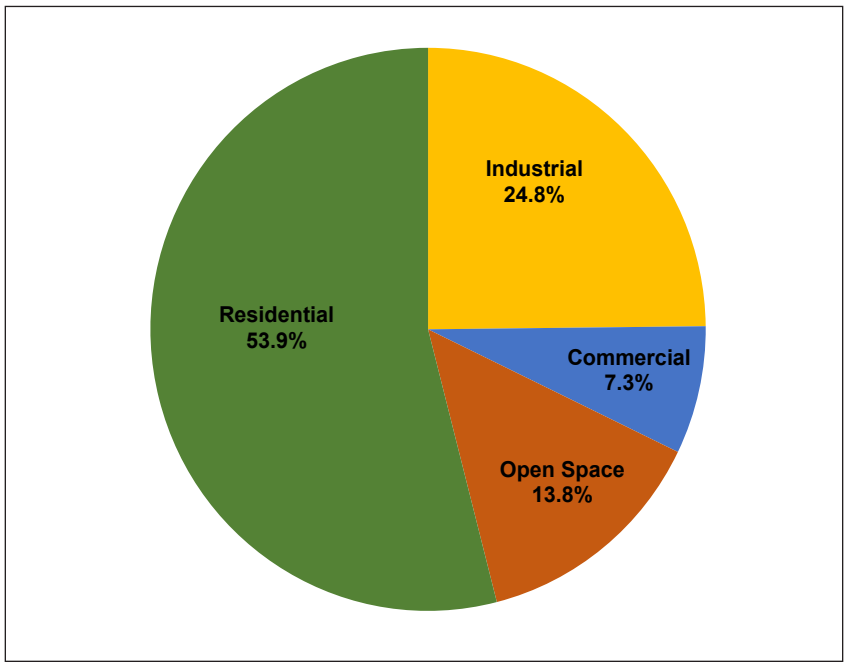

Figure 4: Proportion of citywide canopy potential, by zoning class

Proportions of land area identified as potential canopy varied across zones, ranging from 18.4% of total area in open space zones to 29.2% of industrial zones (Figure 5, Table 5). Total canopy potential, including existing and potential canopy, ranged from 35.8% in commercial zones to 82.1% percent in open space zones.

