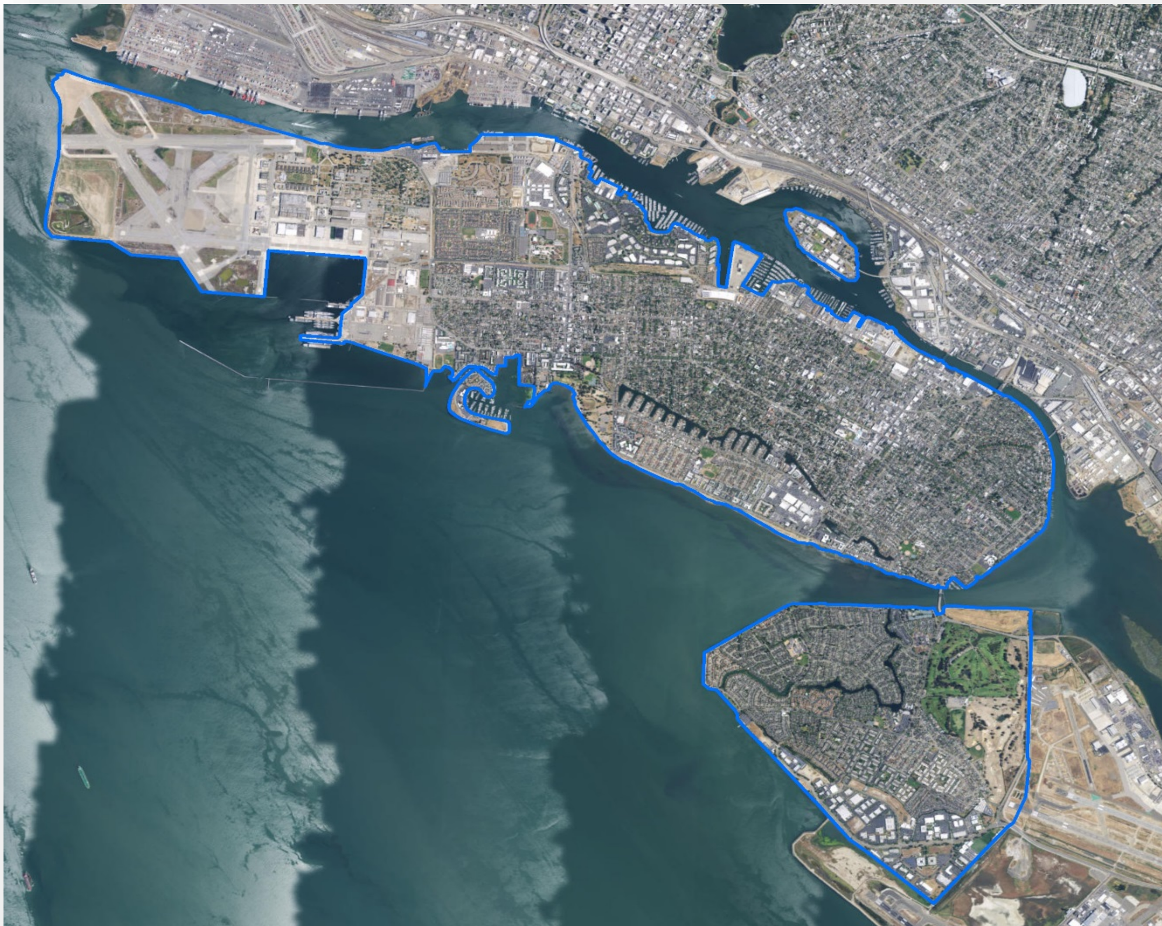
City of Alameda Tree Canopy Assessment



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Executive Summary

The City of Alameda is interested in identifying the amount of canopy cover, air quality and stormwater management benefits provided by their urban forest. They would also like to compare Alameda's urban forest with that of neighboring cities. This report summarizes assessments of Alameda's tree canopy cover and associated improvements to air quality stormwater benefits using i-Tree Canopy and i-Tree Hydro. These are two of a suite of programs developed by the U.S. Forest Services to quantify and value ecosystem services provided by trees.

Research has shown that trees provide a variety of environmental, social, health, and economic benefits to its citizens.

Urban forests….

- improve air quality, reduce energy required for cooling;
- reduce stormwater runoff and improve water quality;
- improve public health and reduce stress;
- provide habitat for wildlife;
- increase property values;
- enhance the economic stability by attracting visitors, businesses, and new residents

Sustaining and augmenting tree canopy cover are important ways to meet Alameda's goals for greenhouse gas reduction and contribute towards protection from climate change.

Tree Canopy in the City of Alameda

Determining the percent of the land that is covered by tree canopy is a way to estimate the benefits trees provide a community. The greater the canopy cover, the more environmental benefits are accrued.

Alameda's tree canopy cover is estimated at 21% (standard error 1.29%) of the total 7230 acre land cover. Other pervious land covers are grasses and low vegetation with17% cover; soil, 6%; and water, 3%. Impervious materials such as concrete, roads, and building rooves cover 53% of the land area.

