Village of Northbrook
Tree Survey and Carbon Sequestration

September 2020

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Introduction and Methodology

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Introduction

The intent of this study is to support the Village of Northbrook in understanding the extent of Village-Wide tree canopy, grass, and impervious surface coverage and in establishing appropriate goals and strategies to improve the environmental impacts and opportunities of land coverage within the Village. The findings of this report are to support establishment of goals, strategies, and actions for the Village's Climate Action Plan. As a visionary planning document, the goals established for the Village should be a "stretch" while also being achievable.

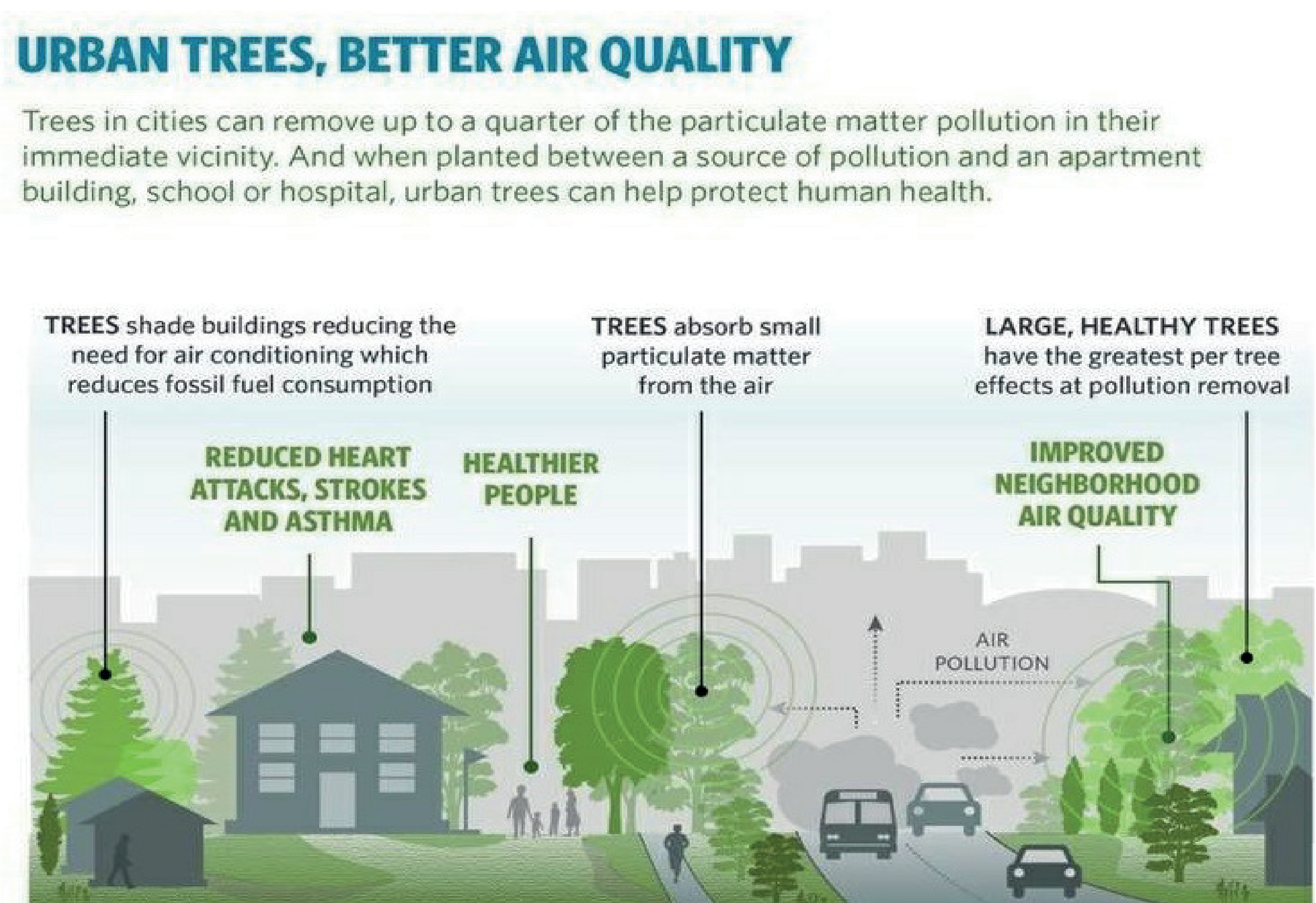
Why Study the Village Wide Tree Canopy?

Trees play a central role in supporting community health, improving air and water quality, helping to reduce building energy use, and supporting climate mitigation.

Community Health Benefit of Trees

Recent studies have shown that sometimes, going to a park, or even looking a single tree can significantly improve a person's health and stress levels. Some doctors have started prescribing parks as a remedy to patients' health issues[1]. Our understanding of the value of trees has been expanded to include mental and physical health benefits.

Trees are critical in filtering air, removing harmful pollutants, such as Carbon Monoxide, particulate matter, and Ground-level Ozone - pollutants that can be toxic at high levels and which can cause asthma and other respiratory impacts.



Trees and community health graphic: Erica Simek Sloniker The Nature Conservancy

1 https://www.washingtonpost.com/national/health-science/why-one-dc-doctor-is-prescribing-walks-in-the-park-instead-of-pills/2015/05/28/03a54004-fb45-11e4-9ef4-1bb7ce3b3fb7_story.html?utm_term=.6720c6d6f545

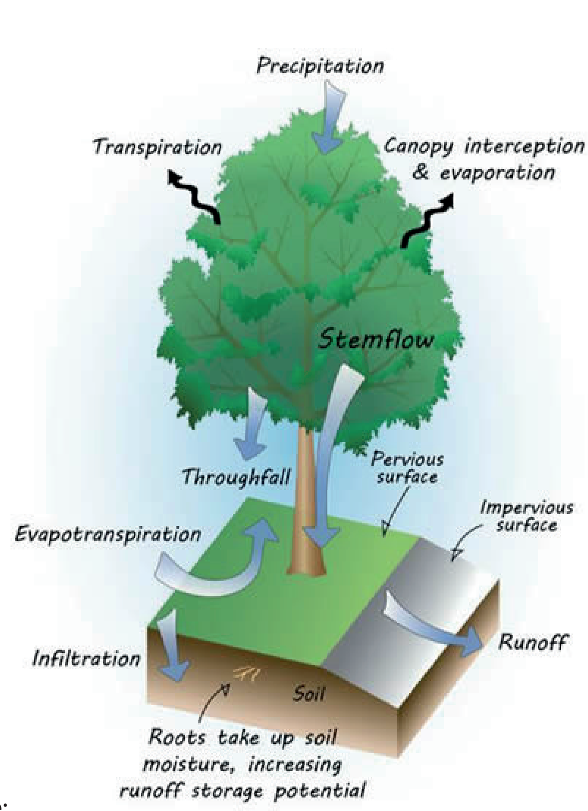
Introduction

Stormwater Management

Every tree catches the rain as it comes down, as well as increasing the soil's capacity to retain water longer. A mature White Oak can intercept up to 12,010 Gallons of water in a single year. This water stays in the leaves until it's absorbed by the tree or evaporates to cool our air. Within an urban environment, this prevents that water from needing to be piped or treated by other stormwater infrastructure.

Trees leaves and branches act to capture and direct water to the tree's roots, providing one of the greatest stormwater benefits: infiltration and storage. Through filtering the water with their roots and soil, pollutants get trapped and diluted which reduces the impact of water pollution.

Additionally, storing all this water makes it available for the tree and other plants around it. This stored water can then be used to grow the tree and evaporate this water back into the air, once more preventing it from impacting our stormwater system.