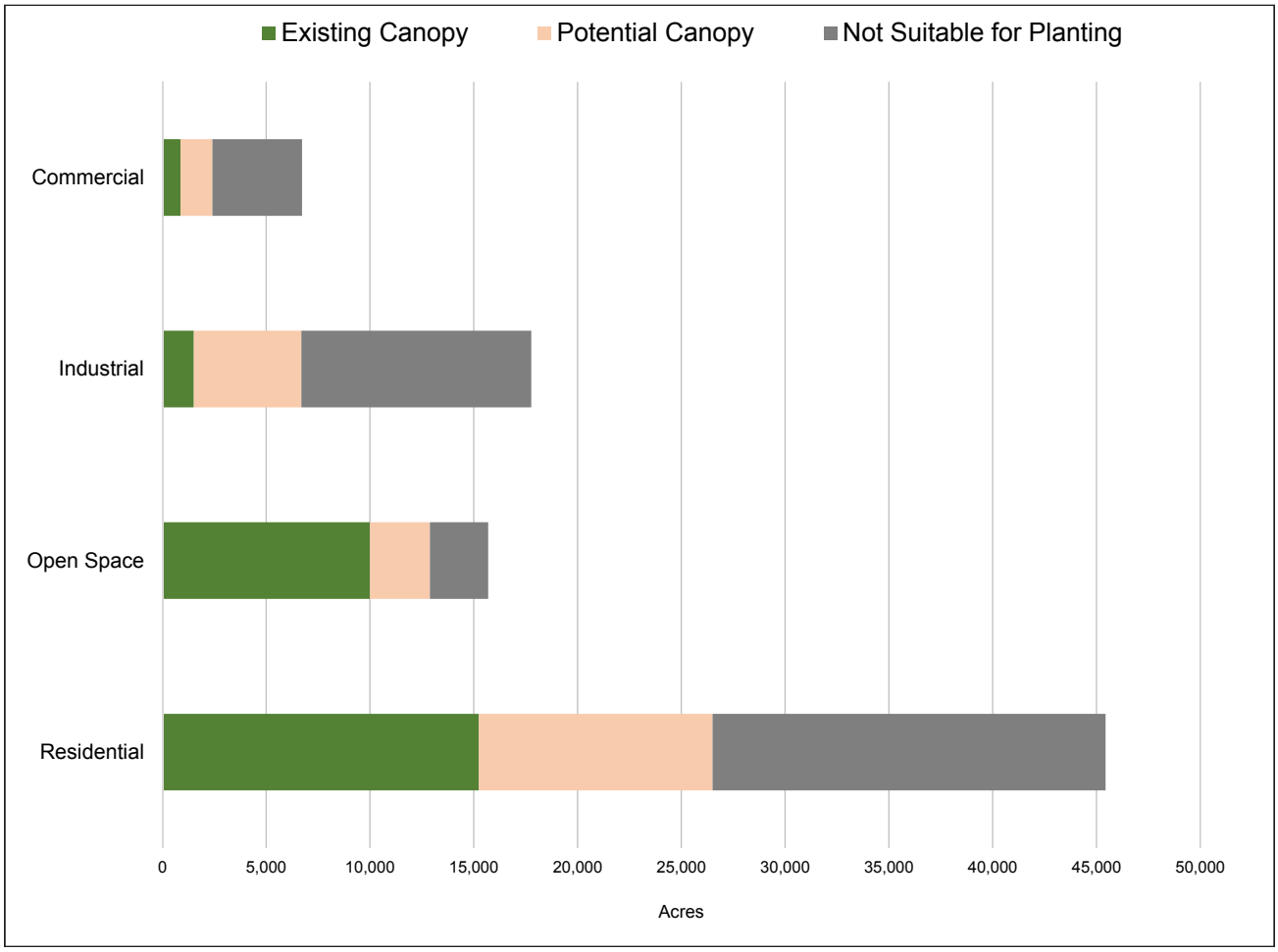

Figure 5: Existing, potential, and unsuitable canopy area, by zone

Table 5: Potential and unsuitable canopy area, by zoning class

Zoning Class	Percent of Area Not Suitable for Planting	Percent Potential Canopy Cover	Total Potential Canopy Cover (incl. existing and potential)
Commercial	64.2	22.8	35.8
Industrial	62.3	29.2	37.3
Open Space	17.9	18.4	82.1
Residential	41.7	24.8	58.3

PROPERTY OWNERSHIP

Citywide, canopy potential is predominantly located on privately-owned lands, which contain 62.2% of canopy potential compared to public lands and rights-of-way (ROW), which hold 21.1% and 16.1%, respectively (Table 6, Figure 6).

Table 6: Existing canopy and potential, by property ownership

Ownership	Percent of Total City Area	Percent Canopy Cover (acres)	Percent of Portland Canopy	Acres of Potential Canopy	Percent of Portland Potential Canopy
Public	24.5	46.9 (9,775)	35.3	4,416	21.1
Private	56.1	29.0 (13,853)	50.0	12,987	62.2
ROW	19.4	22.2 (3,674)	13.3	3,353	16.1

ECOSYSTEM SERVICES AND OTHER BENEFITS

This analysis identifies 20,886 acres of canopy potential in the city of Portland, representing space for planting nearly 1.3 million medium-sized (30 foot diameter canopy spread) trees. Realizing even a portion of this potential would take significant investment by the City and its residents—an investment that would yield substantial returns in the form of environmental, social, and economic benefits. The value of ecosystem services of air quality improvement, carbon capture, reduced stormwater volume, as well as aesthetic and other benefits that this increased canopy represents is included in Table 7 below.

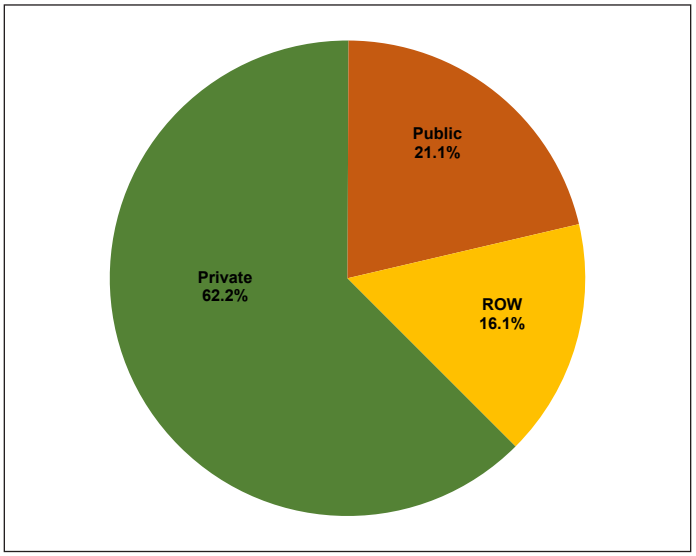

Figure 6: Proportion of citywide canopy potential, by ownership

Meeting Portland's full canopy potential would generate an estimated $197 million in services annually. The cumulative monetary value of these services over 20 years total $3.9 billion (in 2018 dollars). The annual and cumulative values of meeting the current goal of 33.3% canopy cover are $30 million and $600 million respectively. Meeting 35%, 40%, or 50% canopy cover would net between $44 and $176 million in annual services and other benefits. See Appendix B for an explanation of how these figures were calculated.

