# Progress Report on Metro Parks Tacoma's Tree Canopy Cover Plan

## Submitted as partial fulfillment of a Master of Science in Geospatial Technologies

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## Abstract

A robust urban tree canopy is essential to the health of the city of Tacoma. Research shows it provides myriad benefits ranging across environmental, economic and social spectra. Metro Parks Tacoma (MPT) manages the majority of Tacoma's urban forest and is actively increasing its overall tree canopy coverage. Currently midway through a 20-year Canopy Cover Plan, MPT has a tree canopy coverage goal of 66 percent by the year 2030. MPT asked the University of Washington, Tacoma's Geospatial Technologies program to help analyze raw LiDAR data with three goals: measure the change in tree canopy coverage over time to verify that MPT is on track, identify areas of most and least growth over time, and combine LiDAR with NDVI data to identify areas of potential for rapid increase in the tree canopy. These analyses are provided in a publicly accessible format that may be repeated with future LiDAR captures of Tacoma. This study found MPT parks had a 61 percent tree canopy cover as of 2017 and MPT is on track to meet their goals well ahead of schedule. Using these results, MPT may better position itself within the current uncertain economic climate to increase its tree canopy coverage funding and planning and help the city of Tacoma achieve its overarching urban forest goals.

## 1. Introduction

A robust urban tree canopy is essential to the health of Tacoma. Research shows its benefits range across environmental, economic and social spectra. However, Tacoma has the least tree canopy coverage of any city in the Puget Sound region, which is experiencing an overall decline in tree canopy coverage due to development. The City of Tacoma is proactively increasing its urban tree canopy from 20 to 30 percent by the year 2030 with a plan, dubbed the *30-by-30 Initiative*, that includes equitable distribution, public-private partnerships, and transparent data capture (One Tacoma: Comprehensive Plan – Urban Forest Policy Element 2010; Urban Forest Management Action Plan 2019). As the manager of the largest public urban forest in the city, Metro Parks Tacoma (MPT) has its own plan to support the city's overarching goal. Through independent forestry management, tracking and reporting, MPT set a goal in 2012 to increase the tree canopy cover in MPT parks to 66 percent by the year 2030. (This goal excludes the 723-acre Northwest Trek Wildlife Park in nearby Eatonville.) The plan includes tree canopy cover goals specific to each park. While some parks are expected to reduce their tree canopy cover, most parks will increase their canopy coverage for a net result of 66 percent tree canopy cover by the year 2030 (Metro Parks Tacoma Urban Forestry Program Canopy Cover Plan 2012).

This study provides a crucial mid-term report on MPT's progress. Only through continuous observation and adjustment will MPT be able to reach its final goals. This study analyzed Light

Detection and Ranging (LiDAR) data and Normalized Difference Vegetation Index (NDVI) data derived from National Agriculture Imagery Program (NAIP) photographs to answer four research questions:

1. What are the current tree canopy coverage percentages of MPT properties? By identifying and comparing the current tree canopy coverage with that of six years prior, this study ascertains where MPT is and is not on track to meet its goals by 2030.
2. Where are the tree canopies growing most and least quickly? This study identifies which parks are on track to meet their individual goals. Is also points out what areas may fall short of their goals to help MPT prioritize its forestry management.
3. Where would new tree canopies grow the most quickly? By pinpointing areas for potentially rapid tree canopy growth, this study may help MPT meet its goals for areas not already projected to do so.
4. Are Tacoma residents enjoying uniform benefits from this effort? This study compares the Canopy Cover Plan with the Tacoma Equity/Opportunity Index to ensure all populations are fully represented. The Tacoma Equity/Opportunity Index maps obstacles to upward mobility by spatially representing 20 indicators under Tacoma's strategic goals of accessibility, education, economy and livability. The city compiled the Index to facilitate data-driven decisions that better distribute resources and services to minimize inequities and maximize opportunities (OEHR).

A secondary goal of this study is to establish a transparent and repeatable process for conducting future analyses. MPT should feel comfortable stating whether they have met their goals in 2030 with a consistent, in-house GIS process. This study provides MPT a tool that can analyze future data captures to provide consistent results for each of the 84 parks observed in the study.

## 2. Literature Review

These research questions explore the current tree canopy cover percentages of MPT parks. By comparing 2017 data to a 2011 baseline, it provides a progress report on MPT's 20-year plan to increase its overall tree canopy coverage. This simple spot check on an existing plan invites a literature review of similar studies that fall into three broad categories: the value of a healthy urban tree canopy, the methodology of tracking urban tree canopy growth, and social considerations inherent in city-wide planning. The importance of a healthy urban tree canopy drives the ongoing Tree Canopy Cover Plan including this progress report of its effectiveness. Methodology plays a dominant role in this study as several approaches are used to answer similar questions. This "how-to" theme is further broken into three areas: the technical approach chosen for remote sensing, the software used to analyze raw data, and considerations for future data captures that could reduce the burden of developing future progress or final reports. Less dominant in the literature, but of great importance, is a cautionary plea for considering the social implications when approaching this and any urban planning study.

### 2.1 The importance of maintaining a healthy urban tree canopy

Worldwide, urban pollution contributes to 6.6 million premature deaths per year and the urban heat island effect attributes to 250,000 deaths per year. A vibrant urban tree canopy is the best green space solution to counter these issues (Vieira *et al*. 2018). Two studies of urban tree canopies by Brun *et al*. (2016) and Livesley *et al*. (2016) show benefits that span environmental, economic and social spheres. Environmentally, canopy shade helps to cool the city during the summer and the tree infrastructure reduces wind chill during the winter. Specific to cities, tree canopies counter the heat island effect exacerbated by increasingly dangerous heat waves brought on by climate change. Tree canopies reduce pollution – including particulate matter in the air, waste found in storm water runoff, and contaminants in the soil. These benefits provide carbon offsets in the form of utility savings and carbon storage in each tree (Brun, Daniels and Kohlhauff 2016; Livesley, Mcpherson and Calfapietra 2016). The Brun *et al*. (2016) study notes that economically, a healthy urban tree canopy increases real estate value. It increases business district value by 10 percent by encouraging shoppers to linger. It even cuts the resurfacing costs of streets by over half by reducing the harmful effects of direct sunlight. Socially, trees benefit both the mental health and crime and public safety fields. They improve road safety and reduce residents' exposure to ultraviolet light (Brun, Daniels and Kohlhauff 2016).