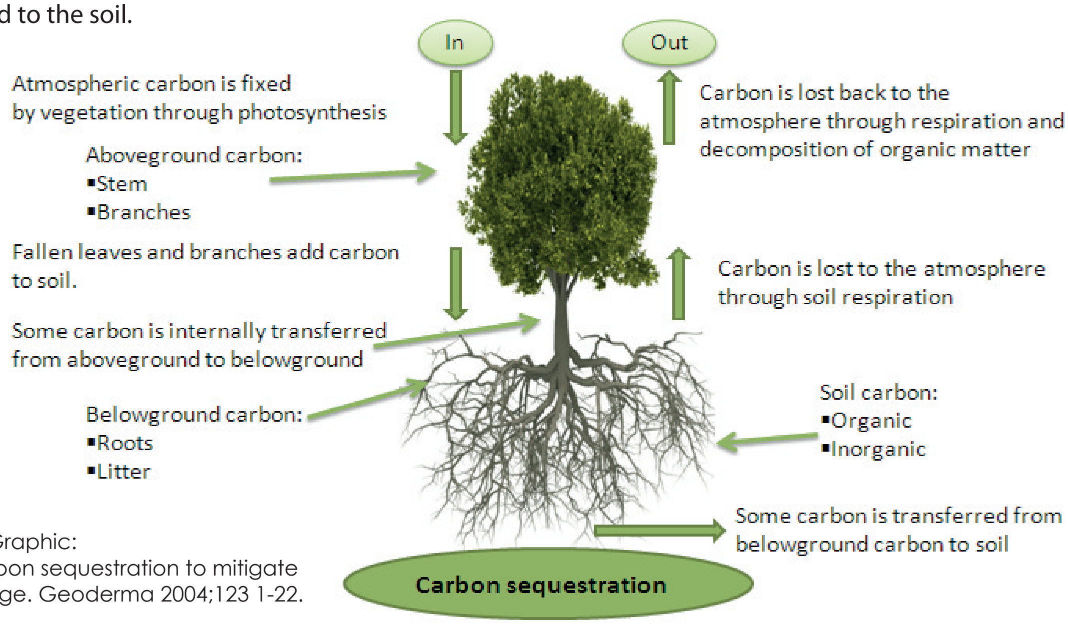
Source and Graphic:
United States Environmental Protection Agency

Pollution Absorption

Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Trees also remove pollution by intercepting airborne particles. (Source: USDA Forest Service)

Carbon Sequestration

Through photosynthesis, trees take in carbon dioxide (CO2) and release oxygen (O2). Trees then transfer the remaining carbon to their trunks, limbs, roots, and leaves as they grow. When leaves or branches fall and decompose, or trees die, the carbon that has been stored will be released by respiration and/or combustion back to the atmosphere or transferred to the soil.



Source and Graphic:
Lal R. Soil carbon sequestration to mitigate climate change. Geoderma 2004;123 1-22.

Heat Island Mitigation

Tree transpiration and tree canopies affect air temperature, radiation absorption and heat storage, wind speed, relative humidity, turbulence, surface albedo, surface roughness and consequently the evolution of the mixing-layer height. These changes in local meteorology can alter pollution concentrations in urban areas. Maximum mid-day air temperature reductions due to trees are in the range of 0.07 to 0.36 degrees F for every percent canopy cover increase. (Source: USDA Forest Service)

Methodology

To arrive at recommended goals, this study looks at the existing extent of tree canopy, grass/shrub, and impervious surface coverage. Coverage for each category are established using aerial imagery and a random point technique using the USDA Forest Service's iTree Canopy Software tool. i-Tree Canopy is a quick and simple method to obtain statistically valid estimates for canopy cover and other land uses based on the point method. Further technical information on i-Tree canopy is included in Appendix 1

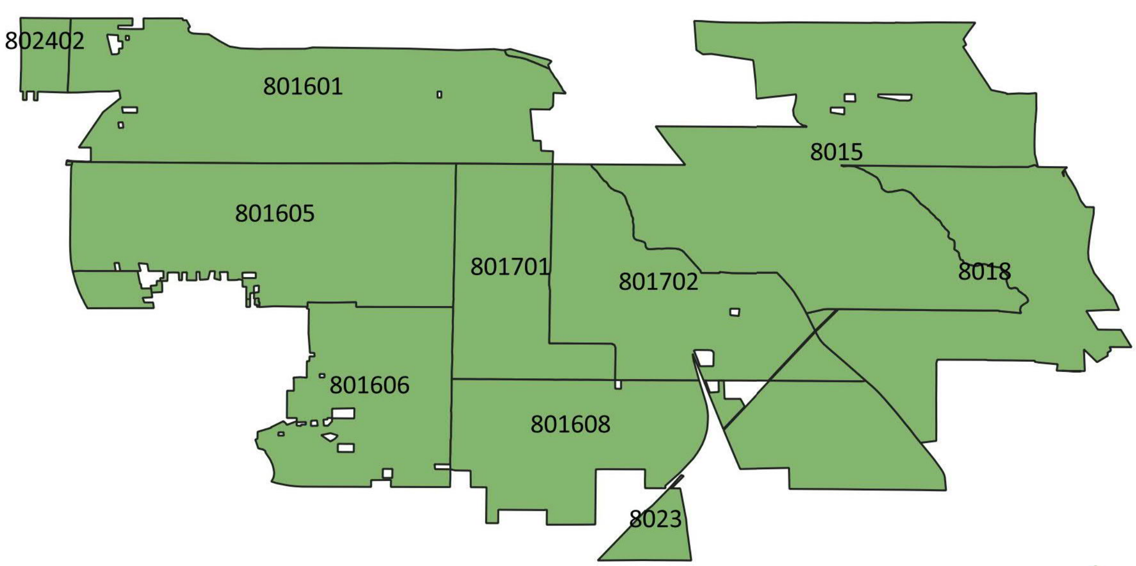
i-Tree Canopy was used to interpret aerial images across the community using 6,138 random points. This overall picture was built up by analyzing the 10 census tracts (see map below) that make up the Village of Northbrook. The point samples averaged 500 plots to each neighborhood until a satisfactory standard error for each land cover category was reached. The standard error (SE) achieved is typically between .2 and 2.2%.

Classification of coverage categories included Tree Canopy, Grass/Shrub/Crop, Water, Impervious Surface Light, and Impervious Surface Dark. The land classes assigned and their descriptions are provided in the table below. Once statistically valid land cover calculations in these classifications were obtained for each neighborhood, calculations were created, by neighborhood, for Tree Canopy Benefits, Tree Canopy Values, and Baselines for community-wide Heat Island Contribution, Stormwater Runoff, and Carbon Sequestration. With these values established a range of potential goals and strategies to protect and improve the environmental benefits of the Village's tree canopy and green infrastructure were identified and are included in the Recommendations Section of this report.

Land Cover Classifications

Cover Class	Description
Tree	Tree, non-shrub
Grass	Grass, Shrubs, Prairie Grass, Cropland
Water	Open Water: Lake, Pond, River; Wetland/Marshes
Impervious - Light	Buildings, Roads, Parking, Sidewalks with light surface
Impervious - Dark	Buildings, Roads, Parking, Sidewalks with dark surface

Northbrook Census Tracts



Section 02

Land Coverage Characteristics

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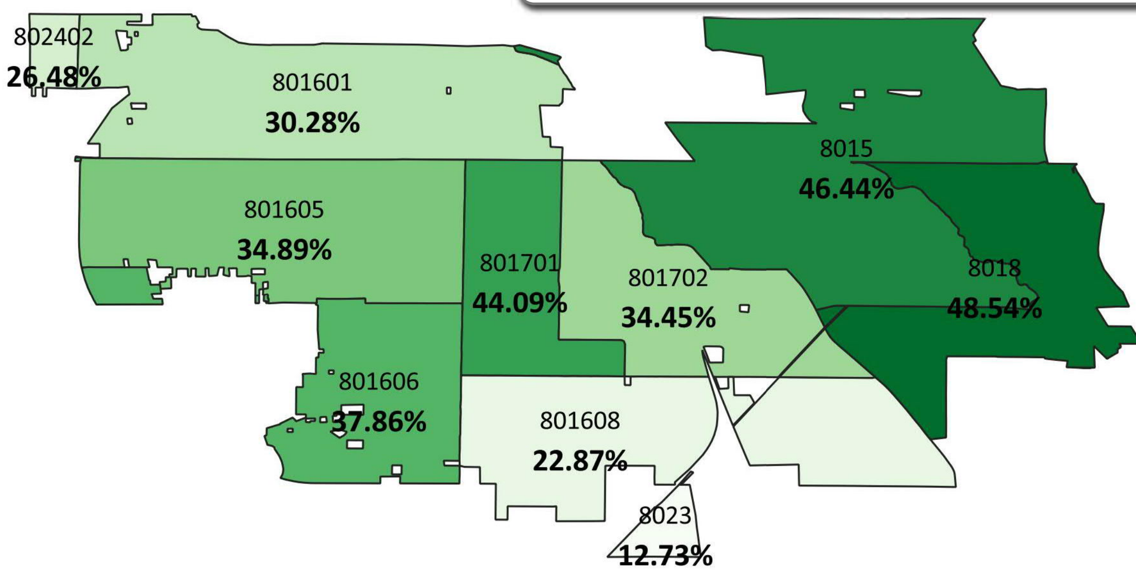
Land Coverage Characteristics