Alameda compares favorably to other cities in the Bay Area with regard to percent canopy cover (figure 2). Of nine Bay Area cities, it ranks number three at 21% canopy cover, below Palo Alto (37%) and Oakland (25%), but above Campbell, Mountain View, Santa Clara, San Jose, San Francisco and Sunnyvale (19-14%).

Air quality benefits

The urban tree canopy is an effective filter for air pollutants. Using i-Tree Canopy we estimated the benefits to air quality provided by Alameda's tree canopy and the monetary value those benefits represent. At the current canopy cover, each year Alameda's tree canopy removes approximately 60 tons of pollutants from the air, thereby improving air quality. The total annual value for removal of carbon monoxide, nitrogen dioxide, ozone, particular matter and sulfur dioxide is $620,055.

The urban forest currently reduces carbon dioxide, the primary greenhouse gas, through tree growth and storage (sequestration) in the wood and foliage. The trees in Alameda sequester 178,110 tons of carbon dioxide, with 9,009 tons added annually. The total value of the carbon dioxide stored in trees is $6,440,350. The value of annual sequestration of carbon dioxide is $325,786.

Stormwater runoff reduction

Tree canopies intercept precipitation. In so doing, they decrease the impact velocity of raindrops hitting the ground and reduce the overall amount of precipitation that eventually hits the ground. Some of the water is temporarily stored in the canopy and eventually evaporates into the atmosphere. Where soil is below the canopy, tree roots and leaf litter improve permeability and increase infiltration of rainfall into the soil. The result of this moderating effect during precipitation is a reduction of runoff and soil erosion.

We estimated the contribution of Alameda’s tree canopy to stormwater runoff reduction using the i-Tree Hydro software. i-Tree Hydro predictions for annual reduction in stormwater runoff attributed to Alameda’s tree canopy is 934,900 cubic meters (246,974,451 gal.) compared to no canopy. The tree canopy reduces peak flows by 33,680 cubic meters per hour (88,973,147 gallons per hour). The model predicts 12 fewer flow events of higher than median flows, and each event lasting 25 hours less, on average, with current tree canopy.

One of the main benefits of tree canopy reduction in stormwater intensity is the reduction in volume of peak flows. This reduces the potential for flooding during storm events.

Table of Contents

Figures

Tables

Appendices

City of Alameda Tree Canopy Assessment

Introduction and Overview

The City of Alameda is interested in identifying the amount of canopy cover, air quality and stormwater management benefits provided by their urban forest. They would also like to compare Alameda's urban forest with that of neighboring cities.

In February 2008, Alameda City Council adopted a Resolution which set a citywide greenhouse gas reduction goal: 25% below 2005 baseline levels. The City Council also adopted the Local Action Plan for Climate Protection, which offers a framework for achieving this goal. Sustaining and augmenting tree canopy cover are important ways to meet this goal.

This report contains the following:

- Overview of environmental, social, and economic benefits provided by trees.
- Tree canopy cover within the City of Alameda as assessed using i-Tree Canopy.
- Improvements to specific air quality parameters provided by the tree canopy.
- Area of impervious and pervious land cover within the City of Alameda as assessed using i-Tree Canopy.
- Stormwater benefits that the canopy provides as assessed using i-Tree Hydro.
- Comparison of Alameda's canopy cover to published data for other cities in the Bay Area.

i-Tree Canopy and i-Tree Hydro are two of a suite of programs developed by the U.S. Forest Services to quantify and value ecosystem services provided by trees.

The Benefits Trees Provide

Over the past two decades there have been tremendous advances in our knowledge of the benefits of urban trees. Quantifying those benefits – environmental, social, and economic – has been the focus of much research.

For planted trees, the greatest benefits are derived from healthy, structurally sound trees planted in locations that support their development. Strategic planting maximizes benefits and minimizes costs.

Environmental Benefits

The environmental benefits provided by the urban forest can include enhanced air quality, carbon sequestering, and energy conservation through shade and wind protection, reduction of stormwater runoff and erosion, and noise attenuation.

Air quality

Vegetation improves air quality by intercepting particulate matter within the canopy and absorbing gaseous contaminants through stomata in the leaves. These urban pollutants are produced through the combustion of fossil fuels for power, transportation, and other industrial processes, as well as wind erosion of bare soils.

The concentration of carbon dioxide in the earth's atmosphere has been increasing since the beginning of the industrial age. Associated with this increase is a warming of global temperatures.

Trees are a tool to mitigate increases in atmospheric carbon dioxide. As they grow, trees remove carbon dioxide from the atmosphere. Through photosynthesis, carbon is initially stored as sugar. A fraction of the stored carbon dioxide is released back to the atmosphere during respiration. Over time, however, the tree accumulates atmospheric carbon in the form of wood, thereby sequestering the carbon. The amount of carbon stored in a tree is a function of the amount of woody material (stems and roots) as well as its quality. This carbon is not released into the atmosphere until the wood is decomposed by fungi, burned, or otherwise chemically destroyed.

Trees remove carbon from the air as they grow and store it in the trunk, branches and roots.

Selecting trees appropriate for the location and providing maintenance allows for the maximal carbon storage.