The urban tree canopies throughout Puget Sound are declining rapidly due to development, and Tacoma has the lowest current canopy cover percentage in the region (One Tacoma: Comprehensive Plan – Urban Forest Policy Element 2010; Urban Forest Management Action Plan 2019). MPT set a goal in 2012 to increase its tree canopy cover to 66 percent by the year 2030. This plan covers 84 separate parks totaling over 2,000 acres (Metro Parks Tacoma Urban Forestry Program Canopy Cover Plan 2012).

### 2.2 Methodology of tracking urban tree canopy growth

Integral to expanding the urban tree canopy across any city is knowing the canopy baseline and conducting regular surveys to track progress. The baseline study for MPT's Tree Canopy Cover Plan was conducted in 2011, based on NAIP imagery taken in 2009. This baseline study commented on the difficulties in using previous data that was collected inconsistently with the 2009 data (Moskal, Styers and Kirsh 2011). For this progress report, MPT provided LiDAR data from a survey taken in 2017. This collection was part of a watershed study and not as a direct follow-up to the 2009 capture (Gleason 2019). The anticipated complications associated with studying disparate data introduced a secondary goal for this study. The intent was to not merely create a progress report but to create a repeatable mechanism that will provide MPT consistent reports throughout the life of the Tree Canopy Cover Plan and beyond. After a review of the literature, providing this tool required three methodological emphases: standardizing the remote sensing package as much as possible, developing software that can correct for different data collections during analysis, and considering alternate data collection strategies developed by similar studies.

Standardizing the remote sensing package may be problematic since MPT has used LiDAR data from multiple sources (Moskal, Styers and Kirsh 2011; Urban Tree Canopy Assessment 2018). However, there is consensus that combining vegetation photographic imagery with LiDAR provides the most accurate multi-dimensional data on forest conditions. Worldwide, forests have been accurately studied with varieties of Landsat data augmented with LiDAR data to confirm tree canopy heights (Caughlin *et al.* 2020; Larue *et al.* 2018; O'Neil-Dunne 2019; Parmehr, Amati and Fraser 2016; Recanatesi, Giuliani and Ripa 2018; Schlund Erasmi and Scipal 2020; Snavely *et al.* 2019). The approach used by the University of Washington in 2011 for the City of Tacoma included National Agricultural Imagery Program (NAIP) photography and Puget Sound LiDAR Consortium data. Object Based Image Analysis (OBIA) was applied to develop Land Use, Land Cover (LULC) classifications that MPT applied to their study a year later (Moskal, Styers and Kirsh 2011; Metro Parks Tacoma Urban Forestry Program Canopy Cover Plan 2012). A very similar approach was applied to the City of Tacoma's Urban Tree Canopy Assessment in 2018 using NAIP data and the 2017 LiDAR capture from Washington State Department of Natural

Resources (Urban Tree Canopy Assessment 2018). The City's assessment provided an effective control group to compare with MPT-specific results.

Developing a software package that analyzes MPT's tree canopy cover addressed two goals. In the short term, it provides MPT a progress report on the effectiveness of their initiative over its first six years. For the long run, it provides MPT the ability to systematically generate consistent reports, in-house, as data comes available. (The internal workings of the 2012 report were lost due to personnel changes and time, requiring this study to start from scratch.) Developing a software model provides flexibility, transparency, and longevity to the study, tailored to MPT's needs while removing the learning curve of off-the-shelf GIS software. Subsequent coders may change the software to comply with future demands (Brunsdon and Comber 2019).

Studies have found alternative approaches that depend less on aerial LiDAR captures to be accurate for long-term studies of tree canopies (Ren *et al.* 2017; Shimizu, Ota, Mizoue and Saito 2020; Staben, Lucieer and Scarth 2018). This may help MPT to shift its data collection approach from applying unrelated, outside data to their program to a more forward looking, predictive model. Technological innovation may provide alternative options for future data captures. By staying abreast of articles in the field, MPT may find accurate means to conduct future data collections that are less dependent on state or regional aerial LiDAR captures. As satellite imagery improves, future progress reports may no longer need LiDAR augmentation (Li, Wang and Jiang 2020; Wooster, Smith and Drake 2016). Land-based laser scanning may be a more economical and consistent option, especially given the relatively small sample area of MPT properties (Disney *et al.* 2018; Pfeiffer *et al.* 2018). Other options include maintaining a detailed database of MPT's trees over its 2,000 acres inside the city limits. Advances in LiDAR have made it possible to define the shape of tree crowns and account for the slope of land that would greatly benefit such a complex record (Nie *et al.* 2019). Of more immediate importance, a study on uncalibrated LiDAR may help develop a software package that accounts for LiDAR captures from different sources for consistently accurate findings (Okhrimenko and Hopkinson 2019).