Table 7: Annual and 20-year cumulative value of meeting potential tree canopy goals						
	33.3% goal	**35% goal**	**40% goal**	**50% goal**	**All potential (52.4% canopy cover)**	
Additional Trees	195,971	291,161	576,731	1,147,872	1,287,123	
Annual Services						**Per Tree**
Air Quality	$109,743	$163,050	$322,969	$642,808	$720,789	$0.56
Carbon Capture	$378,223	$561,941	$1,113,091	$2,215,393	$2,484,147	$1.93
Stormwater	$3,441,242	$5,112,790	$10,127,400	$20,156,631	$22,601,876	$17.56
Aesthetic/Other	$26,073,811	$38,738,893	$76,733,892	$152,723,972	$171,251,281	$133.05
Total	*$30,003,020*	*$44,576,674*	*$88,297,352*	*$175,738,804*	*$197,058,092*	*$153.10*
20 year cumulative	*$600,060,400*	*$891,533,477*	*$1,765,947,047*	*$3,514,776,075*	*$3,941,161,839*	*$3,062*

Of the total service value of potential plantings, eighty-seven percent of expected are in the aesthetic/other category, primarily reflecting positive property value impacts which are a proxy for other, harder to quantify benefits such as improved mental and physical health and safety that buyers have been found to be willing to pay more to enjoy (see Appendix B for a review of this research). Of the remaining, 12 percent are from stormwater savings, 1 percent carbon capture, and less than 1 percent air quality improvement.

ACCOUNTING FOR FUTURE DEVELOPMENT

Expectations of population growth and associated development in Portland must be considered in any discussion of the capacity for long-term growth of the urban forest. Impacts of development on tree canopy and potential will vary based on current landcover, zoning and associated requirements, and the scale and intensity of development. In some cases, canopy potential will be further restricted by future development due to increased building footprints and other impervious areas causing a net loss of canopy and potential. However, in developable areas with very little existing tree canopy, the City's landscaping and tree density standards should increase tree canopy over time as these lots are developed.

The Buildable Lands Inventory (BPS 2012b) identifies vacant and underutilized lots in Portland that are expected to be developed, given market demand. An analysis of existing and potential tree canopy in these areas provides insight into how future development may impact citywide canopy over the long term.

Over 80% of Portland's tree canopy potential lies outside of lands identified in the Buildable Lands Inventory—an encouraging sign for long-term canopy growth (Table 8). However, existing canopy cover on these lands is relatively high, at 42.5% for currently vacant lots and 22.5% for non-vacant "underutilized" lots. While overall these developable lands hold just one-sixth of Portland's total tree canopy, preserving this canopy through development could be a challenge in some areas. A closer examination of the expected canopy and potential on these sites based on the nature of expected

development is necessary for creating a potential canopy estimate that takes future development into account.

Table 8: Existing canopy and potential on Buildable Lands Inventory land

	Percent of Total City Area	Percent Canopy Cover (acres)	Percent of Portland's Existing Canopy	Acres of Potential Canopy	Percent of Portland's Potential Canopy
Vacant lots	8.6	42.5 (3,369)	12.2	2,469	11.8
Non-vacant "underutilized" lots	6.1	22.5 (1,278)	4.6	1,613	7.7

Discussion

DISTRIBUTION OF CANOPY POTENTIAL

Under current land use conditions, ample space exists to meet and surpass Portland's current goal of 33.3% tree canopy cover citywide. Assuming today's land use and development, of the 20,886 acres of potential canopy identified in this report, approximately 15% (3,200 acres) needs to be realized to meet this target (Figure 7).

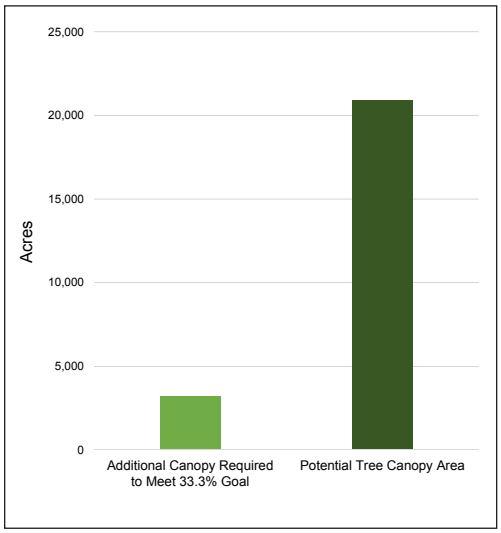

Figure 7: Additional canopy acres required to meet 33.3% canopy goal

Opportunity exists in all areas of the city, however private residential lots hold more canopy potential than any other area. As most Portlanders live in private, residential zones, these are also the areas where trees can have the greatest outcomes in terms of human health and safety, both of which have been positively linked to canopy cover in Portland (Donovan et al. 2011, Donovan and Prestemon 2012).

EQUITY AND PORTLAND'S URBAN FOREST

In addition to expanding tree canopy cover, successful urban forest management policies will also achieve greater environmental equity. Results of this analysis point towards disparities in canopy cover distribution that meeting a citywide canopy goal alone will not address. Providing equitable urban forest services for all residents will entail addressing the fact that 80% of Portland residents live east of the Willamette River, where canopy cover is just 20.5%—a lower rate than New York City or Los Angeles (Grove et al. 2006, McPherson et al. 2008). Existing and potential canopy cover vary greatly across Portland neighborhoods (see Appendix A, and Figure 8 below), and areas of potential identified in this analysis can guide continued efforts to expand Portland's urban forest in an equitable manner.