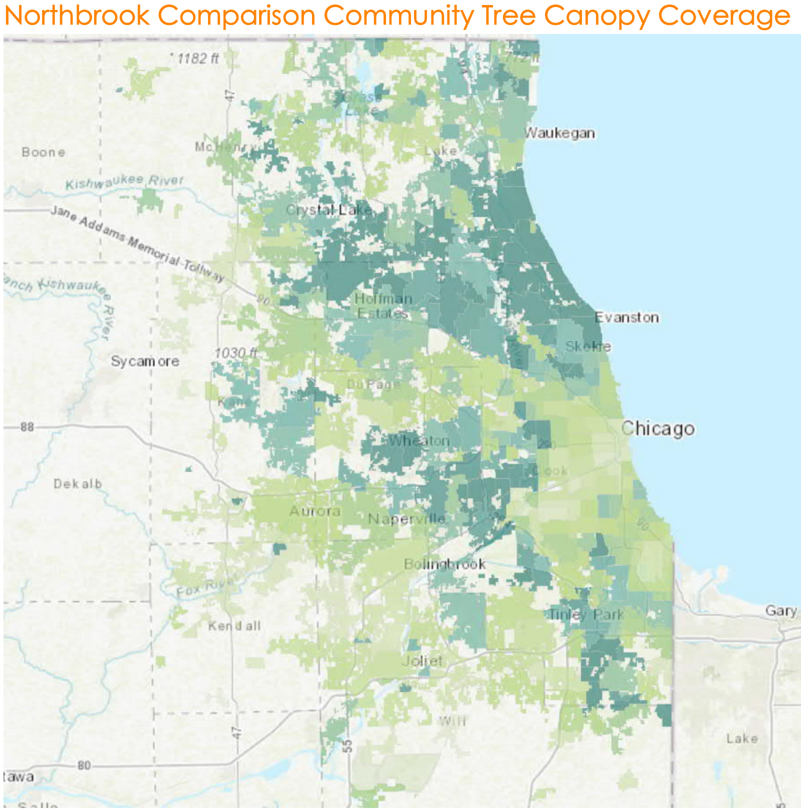
Classification of coverage categories included Tree Canopy, Grass/Shrub/Crop, Water, Impervious Surface Light, and Impervious Surface Dark.

Northbrook Tree Canopy Coverage

Village Average:	37.08%
Census Tract High:	48.5% Tract 8018
Census Tract Low:	12.7% Tract 8023



Northbrook Comparison Community Tree Canopy Coverage



Tree Canopy Coverage

Community	Tree Canopy	% tile
Blue Island	21%	13%
Deerfield	40%	75%
Evanston	38%	50%
Glenview	34%	25%
Highland Park	49%	100%
Oak Park	38%	50%
Park Forest	42%	88%
Northbrook	**37%**	**38%**

Source: Chicago Region Trees Initiative

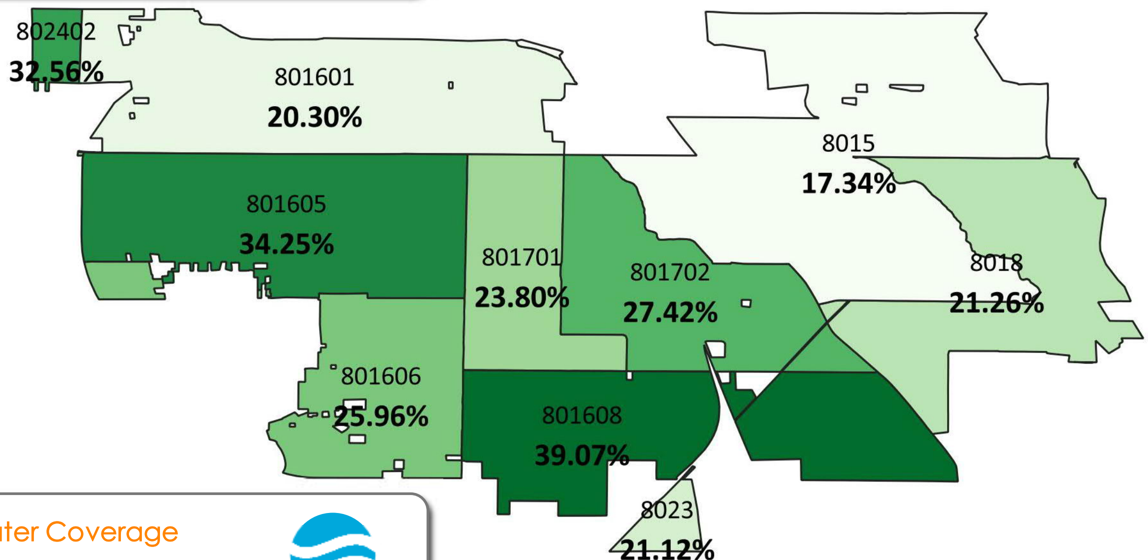
Land Coverage Characteristics

Northbrook Grass/Shrub Coverage

Village Average: 25.5%

Census Tract High: 39.1% Tract 8016.08

Census Tract Low: 17.3% Tract 8015

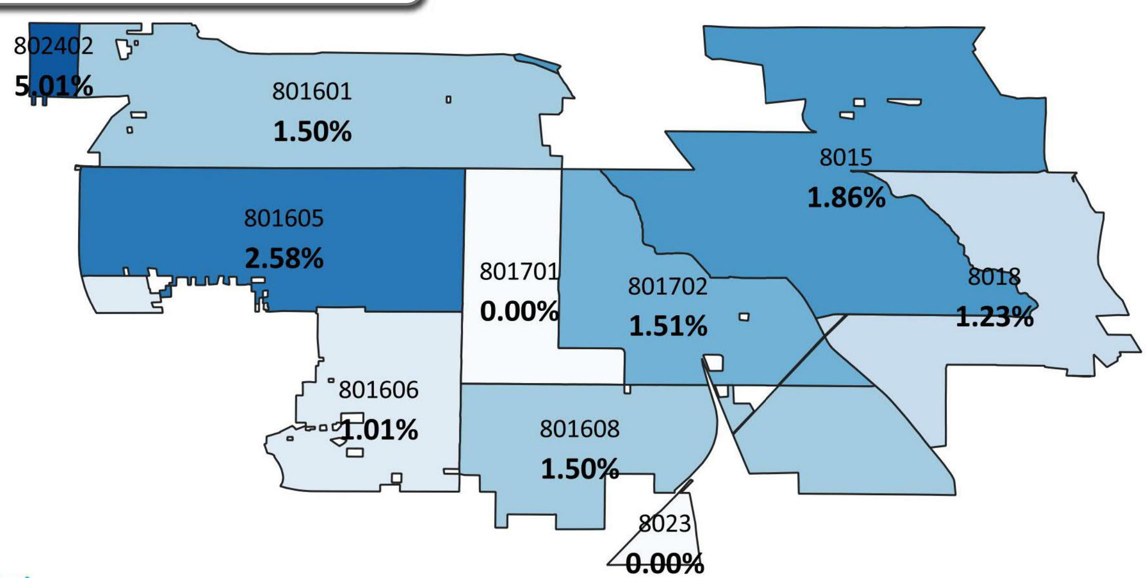


Northbrook Water Coverage

Village Average: 1.6%

Census Tract High: 5.0% Tract 8024.02

Census Tract Low: 0.0% Tract 8017.01

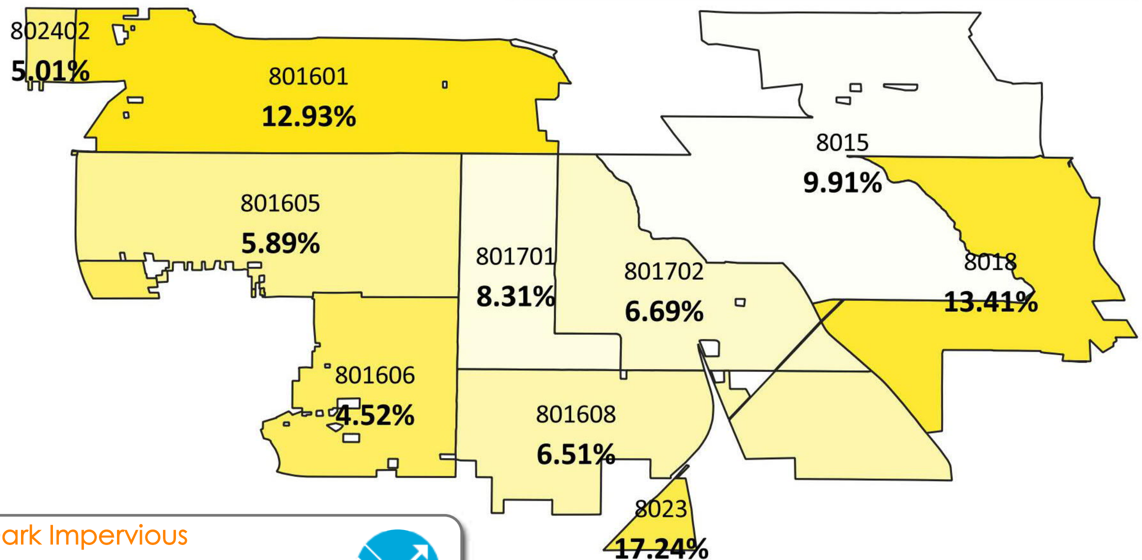


Land Coverage Characteristics

The Impervious Surface classifications include man-made surfaces impervious to water penetration. “Light” impervious surfaces are light colored with higher reflectance values, while “Dark” impervious surfaces are primarily black or dark gray, with high light absorption.