### 2.3 Social considerations inherent in city-wide planning

Trees are found to provide the best benefits over other green spaces when it comes to improving local climate and air quality. Are all residents being afforded the same environmental protections from pollutions and heat islands (Vieira *et al.* 2018)? There are social justice implications to most city planning efforts, which this study endeavored to keep in mind. Simply comparing findings to the Tacoma Equity/Opportunity Index wasn't enough. Critical questions such as "Who is missing, and how would their presence alter my efforts?" are necessary (Thatcher *et al.* 2016). Beyond the immediate goals of this progress report are the residents of Tacoma who are looking to municipal governments to provide critical services. Those benefits discussed in the importance of health urban tree canopies are deserved by all of Tacoma's populations (Brun, Daniels and Kohlhauff 2016; Livesley, Mcpherson and Calfapietra 2016).

The City of Tacoma's Urban Forests Management Action Plan demonstrates a strong commitment to equity and community outreach. Both are built into several levels of its six goals. In fact, Goal 6 (2019: 32) states, "Sustainable urban forest management and equity is achieved through a partnership with the City and its residents resulting in improved well-being, human health outcomes, and stronger local economies."

With a Critical GIS approach, this study uses open-source data and thorough documentation to ensure it is reproducible and replicable. Current and future GIS engineers should have all the data necessary to confirm these findings (Brunsdon and Comber 2020). A simple tool for future data captures will allow MPT to confirm they are on track to or have completed their goals in expanding the public urban tree canopy by the year 2030. Finally, this study hopes to impress upon Metro Parks Tacoma the closing words of Drs. Livesley, McPhereson and Calfapietra (2016: 123):

> The urban forest can play a significant role in making our towns and cities more livable and better adapted to the rigors we expect from a changing climate. But to do this, and to make it a policy, planning, and public reality, urban forest research needs to embrace transdisciplinary approaches and find ways to better communicate the scientific evidence to a nonscientific audience.

## 3. GIS Based Analyses

Answering MPT's research questions resulted in a progress report on their 2012 Tree Canopy Cover Plan presented as a white paper and an interactive Web map. Overall effectiveness of the plan is outlined in Figure 1, Linear Projection of MPT Tree Canopy Cover Percentages. Assessments of each park's progress and forecasted results against their goals are presented in Tables 1 through 3. This assessment shows which parks are not on track to reach their goals including the predicted shortfalls by area. This will allow MPT's arborist to concentrate on larger deficits to maximize results. The interactive Web map provides tree canopy coverage and NDVI imagery of all the parks in the study. MPT may scale the interactive features to help identify areas for increased efforts towards meeting each park's goals. The social justice component is summarized in Table 4. Physical layouts of the Index in relation to parks can be viewed on the Web map with a sample in Figure 4. Finally, a tool for simplifying future tree canopy cover analyses is available for download from the Web site.

## 4. Methods

This study provides an important progress report on MPT's Canopy Cover Plan with a means to consistently measure future data collections. Methodology fell into three sections: data collection and management, operations to answer the research questions, and developing a means to repeat this study going forward.

### 4.1 Data collection and management

Primary data for this study were LiDAR collections and 4-band, NAIP aerial imagery from two time periods – 2011 and 2017. Secondary data included three shapefiles: park boundaries, building footprints, and the Tacoma Equity/Opportunity Index.

Primary data were provided by the City of Tacoma's GIS Analysis and Data Services (GADS) division. These were the basis for the city's *30 by 30 Initiative* urban forest tree canopy assessment. However, both sets of data were clipped to the city limits and omitted four parks managed by MPT that reside in an unincorporated area on Brown's Point. Original source material was available online. The full LiDAR captures for 2011 and 2017 were available on the Washington State LiDAR Portal managed by the Department of Natural Resources (DNR). The full NAIP imagery for 2011 and 2017 were available on the EarthExplorer site hosted by the United States Geological Survey (USGS). The shapefiles were available on Metro Parks Tacoma's Open Data Portal and the city of Tacoma's GeoHub Portal.

Data management was an initial concern since one LiDAR point cloud dataset alone was 42 gigabytes. Reducing the footprint to a workable size was achieved through using the DNR's digital surface and terrain models and reducing the footprint to the parks in question.

Esri's ArcGIS Pro was the primary tool used to analyze data. All data were projected to NAD 1983 HARN State Plane Washington South FIPS 4602 Feet.

## 4.2 Operationalizing the data

A multi-step approach answered the four research questions. The first step was to establish the working extent for the study. This proved tricky as the MPT properties had changed significantly since the Tree Canopy Cover Plan was written. Some parks were added to the portfolio. Many parks in the study were aggregated from smaller parks. E.g., a park called Ruston Way comprised 10 contiguous parks. These factors increased the count of parks from 62 to 84. Finally, many parks had changed size or shape. E.g., Wapato Hills Park grew from 14 to 80 acres while Ursich Park & Natural Area dropped the "& Natural Area" portion of its name and over half its physical size. While it would have been possible to recreate the 2012 park boundaries for the purpose of conducting an "apples to apples" study of tree canopy cover change, that would not provide MPT an accurate assessment of their current properties. Further, it would not promote the development of a tool to automate calculating tree canopy cover of future MPT holdings if it were limited to an antiquated map of park boundaries. Instead, the current parks boundaries were analyzed with 2011 and 2017 data to provide a consistent framework to show tree canopy cover change over time.

NDVI analysis of MPT's 84 parks compared the red and near-infrared bands of the NAIP imagery. Park grounds were classified into four zones: inanimate, unhealthy, moderately healthy and very healthy. Inanimate areas of the parks included parking lots, ponds, overpasses, and other man-made objects. Removing inanimate areas and building footprints from the parks shapefiles effectively masked the LiDAR analysis to consider only vegetation inside park boundaries. This approach was successful for several studies noted in the literature review (Caughlin *et al.* 2020; Larue *et al.* 2018; O'Neil-Dunne 2019; Parmehr, Amati and Fraser 2016; Recanatesi, Giuliani and Ripa 2018; Schlund Erasmi and Scipal 2020; Snavely *et al.* 2019). A very similar approach was applied to the city of Tacoma's Urban Tree Canopy Assessment in 2018 using the same NAIP and LiDAR data as this study (Urban Tree Canopy Assessment 2018). This study's tree canopy cover findings were in step with Tacoma's assessment when clipped to the parks.