The effects of tree canopy on air quality in Alameda is discussed on pages 7-8.

Stormwater runoff and erosion control

Trees in the community can decrease the amount of stormwater runoff and pollutants that drain into streams and bay waters by intercepting precipitation and reducing the volume and velocity of water hitting the ground. Tree canopies slow water that drips through the canopy onto permeable surfaces, allowing longer time for absorption into the soil.

Tree canopy effects on stormwater volume and quality are discussed in greater detail on page 9.

Energy conservation

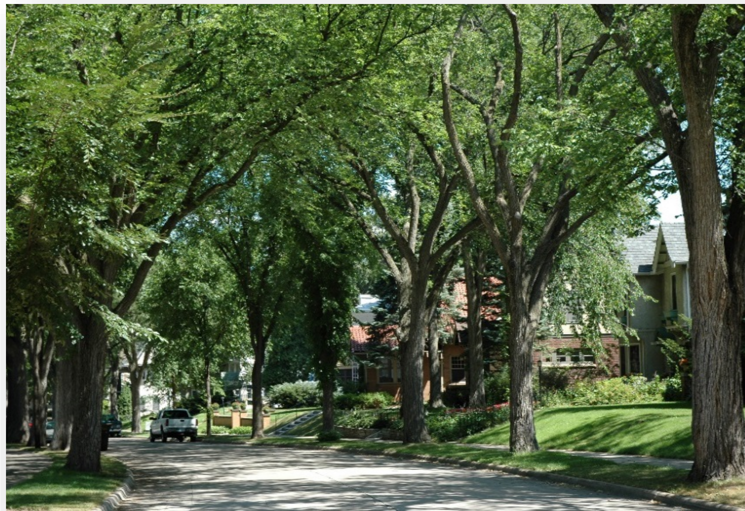
Properly placed trees can reduce building heating and cooling needs. In summer, energy used for cooling is reduced by tree shade. Although use of heating energy in winter can increase because of reduced solar gain caused by tree shade, sheltering of buildings from cold winds by nearby trees tends to reduce heating energy use.

Mitigating the urban heat island

Urban areas are known to be 4°F to 10°F warmer than adjacent rural locations. This phenomenon is known as the urban heat island. Trees are one of the effective means to mitigate the heat island effect by lowering temperatures through shade and evapotranspiration. Smog production increases 10 percent for each 10°F increase in temperature. Even small reductions in air temperature can have a large impact on smog production.

Deferred costs of energy production

Urban trees can help defer the costs of energy production. When trees are planted in locations that reduce air-conditioning demand in the summer by shading buildings, or heating needs in winter by shielding cold winds, peak energy demand is less. The need to build additional power plants to meet peak demand may be reduced. Any long-term management plan to shave peak demand will reduce the need for additional power plants, a major capital expense.



Street trees are a major source of building shade. A well-developed street tree program can be linked directly to the energy-saving benefit accrued by the adjoining property owner.

Psychological, Health, and Social Benefits of Trees

People have a strong emotional attachment to trees. Humans respond to nature, greenspace, and landscape plantings, and our behavior is influenced by those factors. The mental fatigue we experience in modern urban life is relieved by greenspace. The value of this benefit is only now being understood. The psychological value of trees and greenspace has been documented by several studies. These benefits range from quicker recovery from illness and injury, to improved mental health, greater job satisfaction, and less crime.

In addition to the recuperative benefits of viewing trees, greenspaces provide recreational areas in which people can be active. Activity is directly linked to health and well-being.

Shade provided by trees reduces exposure to skin-damaging ultraviolet rays.

Economic Values

A healthy, attractive urban forest enhances the economic stability of a community by attracting visitors, businesses, and new residents. Research has shown that people tend to linger and shop longer when streets are shaded by trees. Apartments and offices that are surrounded by trees tend to rent more quickly and have lower vacancy rates. The presence of mature trees and landscapes increases the value of real estate.

People tend to spend more time in shopping areas shaded by trees.

Tree Canopy in the City of Alameda

Tree canopy cover is the total amount of leaves and branches on all the trees throughout the city that shade the ground and intercept rainfall. There is a direct association between the amount of tree canopy and the environmental benefits provided. Determining the percent of the land that is covered by tree canopy is a way to estimate the benefits trees provide a community. The greater the canopy cover, the more environmental benefits are accrued.