Northbrook Light Impervious Surface Coverage

Village Average:	8.9%
Census Tract High:	17.2% Tract 8023
Census Tract Low:	1.82% Tract 607.42

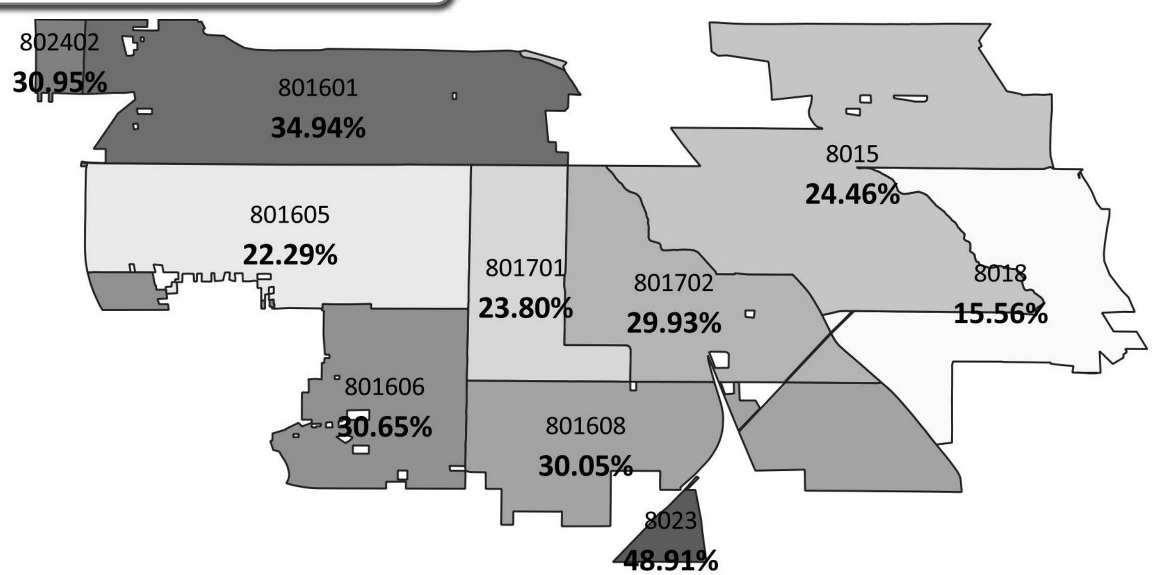


Northbrook Dark Impervious Surface Coverage

Village Average:	26.7%
Census Tract High:	48.9% Tract 8023
Census Tract Low:	15.6% Tract 8018

Northbrook Total Impervious Surface Coverage

Village Average:	35.8%



Section 03

Land Cover Impacts and Benefits

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Land Cover Impacts and Benefits

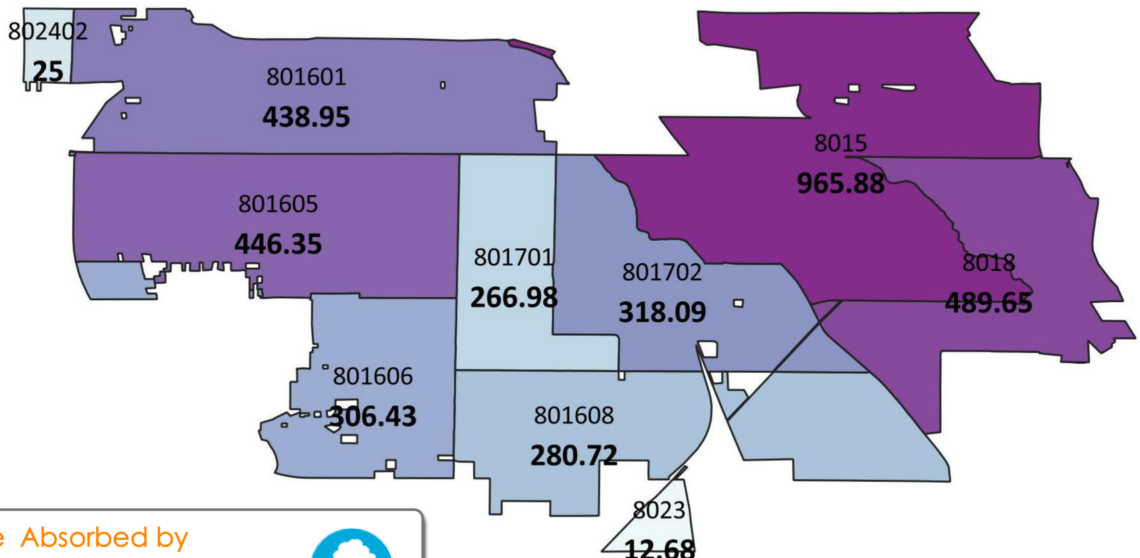
The condition and health of a community's Tree Canopy and green infrastructure and the magnitude and nature of impervious surfaces have meaningful consequences on the area's environment. Estimating the baseline land cover contributions to the community's environment enables the Village to project the impact of potential strategies and to track improvements over time. The following maps in this section diagram the impacts and benefits of the Village's Tree Canopy, grass, and impervious surface coverage.

Pollution Absorption

Air pollution is a major environmental concern in most major metropolitan areas globally. Air pollutants are known to increase incidents of heart disease, asthma, emphysema, and cancer. Meanwhile, global warming projections for Illinois anticipate an increase in the impacts felt by air quality issues. Healthy tree canopies offer the ability to remove significant amounts of air pollutants and consequently improve environmental quality and human health.

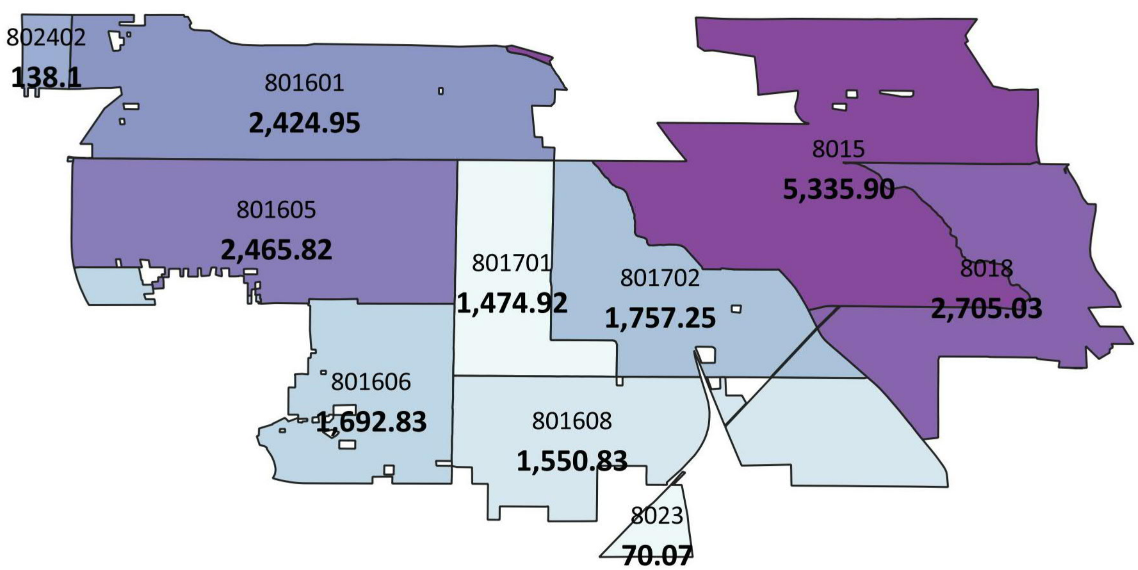
Carbon Monoxide Absorbed by Northbrook Tree Canopy Annually