The 2017 LiDAR point cloud was intended to study the Green River water service area and was limited to three classifications: unassigned, ground, and water. These classifications were not suitable to filtering out trees from buildings or other vegetation. This study developed a normalized digital surface model (nDSM) from the available digital surface and terrain models. The resulting tree canopy cover feature class was created by calculating all the nDSM that was eight feet or higher above the ground. When intersected with the parks boundaries, this provided tree canopy cover area and percentage data for each park.

With a park-by-park tree canopy cover assessment, this study answered the first two research questions of finding the current tree canopy coverage percentages and identifying where the tree canopies are growing most and least quickly. It identified the annual growth rate of each park and forecast a tree canopy cover percentage by the year 2030. It did the same for the overall MPT tree canopy cover.

Returning to the NDVI analysis allowed this study to tackle the third research question of where new tree canopies would grow the most quickly. The healthier areas of the NDVI results determine leaf area index (LAI) throughout the study extent. Areas of consistently higher LAI have been shown to indicate greater productivity and may provide clues for potential areas to invest in rapid tree canopy growth (Coops 2015). Very healthy and moderately healthy zones within each park, not already occupied by trees, are prime candidates for MPT's arborist to consider cultivating more tree canopy cover. With additional support, unhealthy zones can very quickly increase tree canopy cover over previously bare or shrubby terrain. Inanimate areas are poor choices for increasing tree canopy cover due to the cost of removing impervious surfaces or draining water features.

The final research question explored whether Tacoma residents enjoy uniform benefits from MPT's tree canopy cover initiative. Tacoma's Equity/Opportunity Index ranks census block groups on a quintile scale of very high, high, moderate, low, and very low opportunity. To increase clarity, this study grouped the high and very high classes resulting in 40 percent of the block groups named HI. It also grouped the low and very low classes resulting in 40 percent of the block groups being named LO. The moderate classification, called MOD, was left as a 20 percent buffer between HI and LO. Parks' locations were compared to the grouped Equity Index. Any properties that spanned two Index areas were counted in both (e.g., Wapato Park occupied both the LO and MOD areas and was counted in each). Four parks located outside of the city limits (Browns Point Lighthouse Park, Browns Point Playfield, Dash Point Park and Pier, and Jerry Meeker Memorial) were not included in the assessment.

### 4.3 Automation

A secondary goal of this study is to establish a transparent and repeatable process for conducting future analyses. MPT should feel comfortable stating whether they have met their goals in 2030 with a consistent, in-house GIS process. This study provides MPT a tool that can analyze future data captures to provide consistent results for each of the 84 parks observed in the study.

ArcGIS Pro ModelBuilder was employed to create a model that links MPT's Tree Canopy Cover Plan to future Tacoma Urban Tree Canopy Assessments. The user provides two polygon shapefiles, the current parks boundaries and the tree canopy cover that the City of Tacoma created with its latest assessment. This automation assumes Tacoma will continue to create such a shapefile when it performs future urban tree canopy analyses, especially in 2030 upon completing the *30 by 30 Initiative*.

The model creates a feature dataset where it projects the two shapefiles. The feature classes are intersected and dissolved to create a TreeCanopy_MPT feature class with records for all the parks and fields showing Park Area, Tree Canopy Area, and Tree Canopy Percentage. Meanwhile, the model also exports an Excel spreadsheet with the same information. Armed with these data a GIS analyst may quickly deduce and visualize tree canopy cover conditions for MPT's parks.

## 5. Discussion

Metro Parks Tacoma is well on its way to achieving the overarching goal of 66 percent tree canopy cover by the year 2030. However, some parks will fall short of their individual goals and there are serious considerations regarding the social justice connotations of the parks' footprint.

### 5.1 Current Tree Canopy Cover

The overall tree canopy cover for Metro Parks Tacoma's properties was 61.42 percent in 2017. This is up from 56.91 percent in 2011 and represents an annual increase of 0.75 percent. Applying that growth rate over 19 years predicts the tree canopy cover will surpass the plan's goal of 66 percent by the year 2024. While only two observations are a poor basis for establishing a trend, it is reassuring to see such a strong start to the MPT Tree Canopy Cover Plan.

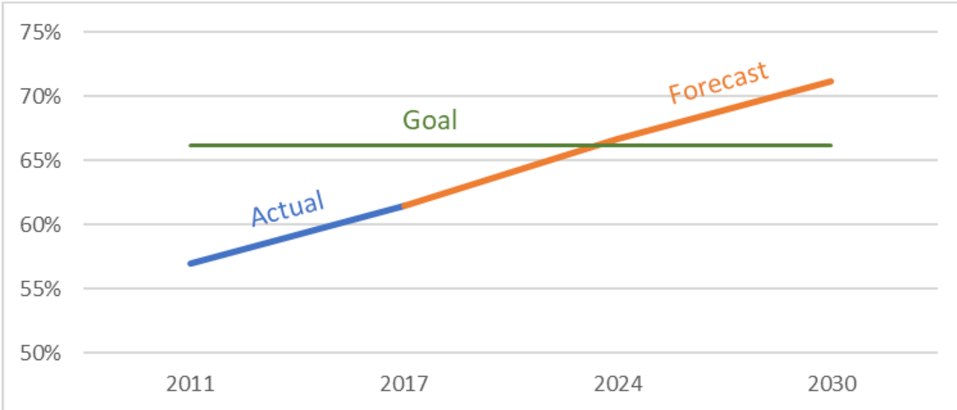


**Figure 1. Linear Projection of MPT Tree Canopy Cover Percentages**

## 5.2 Most and Least Growth

The following tables illustrate MPT tree canopy change between 2011 and 2017. Each park has a linear forecast of its tree canopy cover percentage in 2030 based on its annual growth rate observed during those six years. Comparing each park's forecast to goal percentages, 24 parks will not reach their targets. The shortage for these parks is listed in square feet allowing MPT's arborist to concentrate on larger areas, if appropriate.