Assessing tree canopy

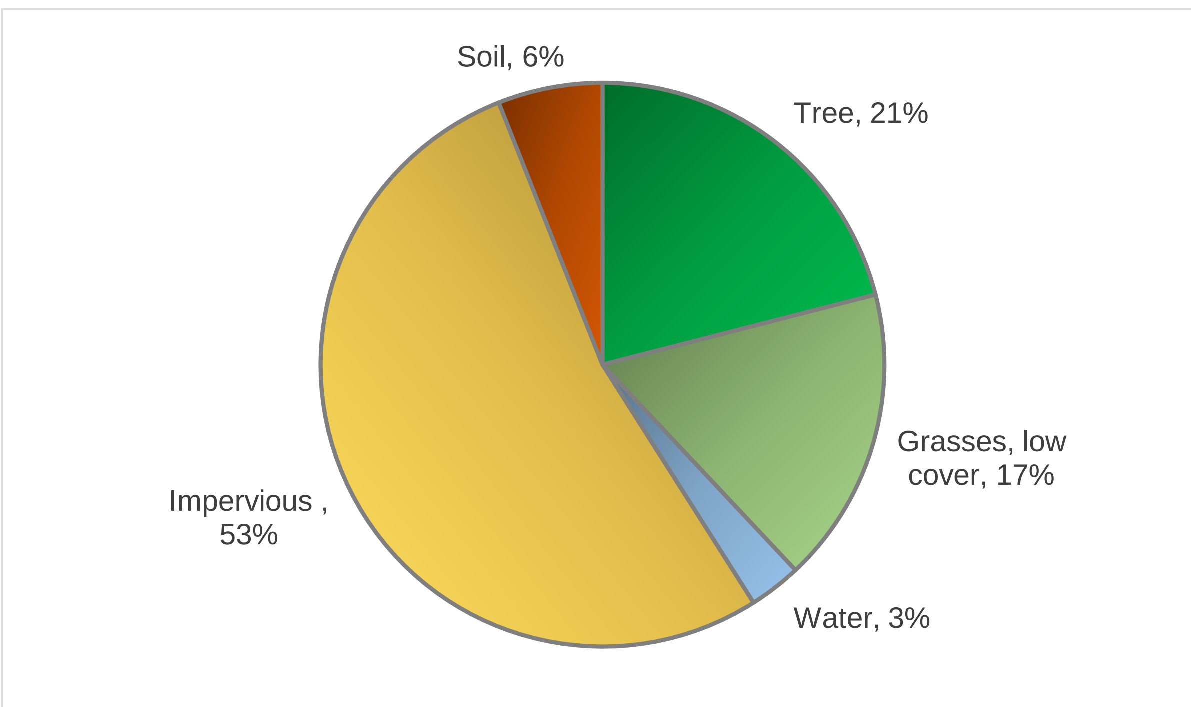
How much of the city that is covered in trees – the percent canopy cover – can be assessed using remote sensing. Using the i-Tree Canopy tool developed by the U.S. Forest Service, we assessed the percent canopy cover in Alameda. This tool interprets randomly generated points on Google Earth imagery. At each point we identified the type of land cover: soil, tree, grasses and low cover, water, and impervious (buildings, pavement). Based on the land cover types we identified at 750 points, the i-Tree Canopy program then determines the percent canopy cover and calculates specific benefits generated from that canopy cover.

Alameda's tree canopy cover

For Alameda, tree canopy cover is estimated at 21% (standard error 1.29%) of the total land (figure 1). Other pervious land covers are grasses and low vegetation with17% cover; soil, 6%; and water, 3%. Impervious materials such as concrete, roads, and building rooves cover 53% of the land area.

An aerial view of Alameda's tree canopy cover.

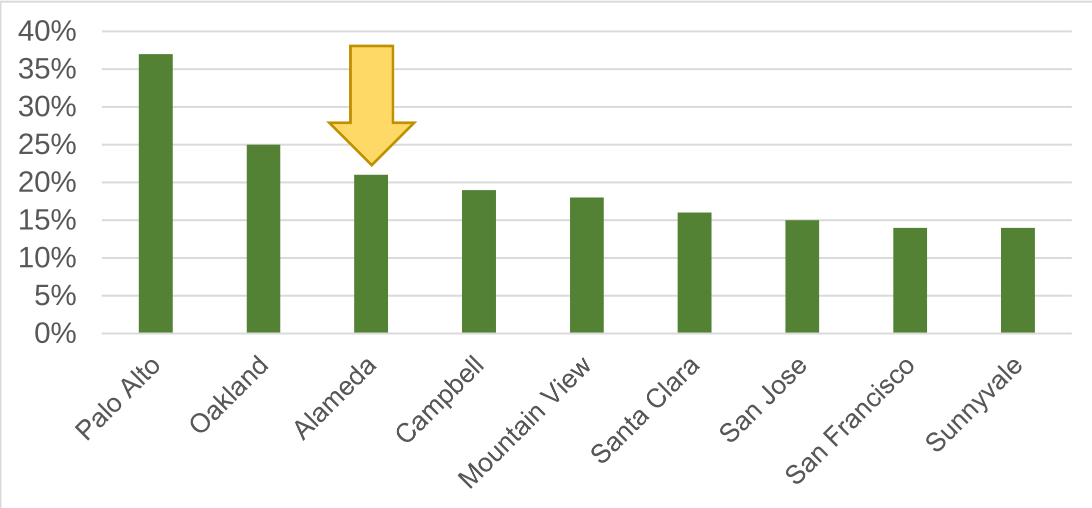
Figure 1. Percent land cover for five cover types in Alameda.
Data generated from i-Tree Canopy.