Village Total: **3,551**



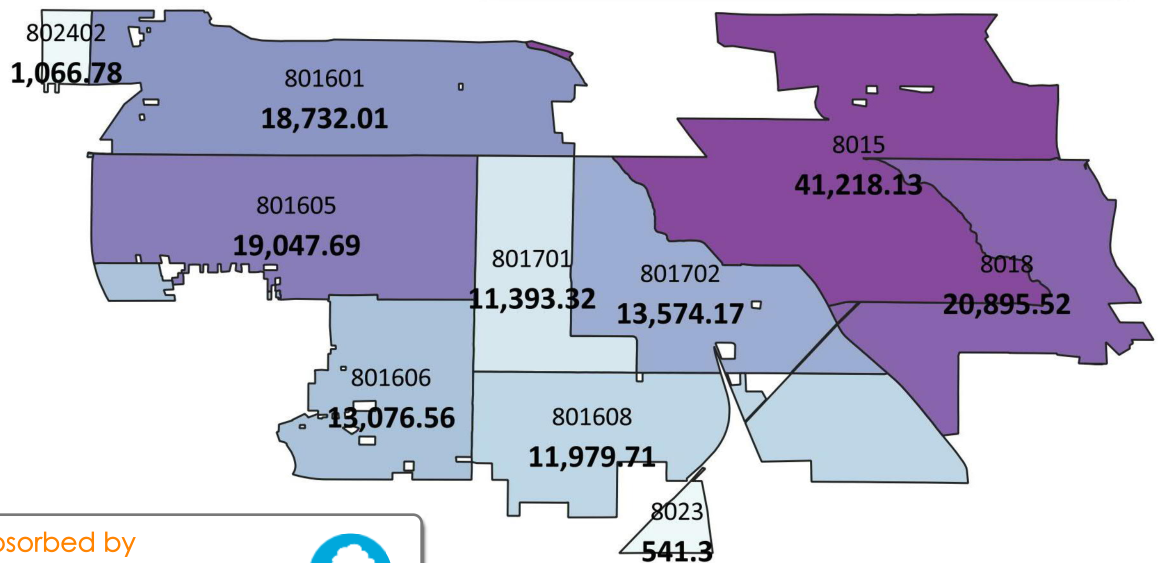
Nitrogen Dioxide Absorbed by Northbrook Tree Canopy Annually

Village Total: **19,616**



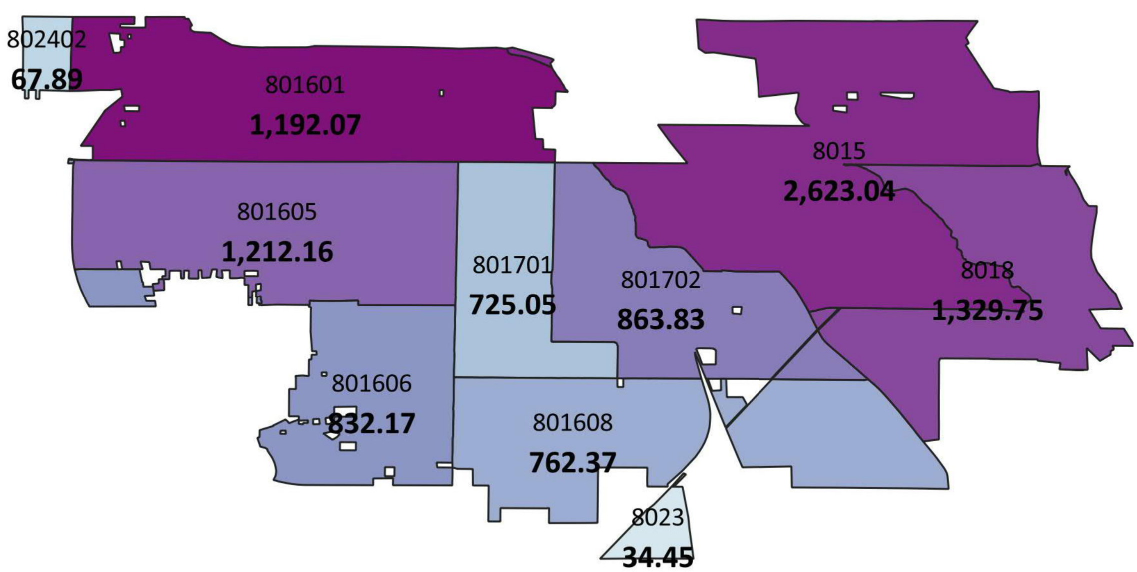
Ozone Absorbed by Northbrook Tree Canopy Annually

Village Total: **151,525**



Sulfur Dioxide Absorbed by Northbrook Tree Canopy Annually

Village Total: **9,643**



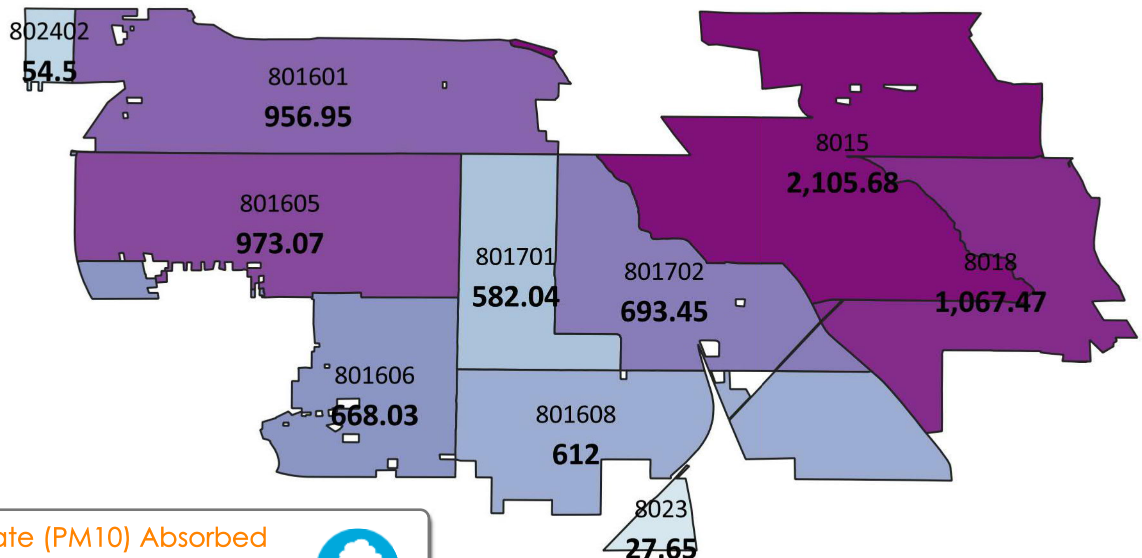
Land Cover Impacts and Benefits

Pollution Absorption - Particulates

Particulate matter pollution is divided into two categories: Fine Particulate (PM2.5) and Course Particulate (PM10). Numerous studies have linked fine particulate pollution with a number of health risks including respiratory disease, asthma, bronchitis, and increased heart disease and heart attacks. Course particulate matter has been shown to aggravate heart and lung diseases and to cause lung damage.

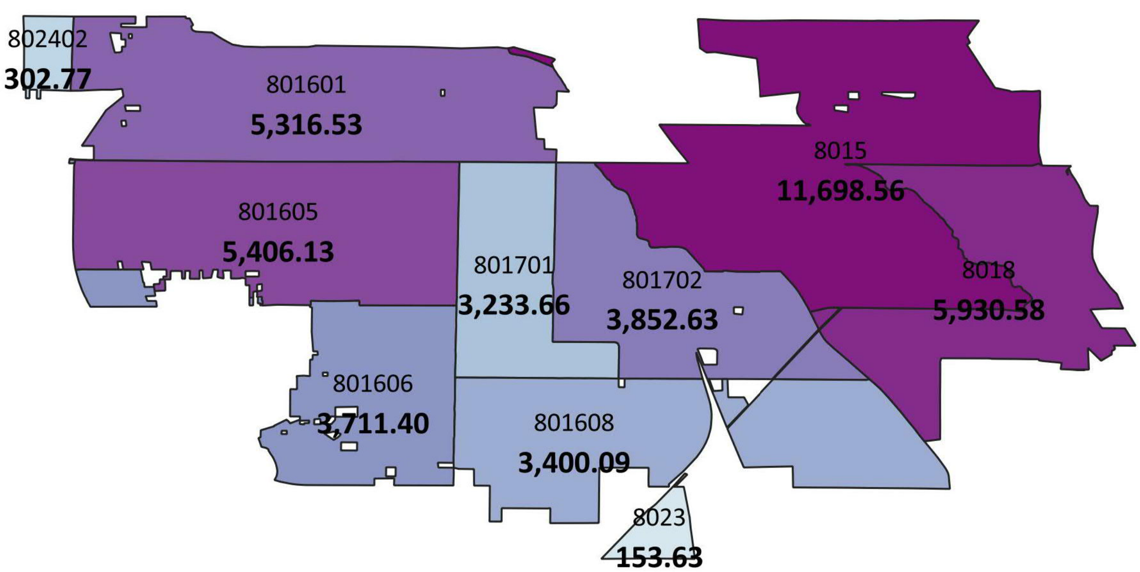
Fine Particulate (PM2.5) Absorbed by Northbrook Tree Canopy Annually