Even with more focused efforts, continued growth and development has the potential to exacerbate current canopy disparities. According to the *2035 Comprehensive Plan*, between 2015 and 2035, Portland's population is expected to increase at a rate twice as fast as was experienced from 2000-2015, with the majority of this development in areas east of the Willamette River. Tree canopy east of the Willamette River is generally less protected during development under current code, due to exemptions from tree preservation standards for lots less than 5000 ft^2—lot sizes more common on the east side. In inner neighborhoods, including Sunnyside, Richmond, and Vernon, up to 50% of current canopy is contained on private lots under 5,000 ft^2. Additionally, there is a lower proportion of land in environmental overlay zones (which have

stronger tree preservation requirements) relative to the number of lots on the east side compared to the west side.

Unequal distribution of canopy cover among Portland's neighborhoods is related to income disparities; in a recent Portland State University study, households in the top quintile of income have on average 20% more canopy than those in the bottom quintile (Voelkel 2017). Strategic focus on planting in low-income/low-canopy neighborhoods aids in reducing residents' exposure to environmental health risks, including poor air quality and excessive urban heating. Areas of potential identified in this report can help guide decisions on how to best expand canopy in these areas to realize the most benefit for residents.

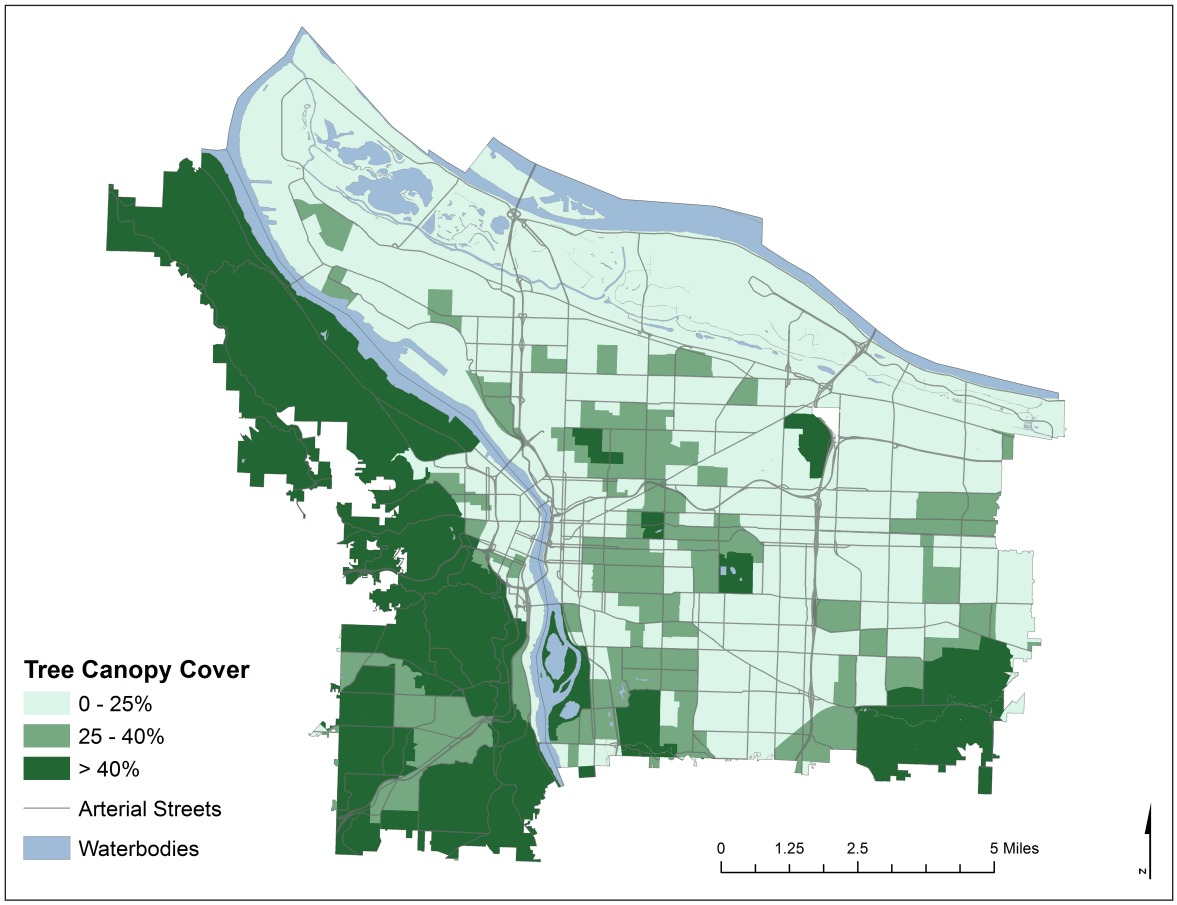

Figure 8: Existing tree canopy cover in Portland census block groups, as proportion of land area

REVISITING CANOPY GOALS

Canopy targets are useful tools to inform policy and management of the urban forest. They provide a measurable goal that encompasses many forest services including improved human health, environmental quality, and economic growth. This report is part of ongoing efforts by PP&R to monitor urban forest canopy trends to aid in adaptive management of the urban forest to extend these services to all Portland residents. The current canopy cover target of 33.3% is an average based on goals set for urban land environments (ULEs) in the 2004 Urban Forest Management Plan. These targets have been

useful guides for planting and management efforts over the past decade, but are now outdated as they are based on a 2002 canopy classification and on land use categories that may include up to 20% classification error (PP&R 2009).