Comparison of Alameda's canopy cover to other Bay Area cities

Alameda compares favorably to other cities in the Bay Area with regard to percent canopy cover (figure 2). Of nine Bay Area cities, it ranks number three at 21% canopy cover, below Palo Alto (37%) and Oakland (25%), but above Campbell, Mountain View, Santa Clara, San Jose, San Francisco and Sunnyvale (19-14%).

Figure 2. Comparison of percent tree canopy cover in Bay Area cities.



Data, except for Alameda, from Oakland Urban Tree Canopy Assessment, American Forests Community Releaf, July 2015.

Air quality benefits

The urban tree canopy is an effective filter for air pollutants. The atmospheric contaminants that were included in the i-Tree Canopy analyses were:

- **Sulfur dioxide** (SO_2), results from burning coal and oil. SO_2 can be a respiratory irritant. It is one of the major components of acid rain.
- **Nitrogen oxides**, particularly nitrogen dioxide (NO_2), result from the high temperatures in internal combustion engines, which in turn cause atmospheric nitrogen to combine with oxygen. Nitrogen dioxide is partially removed by precipitation, contributing to acid rain.
- **Ozone** is formed by a photochemical reaction of nitrogen oxides and volatile organic compounds (hydrocarbons) in ultraviolet sunlight and moisture.
- **Particulates** are solid rather than gaseous, generated by combustion of fossil fuels, construction and demolition, industrial processes, soil tillage and erosion, and complex reactions between sunlight and gaseous pollutants. Particulates have been associated with respiratory (asthma) and cardiopulmonary (heart attacks) diseases, and cancer.
- **Carbon dioxide** concentrations are correlated with warmer temperatures and climate change.

Air quality benefits provided by Alameda's tree canopy

Using i-Tree Canopy we estimated the benefits to air quality provided by Alameda's tree canopy and the monetary value those benefits represent (table 1). At the current canopy cover, each year Alameda's tree canopy removes approximately 60 tons of pollutants from the air, thereby improving air quality. The total annual value for removal of carbon monoxide, nitrogen dioxide, ozone, particular matter and sulfur dioxide is $620,055.

The urban forest currently reduces carbon dioxide, the primary greenhouse gas, tree growth and storage (sequestration) in the wood and foliage. The trees in Alameda sequester 178,110 tons of carbon dioxide, with 9,009 tons added annually. The total value of the carbon dioxide stored in trees is $6,440,350. The value of annual sequestration of carbon dioxide is $325,786.

Table 1. Estimated value of environmental benefits provided by trees in Alameda.
Data generated from i-Tree Canopy

Benefit	Amount (tons)	±Standard Error	Value	±Standard Error
CO - carbon monoxide removed annually	1.22	±0.07	$1,623.05	±99.56
NO2 - nitrogen dioxide removed annually	7.11	±0.44	$5,762.88	±353.51
O3 - ozone removed annually	43.83	±2.69	$281,077.56	±17,242.00
PM2.5 - particulate matter less than 2.5 microns removed annually	1.15	±0.07	$249,634.92	±15,313.23
SO2 - sulfur dioxide removed annually	1.44	±0.09	$361.16	±22.15
PM10 - particulate matter greater than 2.5 microns and less than 10 microns removed annually	13.14	±0.81	$82,093.19	±5,035.80
CO2seq - carbon dioxide sequestered annually in trees	9,009.74	±552.68	$325,786.27	±19,984.55
CO2stor - carbon dioxide stored in trees (Note: this benefit is not an annual rate)	178,110.20	±10,925.73	$6,440,350.80	±395,067.30

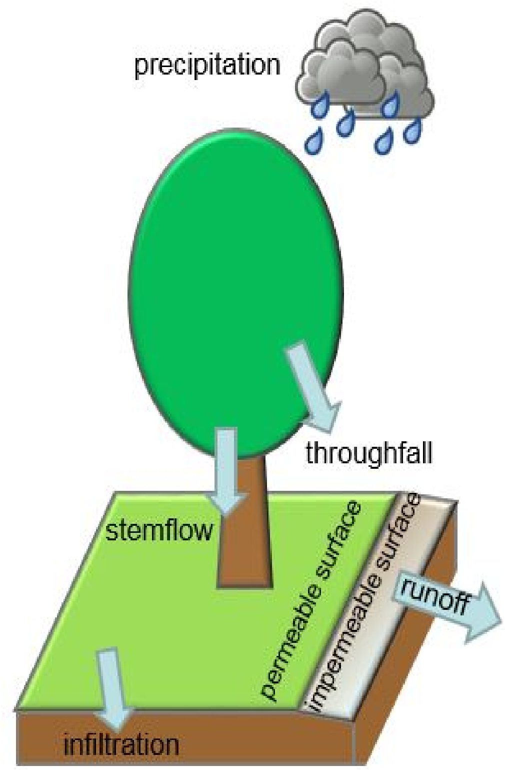
Stormwater runoff reduction

Tree canopies intercept precipitation. In so doing, they decrease the impact velocity of raindrops hitting the ground and reduce the overall amount of precipitation that eventually hits the ground. Some of the water is temporarily stored in the canopy and eventually evaporates into the atmosphere. Where soil is below the canopy, tree roots and leaf litter improve permeability and increase infiltration of rainfall into the soil. The result of this moderating effect during precipitation is a reduction of runoff and soil erosion.