**Table 1. Direct Comparison, Tree Canopy Coverage by Park**

| | Tree Canopy Cover Percentages | | | | Shortage |
|---|---|---|---|---|---|
| Name | 2011 | 2017 | Forecast | Goal | in acres |
| Alderwood Park | 87% | 91% | 100% | 84% | |
| Alling Park | 10% | 17% | 32% | 31% | |
| Baltimore Park | 21% | 21% | 23% | 18% | |
| Browns Point Lighthouse Park | 7% | 13% | 26% | 34% | 0.36 |
| Browns Point Playfield | 20% | 20% | 21% | 31% | 0.41 |
| Charlotte's Blueberry Park | 45% | 52% | 68% | 56% | |
| China Lake Park | 71% | 76% | 87% | 90% | 0.77 |
| Cloverdale Park | 8% | 11% | 17% | 31% | 0.30 |
| Dash Point Park & Pier-3 | 1% | 2% | 2% | 17% | 0.40 |
| DeLong Park | 54% | 66% | 91% | 84% | |
| Fern Hill Park | 14% | 22% | 37% | 34% | |
| Ferry Park | 35% | 50% | 84% | 33% | |
| Franklin Park | 30% | 35% | 47% | 43% | |
| Heidelberg/Davis Sports Complex-2 | 6% | 8% | 12% | 8% | |
| Irving Park | 35% | 40% | 52% | 38% | |
| Jane Clark Park | 10% | 10% | 10% | 13% | 0.18 |
| Jefferson Park | 16% | 19% | 27% | 26% | |
| Kandle Park | 1% | 5% | 15% | 25% | 1.13 |
| Lincoln Park | 36% | 42% | 57% | 39% | |
| Lots for Tots | 16% | 29% | 58% | 31% | |
| Manitou Park | 43% | 44% | 46% | 30% | |

| Name | Tree Canopy Cover Percentages 2011 | 2017 | Forecast | Goal | Shortage in acres |
|---|---|---|---|---|---|
| McCarver Park | 4% | 12% | 28% | 21% | |
| McKinley Park | 74% | 78% | 87% | 88% | 0.06 |
| Meadow Park Golf Course | 27% | 30% | 35% | 25% | |
| Neighbors Park | 25% | 32% | 47% | 24% | |
| Norpoint Park | 37% | 42% | 55% | 46% | |
| North Slope Historic Park | 29% | 62% | 100% | 32% | |
| Northeast Tacoma Playground | 10% | 11% | 13% | 25% | 0.52 |
| Oak Tree Park | 72% | 79% | 93% | 90% | |
| Oakland Madrona Park | 26% | 29% | 37% | 47% | 0.32 |
| Old Town Park | 35% | 44% | 64% | 36% | |
| Optimist Park | 7% | 12% | 23% | 17% | |
| Peck Field | 4% | 5% | 7% | 11% | 0.42 |
| People's Community Center & Pool | 16% | 18% | 23% | 23% | |
| People's Park | 31% | 35% | 43% | 33% | |
| Portland Avenue Park | 13% | 16% | 21% | 23% | 0.27 |
| Proctor Community Garden | 4% | 5% | 7% | 13% | 0.05 |
| Rogers Park | 25% | 31% | 43% | 15% | |
| Roosevelt Park | 20% | 22% | 24% | 37% | 0.38 |
| Ryan's Park | 28% | 42% | 70% | 52% | |
| Sawyer Tot Lot | 6% | 24% | 61% | 30% | |
| SERA | 10% | 13% | 19% | 21% | 0.84 |
| Sheridan Park | 26% | 36% | 58% | 34% | |
| South Park-2 | 52% | 53% | 55% | 32% | |
| Stewart Heights Park-2 | 9% | 14% | 23% | 24% | 0.17 |
| Swan Creek Park | 74% | 79% | 88% | 89% | 3.50 |
| Tacoma Nature Center Park | 71% | 81% | 100% | 87% | |
| Thea's Park | 4% | 9% | 21% | 26% | 0.18 |
| Titlow Park-1 | 59% | 62% | 68% | 80% | 8.78 |
| Ursich Park | 40% | 68% | 100% | 84% | |
| Vassault Park | 4% | 7% | 13% | 16% | 0.54 |
| Verlo Playfield (McKinley Playfield) | 8% | 10% | 15% | 16% | 0.04 |
| Wapato Hills Park | 65% | 75% | 98% | 70% | |
| Wapato Park | 40% | 46% | 58% | 57% | |
| Wright Park | 47% | 53% | 65% | 34% | |