Portland's current canopy goal of 33.3% canopy cover by the year 2035 may be reasonable for that timeframe, however this report demonstrates canopy cover could be higher in Portland over the long term. Revision to canopy goals within the upcoming update to the Urban Forest Management Plan should consider a longer timeframe that accounts for development projections and urban forest needs of residents, providing direction for long term forest management.

In isolation, a single citywide canopy goal can obscure local disparities in canopy cover and its associated benefits. Currently, enough potential exists in high-canopy areas of the city to meet the 33.3% target, and studies have shown that planting is often easiest in these areas, where residents know well the benefits that trees provide and often have the resources to maintain them (Locke and Grove 2014, Donovan and Mills 2014). Meeting Portland's canopy goal in this manner would be a failure in building a forest that serves all residents. The 2015 *Climate Action Plan* attempts to address this potential inequity by suggesting a 25% minimum canopy goal for all residential neighborhoods. Raising the overall canopy target for the city and updating minimum neighborhood goals based on this study's findings will ensure that urban forest canopy continues to expand in an equitable manner.

FUTURE STUDY

Continued efforts to monitor trends in canopy and potential provide an important guide for adaptive management of the urban forest. As new information becomes available, PP&R will update estimates of canopy and potential. The next canopy measurement based on the protocol outlined in the 2017 *Tree Canopy Monitoring Report* will begin in 2021. Updates to the canopy classification used in this study are expected approximately every 5 years, with the next classification planned for 2020.

The adjustment factors used in this study are an attempt to account for physical obstacles to tree planting in areas otherwise capable of supporting tree canopy. A point sampling survey of obstacles within open, pervious land cover in Portland would result in an adjustment factor based on the city's unique land cover.

This report includes a preliminary look at canopy and potential on lands expected to be developed in coming decades. Further analysis is required

before estimating the impact of that development on overall tree canopy and potential in Portland, as the nature of development will vary according to zoning type.

Neither this study nor the 2017 *Tree Canopy Monitoring Report* provide detail on the trees that make up Portland's urban forest. Understanding forest composition, including the species, size, and condition of Portland's trees, provides important information that can be used to increase the resiliency of the urban forest. PP&R's Tree Inventory Project continues to provide this information for important subsets of the urban forest, completing an inventory of all street trees in 2016, and an inventory of park trees scheduled for completion in 2019. A sample-based inventory of private lands, which hold the majority of Portland's tree canopy and potential, is scheduled for Summer 2018 in partnership with the US Forest Service. Once baseline inventories are complete, regular updates to inventories across all property types will be essential to future urban forest management and planning.

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Appendix A: Canopy and Potential, by Neighborhood