The scale and intensity of interception is directly related to the amount of canopy cover. Evergreen species are more effective than deciduous because they provide year-round cover.

One of the main benefits of tree canopy reduction in stormwater intensity is the reduction in volume of peak flows. This reduces the potential for flooding during storm events.

Stormwater quality is better when the precipitation is filtered through tree canopy than when not. This is because water moves more slowly and picks up and carries less sediment and pollutants. This is important because the stormwater eventually enters Alameda's creeks, the Estuary and the San Francisco Bay.



Water can percolate through permeable surfaces, but runs off impermeable surface. Trees are most effective in intercepting rainfall during low-intensity storms. As the duration of precipitation increases, water drips from leaves (throughflow) and runs down stems (stemflow).

Alameda tree canopy's contribution to stormwater management

We estimated the contribution of Alameda's tree canopy to stormwater runoff reduction using the i-Tree Hydro software (see Appendix for description). This is a process-based hydrological model that assesses how tree cover affects water quantity and quality within a specified area with the land cover information we derived from i-Tree Canopy. The model uses rainfall data from 2005 to estimate volume of runoff for each rain event because that was an average year.

i-Tree Hydro predictions for annual reduction in stormwater runoff attributed to Alameda's tree canopy is 934,900 cubic meters (246,974,451 gal.) compared to no canopy. The tree canopy reduces peak flows by 33,680 cubic meters per hour (88,973,147 gallons per hour). The model predicts 12 fewer flow events of higher than median flows, and each event lasts 25 hours less, on average, with current tree canopy.

One of the main benefits of tree canopy reduction in stormwater intensity is the reduction in volume of peak flows. This reduces the potential for flooding during storm events.

Table 2. Estimated annual stormwater runoff reduction from Alameda's tree canopy compared to no canopy.
Data generated from i-Tree Hydro

Land Cover	
Watershed area (square kilometers)	29.26
Area covered by tree canopy coverage	21%
Area covered by Impervious surfaces	53%

Streamflow Predictions	With Tree Canopy	Without Tree Canopy
Total runoff flow (cubic meters)	9,534,683	10,469,583
Annual runoff flow reduction attributed to canopy (cubic meters)	934,900	
Highest runoff flow (cubic meters/hr.)	199,815	233,495
Peak flow reduction with canopy (cubic meters/hr.)	33,680	
No. flow events below median flow	52	40
Ave. length of flow events below median (hours)	84	109

Summary

The City of Alameda is interested in identifying the amount of canopy cover, air quality and stormwater management benefits provided by their urban forest.

Sustaining and augmenting tree canopy cover are important ways to meet this Alameda's goals for greenhouse gas reduction and contribute towards protection from climate change.

Alameda's tree canopy cover, estimated at 21%, is an effective filter for air pollutants. At the current canopy cover, each year Alameda's tree canopy removes approximately 60 tons of pollutants from the air, thereby improving air quality. The urban forest currently reduces carbon dioxide, the primary greenhouse gas, by sequestering 178,110 tons of carbon dioxide, with 9,009 tons added annually.

Predictions for annual reduction in stormwater runoff attributed to Alameda's tree canopy are 934,900 cubic meters (246,974,451 gal.) compared to no canopy, with reduction in peak flows by 33,680 cubic meters per hour (88,973,147 gallons per hour). One of the main benefits of tree canopy reduction in stormwater intensity is the reduction in volume of peak flows. This reduces the potential for flooding during storm events.