**Table 2. Aggregate Parks, Tree Canopy Coverage by Incorporated Park**

| Name | Tree Canopy Cover Percentages 2011 | 2017 | Forecast | Goal | Shortage in acres |
|---|---|---|---|---|---|
| ***Garfield Park & Gulch** | **65%** | **69%** | **79%** | **74%** | |
| Garfield Gulch | 90% | 94% | 100% | | |
| Garfield Park | 10% | 16% | 27% | | |
| ***Lincoln Heights Park & Nat. Area** | **23%** | **30%** | **46%** | **69%** | **0.90** |
| Lincoln Heights Parcel | 38% | 48% | 72% | | |
| Lincoln Heights Park | 7% | 10% | 18% | | |
| ***Metro Parks HQ and Natural Area** | **41%** | **55%** | **83%** | **79%** | |
| Boy Scouts of America Pacific Harbors Council | 31% | 42% | 65% | | |
| Metro Parks Headquarters | 44% | 58% | 88% | | |
| ***Point Defiance Park** | **73%** | **76%** | **84%** | **78%** | |
| Dune Peninsula at Point Defiance Park | 0% | 0% | 0% | | |
| Fort Nisqually | 63% | 66% | 74% | | |
| Point Defiance Marina | 4% | 4% | 3% | | |
| Point Defiance Park | 78% | 82% | 90% | | |
| Point Defiance Zoo & Aquarium | 29% | 31% | 37% | | |
| ***Puget Park & Gulch** | **90%** | **94%** | **100%** | **89%** | |
| Puget Park-1 | 91% | 96% | 100% | | |
| Puget Park-2 | 90% | 93% | 100% | | |
| ***Ruston Way** | **10%** | **14%** | **24%** | **35%** | **4.95** |
| Cummings Park | 20% | 24% | 32% | | |
| Dickman Mill Park | 5% | 7% | 13% | | |
| Hamilton Park | 23% | 22% | 19% | | |
| Jack Hyde Park | 5% | 10% | 22% | | |
| Judge Jack Tanner Park | 14% | 18% | 27% | | |
| Old Town Dock | 7% | 6% | 3% | | |
| Ruston Way Area 1 | 2% | 13% | 37% | | |
| Ruston Way Area 2 | 27% | 33% | 46% | | |
| Ruston Way Area 3 | 8% | 11% | 17% | | |
| Ruston Way Area 4 | 11% | 15% | 24% | | |
| ***Stanley Playfield** | **4%** | **4%** | **6%** | **23%** | **1.37** |
| Al Davies Boys and Girls Club | 4% | 4% | 5% | | |
| Stanley Playfield | 4% | 4% | 6% | | |

*Names in bold are from the 2012 Tree Canopy Cover Plan comprising the parks listed immediately after. Goals from the Plan apply directly to the composite park and indirectly to its aggregate parks. (E.g., the Plan lists one park as Stanley Playfield, but that geographic area is currently listed as two parks – Al Davies Boys and Girls Club and Stanley Playfield.)

**Table 3. Properties not included in the 2012 MPT Tree Canopy Plan**

| | Tree Canopy Cover Percentages | | | | Shortage |
|---|---|---|---|---|---|
| Name | 2011 | 2017 | Forecast | Goal | in acres |
| Eastside Community Center | 9% | 2% | 0% | N/A | N/A |
| Jerry Meeker Memorial | 5% | 0% | 0% | N/A | N/A |
| Julia's Gulch | 86% | 90% | 100% | N/A | N/A |
| Stadium Outlook | 30% | 34% | 42% | N/A | N/A |

The total shortage of all parks that are not forecasted to reach their goals amount to just under 27 acres. This quantity represents 1.26 percent of all the MPT properties and will be more than offset by other parks exceeding their goals.

Almost all the 84 parks studied saw growth in their tree canopy cover. However, six parks experienced reductions of their tree canopy cover between 2011 and 2017. None of these six parks have specific tree canopy cover goals in the MPT Tree Canopy Cover Plan. Four parks with shrinking tree canopy cover are incorporated into aggregated parks in the Plan (Dune Peninsula and the Marina at Point Defiance; Hamilton Park and Old Town Dock on Ruston Way). The remaining two properties with dwindling tree canopy cover were not included in the Plan (Eastside Community Center and Jerry Meeker Memorial).