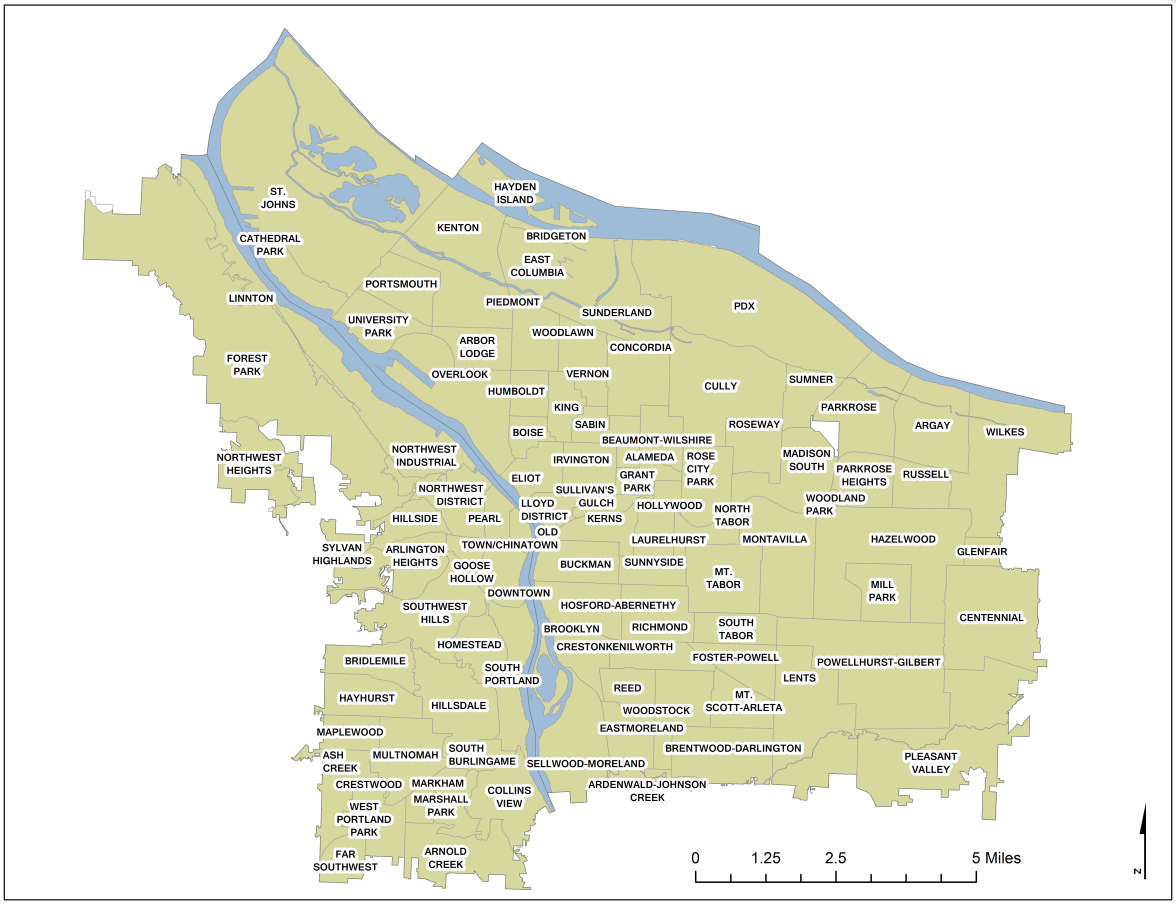

Figure 9: Map of Portland neighborhoods

Appendix A

Neighborhood	Canopy %	Potential %	% of PC in residential	% of PC in industrial	% of PC in commercial	% of PC in OS
Alameda	30.3%	23.1%	99.6%	0.0%	0.4%	0.0%
Arbor Lodge	18.2%	29.1%	82.9%	0.0%	10.1%	7.1%
Ardenwald-Johnson Creek	37.9%	22.5%	61.3%	28.7%	2.6%	7.5%
Argay	12.8%	31.9%	44.3%	47.4%	3.1%	5.2%
Arlington Heights	70.0%	11.7%	19.8%	0.0%	0.0%	80.2%
Arnold Creek	71.5%	12.3%	97.2%	0.0%	0.0%	2.8%
Ash Creek	45.1%	21.1%	95.5%	0.0%	4.3%	0.2%
Beaumont-Wilshire	25.8%	27.4%	95.7%	0.0%	1.9%	2.4%
Boise	21.1%	23.9%	62.6%	11.8%	18.6%	7.0%
Brentwood-Darlington	22.5%	31.2%	86.0%	3.0%	2.4%	8.6%
Bridgeton	16.7%	37.6%	11.4%	0.2%	81.7%	6.8%
Bridlemile	48.1%	19.8%	88.6%	0.0%	4.1%	7.3%
Brooklyn	24.9%	26.7%	19.2%	43.9%	8.1%	28.8%
Buckman	18.5%	17.4%	42.7%	34.5%	10.7%	12.2%
Cathedral Park	22.6%	30.0%	42.9%	36.3%	6.9%	13.9%
Centennial	22.5%	29.9%	89.0%	0.0%	6.3%	4.7%
Collins View	62.6%	16.6%	63.4%	0.0%	0.5%	36.2%
Concordia	20.5%	29.2%	82.2%	8.9%	3.6%	5.3%
Creston-Kenilworth	23.7%	24.6%	81.8%	0.0%	13.8%	4.4%
Crestwood	57.8%	15.8%	81.5%	0.0%	2.5%	16.0%
Cully	19.2%	32.2%	49.4%	32.8%	2.7%	15.1%
Downtown	17.5%	15.7%	10.8%	0.1%	75.8%	13.2%
East Columbia	15.8%	38.4%	15.8%	54.9%	2.3%	27.0%
Eastmoreland	41.9%	25.3%	52.0%	0.0%	0.2%	47.8%
Eliot	16.8%	22.8%	31.4%	33.5%	31.8%	3.3%
Far Southwest	47.6%	19.2%	57.5%	0.0%	42.2%	0.3%
Forest Park	91.8%	4.3%	62.7%	0.5%	0.3%	36.5%
Foster-Powell	19.3%	27.9%	79.9%	0.0%	16.2%	3.9%
Glenfair	25.7%	29.6%	90.7%	0.0%	4.8%	4.5%
Goose Hollow	24.5%	16.5%	45.5%	0.0%	46.3%	8.2%
Grant Park	31.7%	23.7%	86.0%	0.0%	3.4%	10.6%
Hayden Island	14.4%	29.9%	29.2%	21.5%	48.8%	0.5%
Hayhurst	41.4%	23.5%	96.0%	0.0%	2.4%	1.7%
Hazelwood	20.2%	31.1%	64.2%	2.1%	16.5%	17.2%
Hillsdale	47.0%	19.2%	89.6%	0.0%	6.5%	3.8%
Hillside	65.9%	11.3%	91.1%	0.0%	2.2%	6.7%
Hollywood	15.2%	22.1%	36.4%	0.1%	63.2%	0.2%
Homestead	70.3%	8.7%	46.9%	36.8%	4.9%	11.4%
Hosford-Abernethy	19.7%	21.8%	55.6%	38.1%	4.8%	1.5%