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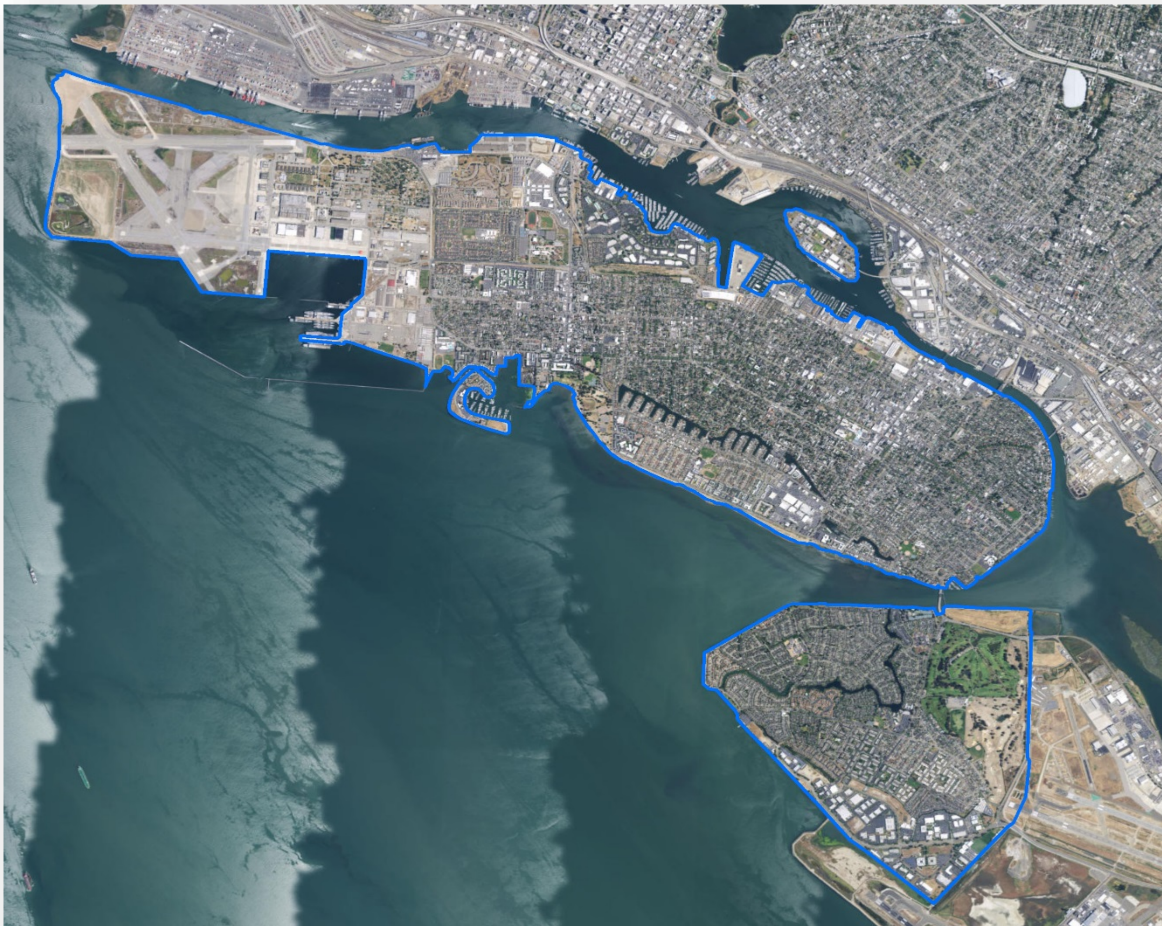

i-Tree Canopy Technical Notes
i-Tree Hydro in 2017

HORT SCIENCE

i-Tree Canopy Technical Notes

This tool is designed to allow users to easily and accurately estimate tree and other cover classes (e.g., grass, building, roads, etc.) within their city or any area they like. This tool randomly lays points (number determined by the user) onto Google Earth imagery and the user then classifies what cover class each point falls upon. The user can define any cover classes that they like and the program will show estimation results throughout the interpretation process. Point data and results can be exported for use in other programs if desired.

There are three steps to this analysis:

1) Import a file that delimits the boundary of your area of analysis (e.g., city boundary). Some standard boundary files for the US can be located on the US Census website. Data from these sites will require some minor processing in GIS software to select and export a specific boundary area polygon.
2) Name the cover classes you want to classify (e.g., tree, grass, building). Tree and Non-Tree are the default classes given, but can be easily changed.
3) Start classifying each point: points will be located randomly within your boundary file. For each point, the user selects from a dropdown list the class from step 2 that the point falls upon.

The more points that are interpreted, the more accurate the estimate.

Credits

The concept and prototype of this program were developed by David J. Nowak, Jeffrey T. Walton and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company).

Limitations

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. Thus the classes that are chosen for analysis must be able to be interpreted from an aerial image. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate. Information on calculating standard errors can be found below. Another limitation of this process is that the Google imagery may be difficult to interpret in all areas due to relatively poor image resolution (e.g., image pixel size), environmental factors, or poor image quality.

Calculating Standard Error and Confidence Intervals from Photo-Interpreted Estimates of Tree Cover

In photo-interpretation, randomly selected points are laid over aerial imagery and an interpreter classifies each point into a cover class (e.g., tree, building, water).

From this classification of points, a statistical estimate of the amount or percent cover in each cover class can be calculated along with an estimate of uncertainty of the estimate (standard error (SE)). To illustrate how this is done, let us assume 1,000 points have been interpreted and classified within a city as either “tree” or “non-tree” as a means to ascertain the tree cover within that city, and 330 points were classified as “tree”.

To calculate the percent tree cover and SE, let:

N = total number of sampled points (i.e, 1,000)
n = total number of points classified as tree (i.e., 330), and
p = n/N (i.e., 330/1,000 = 0.33)
q = 1 – p (i.e., 1 - 0.33 = 0.67)
SE = √ (pq/N) (i.e., √ (0.33 x 0.67 / 1,000) = 0.0149)

Thus in this example, tree cover in the city is estimated at 33% with a SE of 1.5%. Based on the SE formula, SE is greatest when p=0.5 and least when p is very small or very large (Table 1).

Table 1. Estimate of SE (N = 1000) with varying p.

p	SE
0.01	0.0031
0.1	0.0095
0.3	0.0145
0.5	0.0158
0.7	0.0145
0.9	0.0095
0.99	0.0031

Confidence Interval

In the case above, a 95% confidence interval can be calculated. “Under simple random sampling, a 95% confidence interval procedure has the interpretation that for 95% of the possible samples of size *n*, the interval covers the true value of the population mean” (Thompson 2002). The 95% confidence interval for the above example is between 30.1% and 35.9%. To calculate a 95% confidence interval (if N>=30) the SE x 1.96 (i.e., 0.0149 x 1.96 = 0.029) is added to and subtracted from the estimate (i.e., 0.33) to obtain the confidence interval.