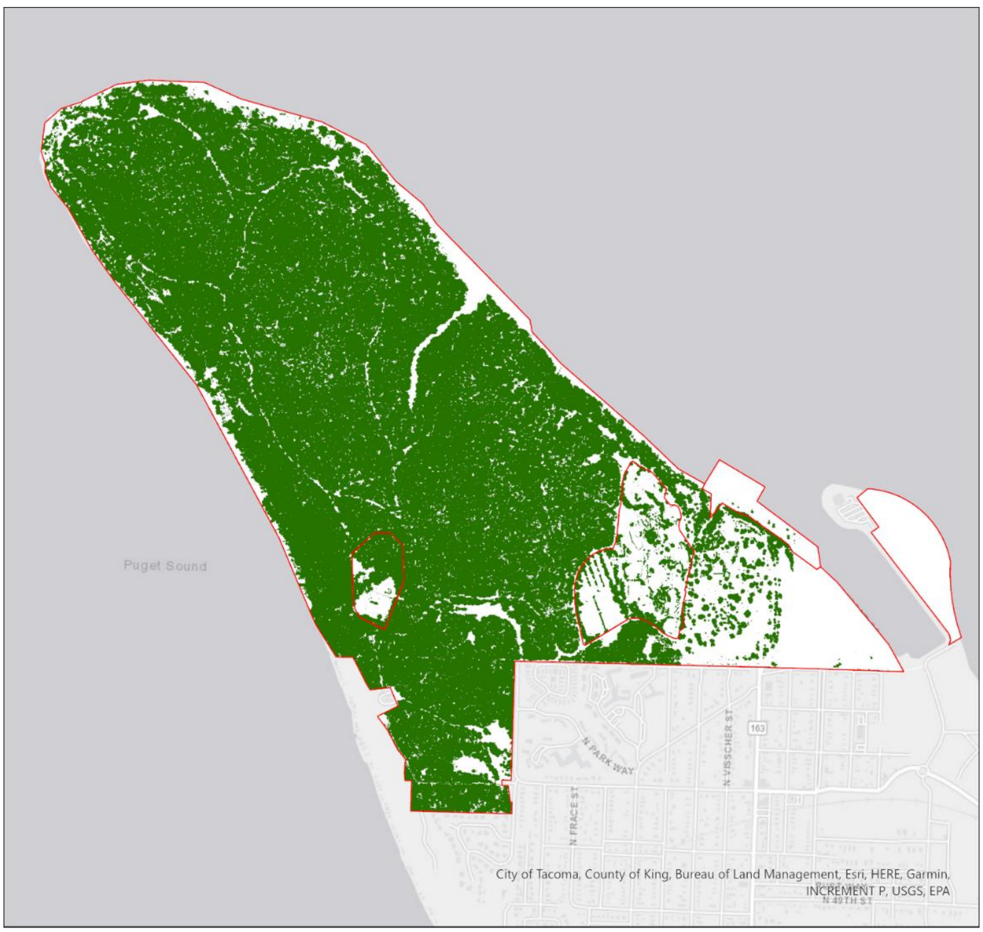


**Figure 2. Tree Canopy Coverage of Point Defiance Park, Fort Nisqually Park, Port Defiance Zoo and Aquarium, Point Defiance Marina, and Dune Peninsula Park**

## 5.4 Areas for Quick Tree Canopy Growth

The healthier areas of the NDVI analysis are prime targets for accelerating tree canopy growth in parks not forecasted to reach their goals. Very healthy and moderately healthy areas (shown in green in Figure 3) not already planted with maturing trees are the best zones to consider new tree growth. With additional support, unhealthy zones (shown in orange) can very quickly increase tree canopy cover over previously bare or shrubby terrain. Inanimate areas (shown in red) are poor choices for increasing tree canopy cover due to the cost of removing impervious surfaces or draining water features.



**Figure 3. Titlow Park Showing NAIP Imagery and NDVI Analysis**

## 5.5 Uniform Benefits for all Tacoma Residents

By comparing the parks to their corresponding Equity/Opportunity Index block groups, it became apparent that despite having a lower overall population, HI neighborhoods enjoy twice the tree canopy coverage area than LO neighborhoods. This results from a combination of more parks comprising more overall space with higher tree canopy cover percentages in the HI neighborhoods as compared to LO neighborhoods (see Table 4). The parks placement in relation to the Equity/ Opportunity Index are illustrated in Figure 4.

Tacoma's Equity/Opportunity Index is one of the primary tools that city staff, community members, partners, and other decision-makers use to ensure that they are making data-informed decisions. Its purpose is to improve access to opportunities for all Tacoma residents. The Index highlights successes and obstacles connected to upward mobility. It consists of indicators within the Tacoma 2025 Strategic Goals: accessibility, livability, education, economy, and environmental health.

HI Equity/Opportunity represents locations that have access to better opportunities to succeed and excel in life. The indicators include high-performing schools, access to adequate transportation, safe neighborhoods, and sustainable employment. In contrast, LO Equity/Opportunity communities have more obstacles and barriers. These neighborhoods have limited access to institutional or societal investments which limits their quality of life (Equity Index 2020).

**Table 4. MPT Tree Canopy Coverage by Equity/Opportunity Index**

| Equity Index | Tree Canopy Cover Area | U.S. Census Population 2019 | Number of Parks | Combined Parks Area | Tree Canopy Cover Percentage |
|---|---|---|---|---|---|
| LO | **19,725,136** | 105,543 | 36 | 38,211,980 | 52% |
| MOD | 6,451,951 | 46,121 | 7 | 10,781,930 | 60% |
| HI | **42,552,606** | 94,422 | 41 | 60,405,913 | 70% |