Neighborhood	Canopy %	Potential %	% of PC in residential	% of PC in industrial	% of PC in commercial	% of PC in OS
Humboldt	20.6%	25.5%	79.0%	0.0%	17.0%	3.9%
Irvington	37.2%	19.2%	90.8%	0.3%	2.9%	6.0%
Kenton	16.8%	32.7%	22.2%	29.7%	1.6%	46.5%
Kerns	18.8%	18.5%	41.0%	18.2%	31.3%	9.6%
King	20.7%	25.1%	79.4%	0.0%	18.6%	2.0%
Laurelhurst	38.2%	19.6%	88.7%	0.0%	4.4%	6.9%
Lents	22.2%	30.7%	56.4%	14.3%	11.0%	18.4%
Linnton	40.6%	25.5%	17.3%	76.4%	1.8%	4.4%
Lloyd District	11.2%	18.3%	0.0%	11.6%	86.9%	1.4%
Madison South	32.4%	28.2%	53.6%	10.5%	4.6%	31.3%
Maplewood	48.6%	21.1%	96.5%	0.0%	1.0%	2.6%
Markham	44.5%	20.6%	99.8%	0.0%	0.1%	0.1%
Marshall Park	68.5%	12.9%	98.1%	0.0%	0.0%	1.9%
Mill Park	21.4%	28.9%	83.1%	0.0%	11.8%	5.1%
Montavilla	18.8%	28.4%	75.8%	3.4%	12.3%	8.6%
Mt. Scott-Arleta	20.3%	27.8%	87.1%	0.0%	10.3%	2.6%
Mt. Tabor	34.4%	23.1%	84.6%	0.0%	2.1%	13.3%
Multnomah	36.1%	24.3%	66.9%	0.8%	16.2%	16.1%
North Tabor	22.9%	23.2%	84.4%	0.5%	14.6%	0.5%
Northwest District	23.0%	18.2%	46.3%	24.9%	26.8%	2.0%
Northwest Heights	51.8%	17.3%	98.5%	0.0%	0.6%	0.9%
Northwest Industrial	4.2%	30.8%	0.0%	99.9%	0.0%	0.1%
Old Town/Chinatown	13.0%	19.3%	13.1%	0.0%	71.2%	15.7%
Overlook	16.0%	28.8%	21.4%	66.2%	5.1%	7.4%
Parkrose	16.7%	30.8%	43.0%	44.7%	10.5%	1.8%
Parkrose Heights	21.9%	30.2%	91.1%	0.0%	3.9%	5.0%
PDX	4.0%	15.1%	0.2%	97.1%	0.1%	2.7%
Pearl	8.3%	17.4%	0.0%	87.9%	6.2%	5.9%
Piedmont	18.9%	28.1%	69.5%	16.4%	3.5%	10.6%
Pleasant Valley	53.9%	23.2%	53.0%	0.4%	1.4%	45.2%
Portsmouth	25.0%	28.1%	77.6%	8.0%	4.1%	10.3%
Powellhurst-Gilbert	25.4%	30.5%	80.7%	4.1%	7.0%	8.2%
Reed	27.7%	23.1%	83.8%	14.8%	1.5%	0.0%
Richmond	27.0%	22.7%	87.9%	0.2%	10.7%	1.1%
Rose City Park	22.2%	26.9%	80.6%	6.8%	5.3%	7.3%
Roseway	18.9%	31.2%	86.4%	0.0%	5.6%	7.9%
Russell	20.2%	31.1%	88.7%	0.0%	6.7%	4.6%
Sabin	27.7%	24.2%	97.8%	0.0%	2.2%	0.0%
Sellwood-Moreland	31.4%	22.9%	67.4%	1.4%	10.6%	20.6%

Neighborhood	Canopy %	Potential %	% of PC in residential	% of PC in industrial	% of PC in commercial	% of PC in OS
South Burlingame	43.7%	18.3%	86.3%	0.0%	2.9%	10.7%
South Portland	26.5%	22.5%	43.0%	0.0%	47.8%	9.2%
South Tabor	21.8%	28.1%	85.9%	0.0%	8.3%	5.8%
Southwest Hills	62.5%	12.9%	92.3%	0.0%	1.0%	6.7%
St. Johns	18.5%	35.5%	11.2%	67.7%	0.9%	20.3%
Sullivan'S Gulch	24.2%	22.2%	50.5%	8.7%	37.5%	3.3%
Sumner	18.5%	27.2%	41.7%	54.4%	3.8%	0.1%
Sunderland	17.6%	35.9%	1.7%	65.6%	0.0%	32.8%
Sunnyside	26.2%	20.5%	82.3%	0.0%	16.3%	1.3%
Sylvan Highlands	60.2%	15.0%	54.9%	7.2%	5.8%	32.0%
University Park	23.5%	32.7%	78.1%	15.2%	2.7%	3.9%
Vernon	22.1%	27.2%	81.0%	0.0%	7.3%	11.7%
West Portland Park	39.1%	21.3%	67.5%	0.0%	12.0%	20.5%
Wilkes	23.3%	30.3%	45.0%	45.4%	1.1%	8.5%
Woodland Park	32.4%	23.7%	96.7%	3.3%	0.0%	0.0%
Woodlawn	17.9%	28.6%	71.7%	19.2%	6.3%	2.8%
Woodstock	25.7%	26.3%	92.8%	0.0%	4.7%	2.5%