Village Total: **7,741**



Course Particulate (PM10) Absorbed by Northbrook Tree Canopy Annually

Village Total: **43,006**



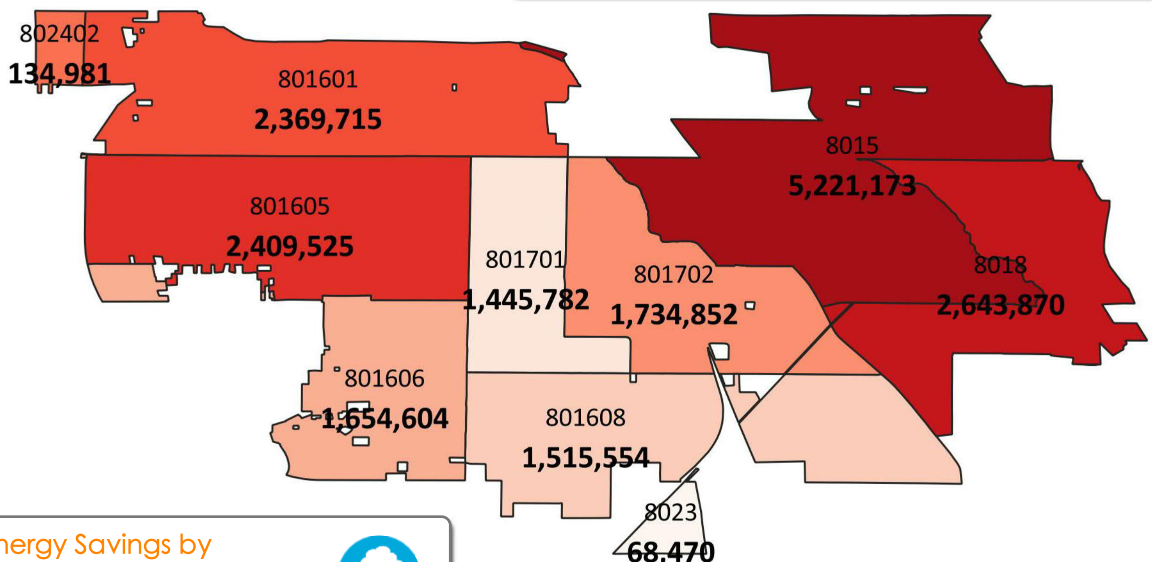
Land Cover Impacts and Benefits

Energy Savings

Trees are important elements in many urban areas and alter the local climates by producing shade, blocking winds and reducing air temperatures through evaporation of water from leaves. To determine exact energy savings values, tree locations and relationships to buildings need to be assessed in detail. Trees which help buildings reduce their energy consumption based on their location - an example is a tree planted on the South side of a building helping to shade the building from hot summer sunlight - are known as energy-affecting trees. At the community-wide scale, however, reasonable approximations can be calculated using average energy affecting trees per acre based on community density type established through the study "*Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States*." Using these averages, we can estimate the total electrical and natural gas savings contributed by Northbrook's tree canopy.
(Note; based on regional averages, it is assumed 25% of electricity consumption is for air conditioning and 80% of natural gas use is for heating buildings.)

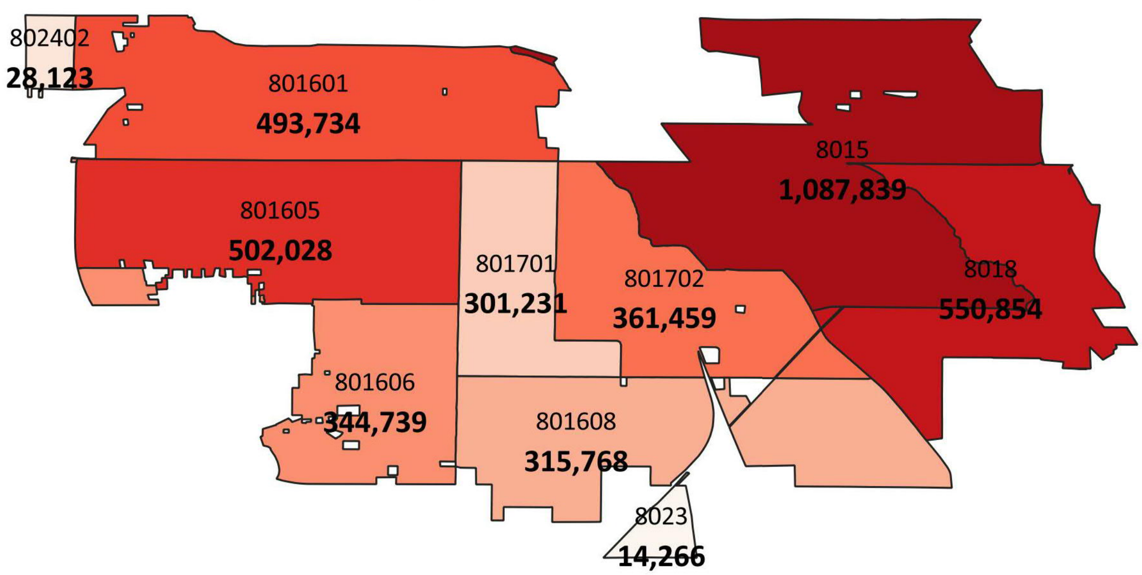
Electrical Energy Savings by Northbrook Tree Canopy Annually