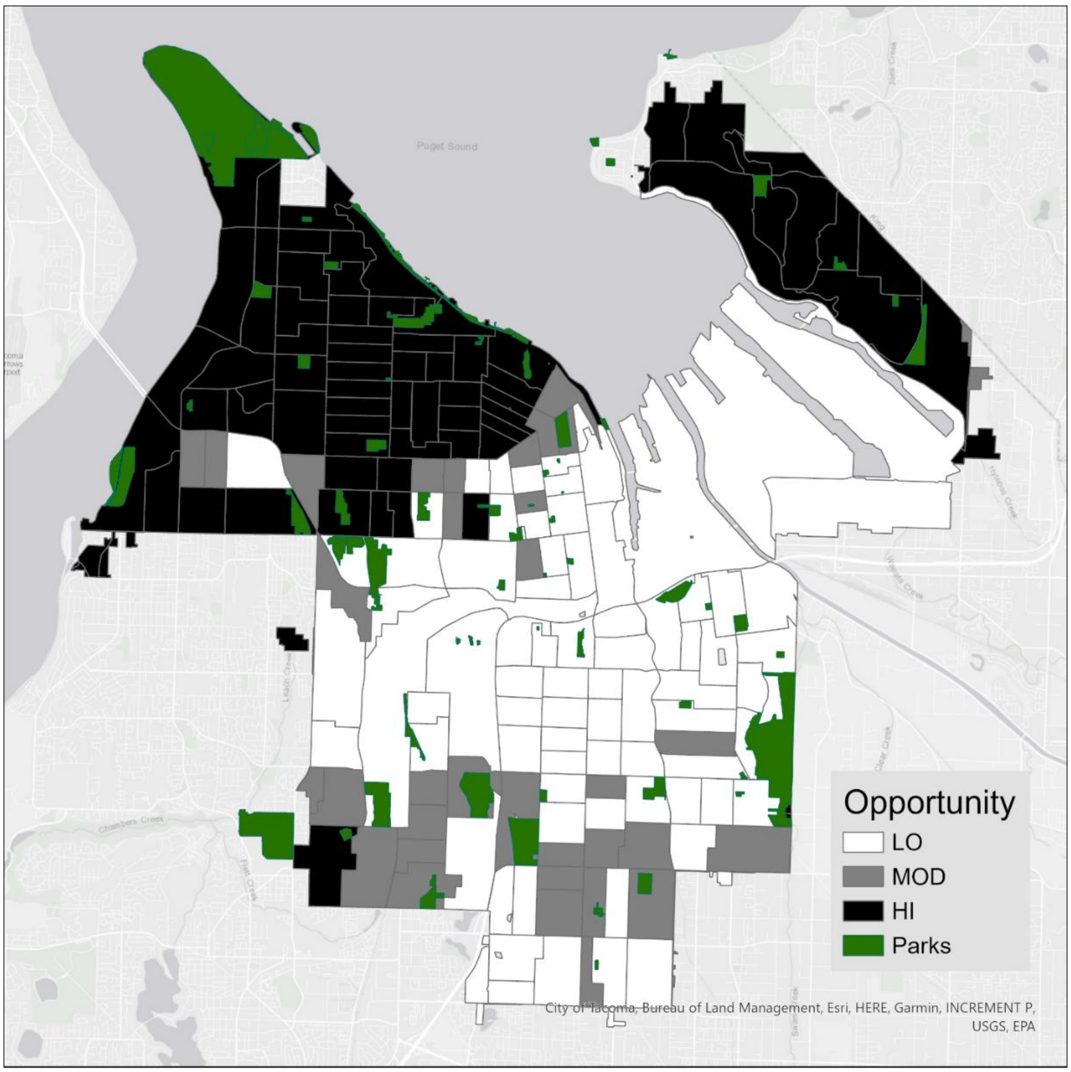


**Figure 4. MTP Parks in Relation to Tacoma's Equity/Opportunity Index**

# 6. Conclusion

MPT cannot realistically navigate to the goals of its 20-year Tree Canopy Cover Plan without tracking progress along the way. If the plan falls short, Tacoma and its residents will pay the price environmentally, economically and socially. This study provides an important, progress report by exploring four key questions: What are the current tree canopy coverage percentages? Where are the tree canopies growing most and least quickly? Where would new tree canopies grow the most quickly? Are Tacoma's residents enjoying uniform benefits of this effort?

A combination of LiDAR and NDVI analyses from 2011 and 2017 were used to answer the first two questions. NDVI derived from NAIP imagery identified inanimate areas within the parks such as parking lots, overpasses, and water features. This provided a mask for developing a normalized digital surface model (nDSM) from the LiDAR data that counted only vegetation that was eight or more feet tall. That nDSM translated into a representation of the tree canopy cover that was intersected with parks' boundaries to provide areas and percentages of the tree canopy cover for each park. A comparison of results from 2011 and 2017 data found that the overall tree canopy cover had increased from 57 to 61 percent and is on track to hit the goal of 66 percent by the year 2024, well ahead of schedule.

The results were further broken down by park. Each park had specific goals within the plan. This study found the growth rate for each park and identified those not on track to hit their targets by the year 2030. The shortage for these parks was provided in acres, allowing MTP to prioritize which parks to address with limited resources. However, the amount of tree canopy cover that is currently falling behind amounts to only one percent of the overall inventory.

NDVI data provided additional clues to address the parks not on track to hit their goals by 2030. Healthy areas give MTP starting points to expedite additional tree growth as desired. Inanimate areas are likely poor choices due to the cost associated with planting and cultivating trees there.

Comparing the MPT tree canopy data to Tacoma's Equity/Opportunity Index uncovered a disturbing trend. Residents living in HI Equity Index areas enjoy over twice the tree canopy cover than those living in the LO Equity Index neighborhoods.

A secondary goal of this study was to establish a transparent and repeatable process for conducting future analyses. MPT now has a tool that can analyze future urban forest tree canopy assessments conducted by the City of Tacoma for its *30 by 30 Initiative*. This tool will provide consistent results for MPT properties, even if the parks change in size or numbers.

Interactive maps, the analysis tool, and a summary of this paper are available at https://saschu-uwt.github.io/TreeCanopy/index.html.

## 6.1 Recommendations

If MPT makes changes to its Tree Canopy Cover Plan, parks within the LO Equity Index neighborhoods should receive priority.

The MPT Tree Canopy Cover Plan could be updated to improve several administrative areas. Parks not listed in the plan could be added and assigned tree canopy cover goals. Parks that have changed their primary use may require updating in the plan. For example, some parks have removed "Natural Area" from their titles (e.g., Irving Park, Lincoln Heights, Metro Parks HQ, and Ursich Park). If the intent for these properties no longer requires high percentages of tree canopy cover, their numbers should reflect that in the Plan. Some parks seem to have incongruous tree canopy cover goals. For example, Heidelberg Sports Complex is listed in the Plan's summary table with a goal of 47 percent, but the details page states the goal is 8 percent. The latter seems more likely given the nature of the property. Similarly, McKinley Playfield has changed to Verlo Playfield and should be updated in the Plan.

Some properties have changed dramatically, and their tree canopy cover goals should be reevaluated. For example, Wapato Hills Park grew from 14 to 80 acres while Ursich Park & Natural Area dropped "& Natural Area" from its name and its wooded portion was reduced by over half its overall size. Finally, there are seven parks listed in the Plan that are aggregates of several smaller parks (e.g., "Ruston Way" comprises 10 smaller parks and areas). The smaller parks do not have individual tree canopy cover goals, making it difficult to plan for their futures. The Tree Canopy Cover Plan could be updated to address each park.

Future analysis would greatly benefit from another LiDAR capture of the study extent. Additional observations would give MPT a stronger trend to work with. The most current data is already four years old and does not reflect significant tree canopy growth initiated in 2012.

## Acknowledgements

The author gratefully appreciates the support and encouragement received from Renee Opatz of Metro Parks Tacoma; Dr. Emma Slager and Dr. Jim Thatcher from the University of Washington Tacoma, and Christina Chelf from the City of Tacoma.

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