SE if n < 10

If the number of points classified in a category (n) is less than 10, a different SE formula (Poisson) should be used as the normal approximation cannot be relied upon with a small sample size (<10) (Hodges and Lehmann, 1964). In this case:

SE = (√n) / N

For example, if n = 5 and N = 1000, p = n/N (i.e., 5/1,000 = 0.005) and SE = √5 / 1000 = 0.0022. Thus the tree cover estimate would be 0.5% with a SE of 0.22%.

References

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i-Tree Hydro in 2017

State-of-the-Art, Peer-Reviewed, Public-Domain

Process-Based Hydrological Model

Assessing How Changes in **Tree and Impervious Cover** Affect **Water Quantity & Quality**

Based on *Cutting-Edge U.S. Forest Service Science*

What Hydro Can Inform Us About

- How management practices & urbanization affect water resources.
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- Hourly & total results available in tabular & graphical form, including an automatically-generated Executive Summary report.

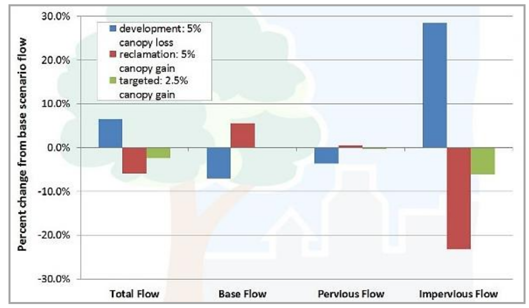

Figure 1: i-Tree Hydro simulation of alternative management scenarios as compared to initial conditions

How It Works

- **Data needs:** location; topography; weather; optional stream flow for calibration; land cover for initial case & optional alternatives.
- **Users inputs:** location, simulation period, and land cover information derived from i-Tree Canopy, NLCD data, and/or local knowledge.
- **Pre-loaded & increasing automated data inputs** with vast coverage in the U.S. for topography, weather data, and hydrological parameters.

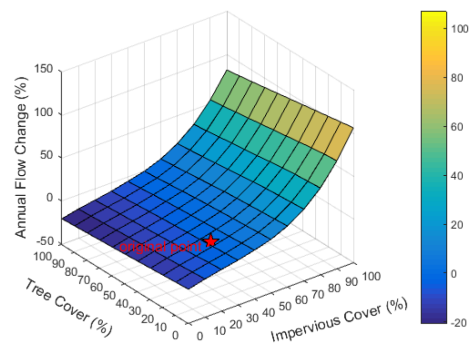

Figure 2: i-Tree Hydro simulated effects of incremental changes to Tree Cover and Impervious Cover in 161km²
Rock Creek watershed near Washington, DC.

What's Planned for 2017: i-Tree Hydro version 6

- **Green infrastructure modeling** of tree pits; rain barrels; green roofs; rain gardens; and pervious pavement – each uniquely parameterized.
- **Design Rain tool** for simulating storms using regional NOAA data and Intensity-Duration-Frequency (IDF) curves for the U.S.
- **Curve Number tool** for simple runoff prediction using the empirical NRCS TR-55 method based on small-catchment hydrology studies.
- **Increased functionality** & **accessibility**, e.g. 4 scenarios can be paired with different parameter sets & canopy properties in a single project.

How Can Hydro Help

- **By supporting decision-making** to **reduce stormwater damage** and improve urban forests, environmental quality, and human health.

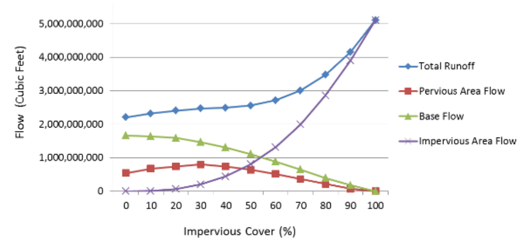

Figure 3: i-Tree Hydro simulation scaling Impervious Cover, with constant Tree Cover, in Rock Creek watershed near Washington, DC.

What's Planned for the Future – Projects, Partnerships, & Research

- **Nation-wide simulations** to assess hydrological effects of changes in tree cover and impervious cover across the United States.
- **Improved water quality modeling**, including pollution build-up & buffering hotspot identification and land cover specific effects.
- **Climate change scenarios**, simulating land cover changes using USGS weather stations and 25-year past & projected-future data from the international, high-resolution NARCCAP climate models.
- **Localized soil & hydrology parameters** informed by the NRCS SSURGO database for users all over the U.S.
- **Spatially-distribution of model**, providing advanced users with localized land use decision-making support.

DAVEY Arbor Day Foundation SMA SOCIETY OF MUNICIPAL ARBORISTS ISA International Society of Arboriculture Casey Trees WASHINGTON DC ESF