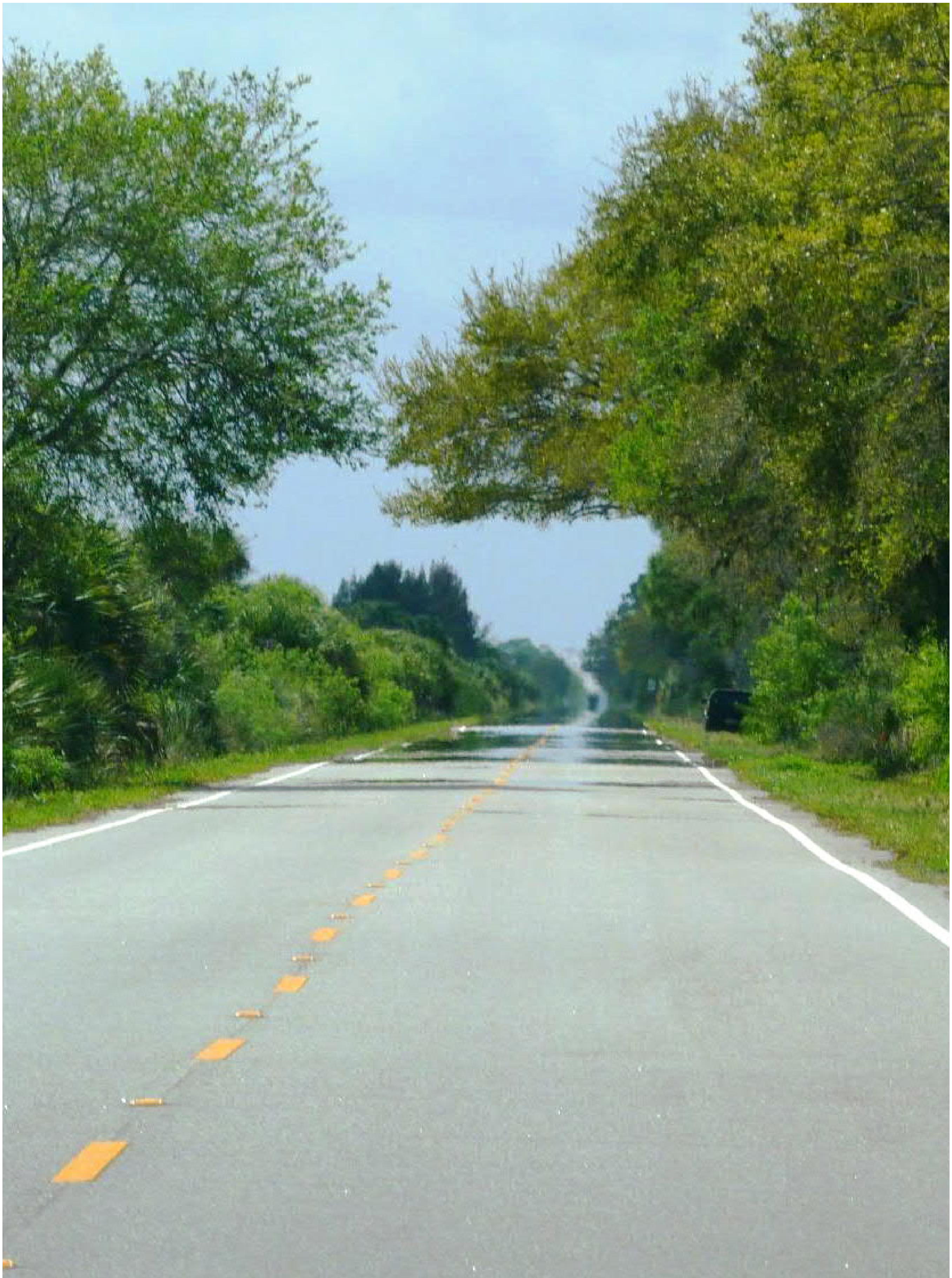
Village Total: **19.198** Million KWH



Natural Gas Energy Savings by Northbrook Tree Canopy Annually

Village Total: **4.0** Million Therms





Land Cover Impacts and Benefits

Heat Island Contribution

Heat island refers to the phenomenon of higher atmospheric and surface temperatures occurring in developed areas than those experienced in the surrounding rural areas due to human activities and infrastructure. Increased heat indicies during summer months due to heat island effects effectively raise human discomfort and health risk levels in developed areas, especially during heat waves.

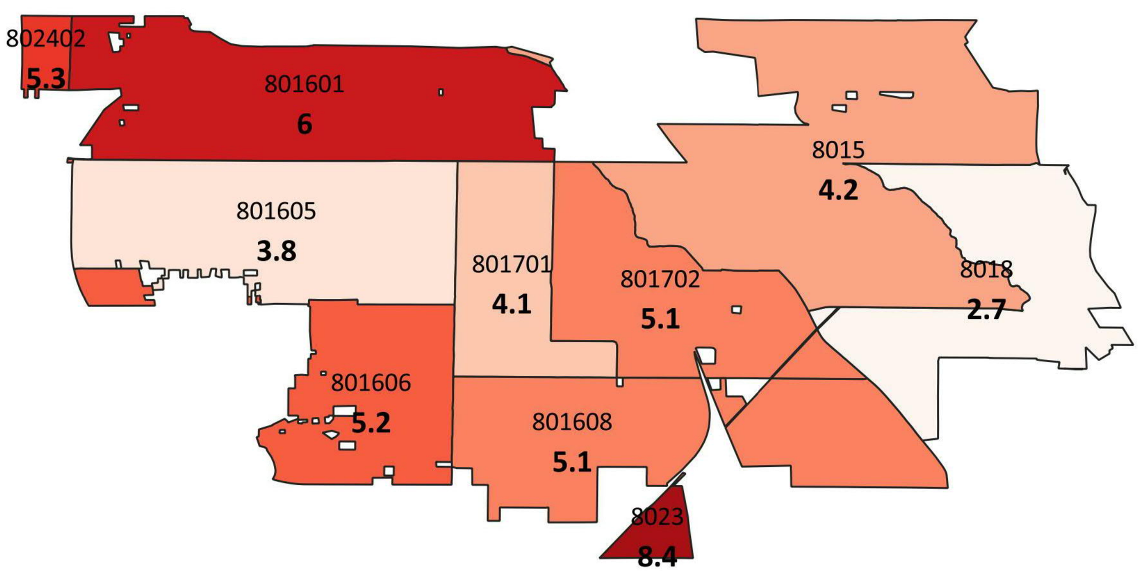
According to NOAA projections, if global greenhouse gas emissions proceed under a "business as usual" scenario, Northbrook may have an annual average of 55 days above 95 degrees. Depending upon humidity, wind, access to air-conditioning, humans may feel very uncomfortable or experience heat stress or illness, or even death on days with such high heat indicies. Consequently, planning and management efforts to address Heat Island effects will be increasingly important to the Village of Northbrook.

Based on a 2006 study done by Minnesota State University and the University of Minnesota*, the relationship between impervious surface percentage of a Village and the corresponding degree of heat island temperature increase can be understood as a ratio. The ratios vary slightly for each season. We've selected the ratio for summer heat island contribution as the effects of heat island on heat related risks are and will become increasingly more acute during summer heat waves. The numbers shown below for each of the Census Tracts represents the increase in summer temperatures a Village would experience if the entire region had impervious land characteristics identical to that Census Tract. These numbers do not necessarily represent the actual summer time temperature difference from tract to tract, but instead are a representation of the comparative level of overall heat island impacts for the overall community.

*_Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery._ Fi Yuan and Marvin Bauer, February 2007

Heat Island Contribution of Northbrook Impervious Surfaces (summer values)

Village Average:	4.6°
Census Tract High:	8.4° Tract 8023
Census Tract Low:	2.7° Tract 8018



Land Cover Impacts and Benefits

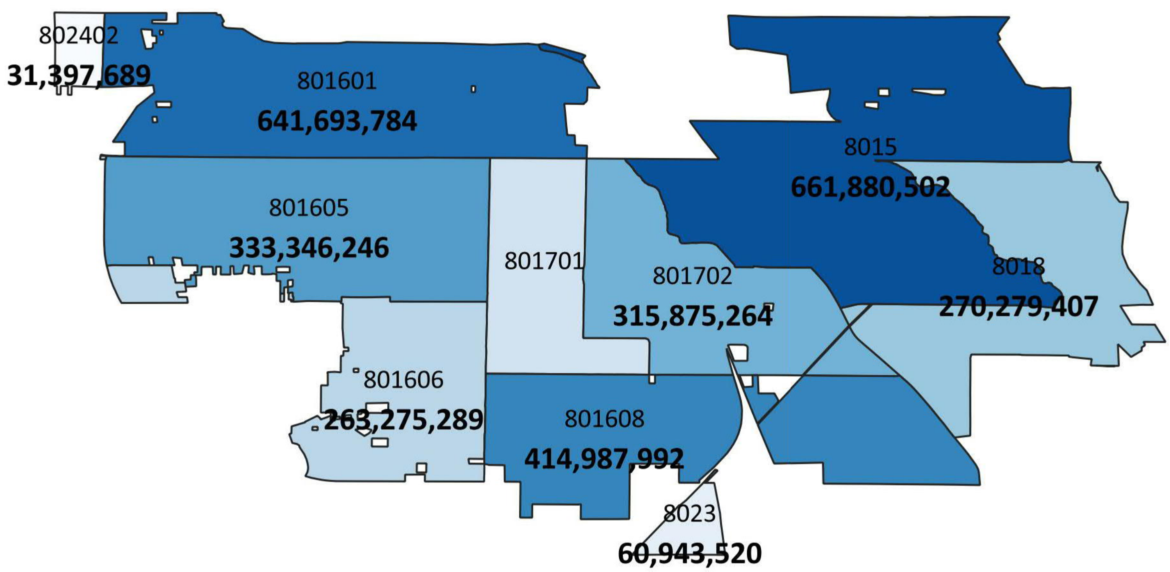
Stormwater Runoff and Management by Green Infrastructure

Increases in impervious cover can dramatically increase the impact of so-called 100-year flood events. Typically, floods in areas of high impervious surfaces are short-lived, but extended flooding can stress trees, leading to leaf yellowing, defoliation, and crown dieback. If damage is severe, tree mortality can occur. In addition, flooding can lead to secondary attacks by insect pests and diseases. Some species are more tolerant of flooding than others.

According to data from National Climatic Data Center and NOAA, Northbrook receives 36.83" of precipitation annually. That total precipitation level and the impervious surface coverages can then be used to estimate the total stormwater runoff values by neighborhood as indicated below.