Appendix B: Methods

CANOPY COVER

This study does not include canopy cover estimates developed in the 2017 *Tree Canopy Monitoring Report*, which used visual point interpretation to estimate canopy extent and did not result in an updated map of tree canopy cover—a necessary component for calculating canopy potential. Estimates of existing canopy included in this study are based on Metro's 2014 land cover classification, which was produced using a different method, and cannot be directly compared to the 2017 report's findings.

ZONING CATEGORIES

Zoning categories for this study are based on the zoning map adopted as part of the *2035 Comprehensive Plan*. While additional refinement to the zoning map is expected in early 2018, zones used in this analysis reflect changes to the map expected to take effect in May 2018, which will guide development in the City for the remainder of the Plan. See Table 9 below for an explanation of how individual zones were categorized into the four aggregations used in this analysis.

Table 9: Zoning class categorization

Commercial	Industrial	Open Space	Residential	
			Low Density	*High Density*
CI2 CM1 CM2 CM3 CE CR CX	EG1 EG2 EX IG1 IG2 IH	OS	RF R20 R10 R7 R5 R2.5	R3 R2 R1 RH RX IR CI1

ECOSYSTEM SERVICES AND OTHER BENEFITS

Benefit calculations assume no net change in existing tree canopy, attributing all canopy increases to the planting of 1.5" diameter, medium form, broadleaf deciduous trees. Ecosystem service totals are based on the annual services that trees would provide over 20 years of growth (McPherson et al. 2002). Aesthetic and other benefits are based on Portland's median home value as of December 20, 2017 (Zillow 2017). For a full summary of values used in this study, see Table 10.

Ecosystem Services

Air Quality

Trees intercept and absorb air pollutants on their leaf surfaces. Their ability to do so is based on tree size and species, which together determine total leaf surface area. The average yearly monetary value of the removal of ozone, nitrogen dioxide, sulfur dioxide, and particulate matter less than 10 microns (PM_{10}) were calculated based on hourly deposition rates, pollutant concentrations, and meteorological data for a regional reference city (McPherson et al. 2002) and current prices (see Table 8), using a common medium sized tree, Norway maple, as a model for potential plantings. Net calculated air quality benefits were reduced to account for estimated annual emissions of biogenic volatile organic compounds (BVOCs) (Guenther et al. 1993).

Carbon Sequestration

Trees store carbon from the atmosphere in their biomass, which has the effect of reducing overall atmospheric carbon dioxide, a pollutant linked to global climate change. The monetary value of this service was calculated using species-based biomass equations (Pillsbury et al.1998) and the Environmental Protection Agency's estimate of the social cost of carbon (IWG 2010).

Stormwater Reduction

Trees reduce the amount of rain that enters the stormwater system by intercepting precipitation with their foliage, which reduces water treatment costs. As with the interception of air quality pollutants, a tree's ability to provide this service is a function of its leaf surface area, with large and evergreen trees providing the most benefits. Stormwater reductions and associated savings were calculated based on leaf area, canopy area, water depth (Xiao et al. 2000), local meteorological data, and the avoided cost of stormwater processing, valued at $.02779/gallon (McPherson et al 2002).

Aesthetic and Other Benefits

Aesthetic and other benefits were calculated as the increase in property sales price attributable to the presence of trees on site. Potential tree planting sites in rights-of-way adjoining low-density residential zones were each priced at 3% of the median home value for Portland, based on Donovan and Butry's (2010) finding that street trees contribute a 3% increase in sales price of Portland single family homes.

Prices for all other potential trees were based on Anderson and Cordell's (1988) finding that large front yard trees increase single family home sale values by 0.88%. In order to be conservative, and to acknowledge that trees elsewhere in the yard might contribute less to overall sales price increases, reduction factors were applied to areas outside single family residential rights-of-way (McPherson et al. 2008). Potential planting sites in low-density residential zones outside the right-of-way were each valued at 70% of this total, and all sites in all other zones were valued at 40%.

To estimate annual benefits, values were divided by leaf surface area of a 20-year-old medium-sized tree (4,770ft^2) and multiplied by average annual growth of leaf surface area over that time period (McPherson et al. 2013).

Table 10: Ecosystem service values		
Service Type	**Service Value**	**Unit**
Ecosystem Services		
Air Quality		
O_3	$2.40	lb.
VOC	$6.65	lb.
NO_2	$2.40	lb.
SO_2	$1.00	lb.
PM_{10}	$2.72	lb.
Carbon	$0.00969	lb.
Stormwater	$0.02779	gallon
Aesthetic/Other Benefits		
low density residential ROW	$608.25	tree
low density res. Non-ROW	$124.89	tree
all other	$71.37	tree