Total Stormwater Runoff Generated
Northbrook Impervious Surfaces Annually

Village Total: **3.174** Billion Gallons



Stormwater Runoff and Management by Green Infrastructure

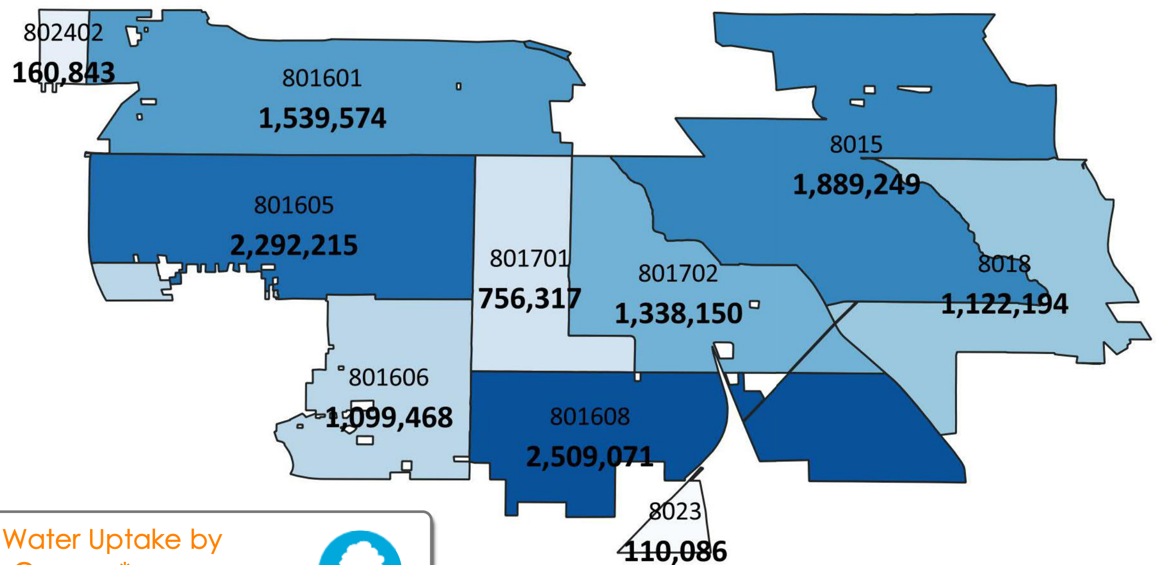
Green Infrastructure such as native grasses, wetlands, and especially trees are a critical stormwater management tool. Healthy green infrastructure within a community can help protect, restore, and mimic the natural water cycle - which has typically been significantly impacted through community development.

To estimate the total stormwater uptake, in gallons, by neighborhood, we have used calculations developed by stormwater sustainability specialist Aarin Teague and US Forestry Service forester Eric Kuehler. Detailed values can only be calculated using detailed soil hydrology data and accurate runoff curve numbers. As that level of detail is not a part of this study, we've used curve number averaged across soil groups A-D for "fair" hydrology and cover conditions. The result should not be considered an accurate indication of total uptake volumes, but rather as an "order of magnitude" analysis tool for comparison between neighborhoods.

The maps on the following page indicate the estimated total annual water uptake of trees and of grass/open land as well as the total green infrastructure water uptake as a percentage of the total stormwater runoff of each neighborhood.

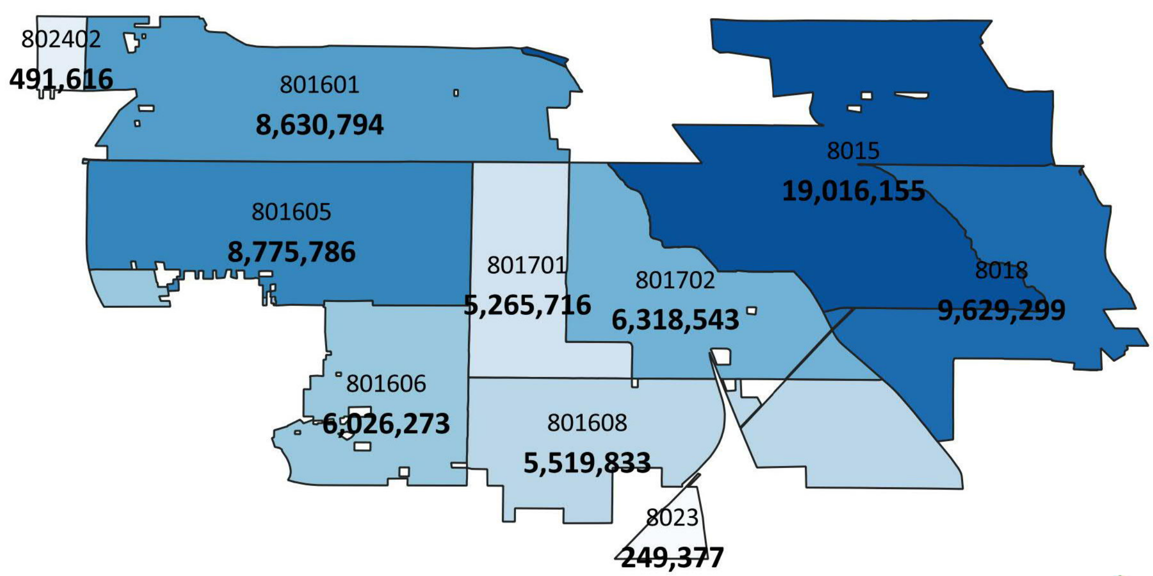
Total Estimated Water Uptake by Northbrook Grass and Greenspace*

Village Total: **12.871** Million Gallons



Total Estimated Water Uptake by Northbrook Tree Canopy*

Village Total: **69.923** Million Gallons

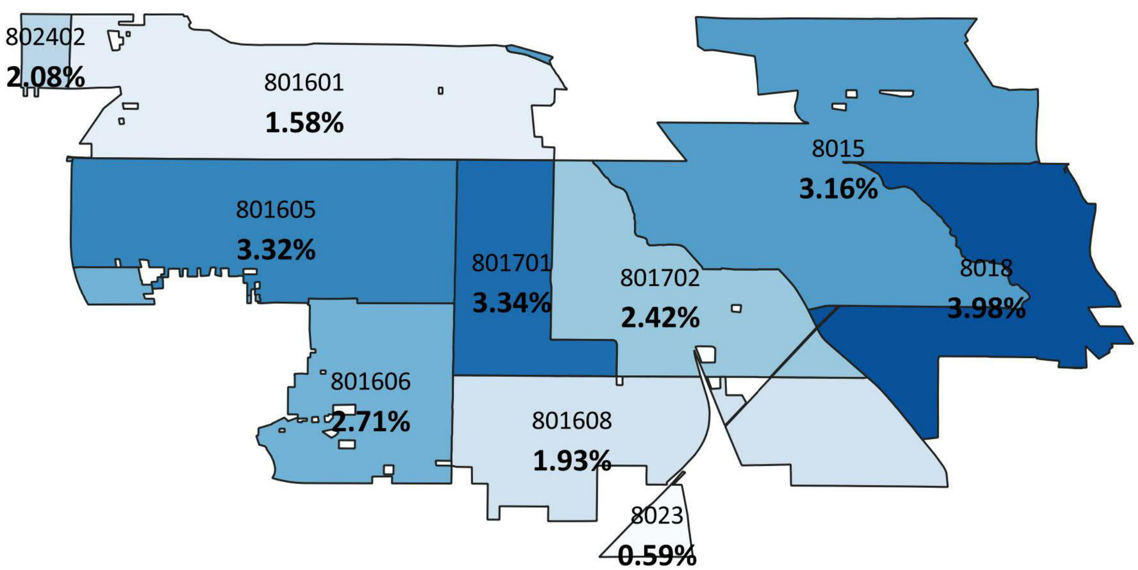


Estimated Water Uptake of Green Infrastructure, as a Percentage of Total Stormwater Runoff

Village Average: 2.2%

Census Tract Low: 0.41% Tract 8023

Census Tract High: 3.56% Tract 8018



* Calculating Water Uptake

Sorptivity, the potential maximum stormwater retention (S in inches), can be used as a surrogate for stormwater function. This term, defined as the maximum amount of rainfall that does not run off, can be calculated as:

where CN is the curve number parameter for forested areas dependent on soil types. This parameter is often interpreted to account for infiltration and rainfall interception by vegetation. When used in conjunction with the area of preserved canopy (square feet), the volume of stormwater capture can be calculated as:

According to USDA tables Curve Number (CN) Values average 62 for tree cover and 86 for shrub/grassland coverage.

Sources: Forester Network, Forester Media; USDA TR-55 Urban Hydrology for Small Watersheds.

Land Cover Impacts and Benefits

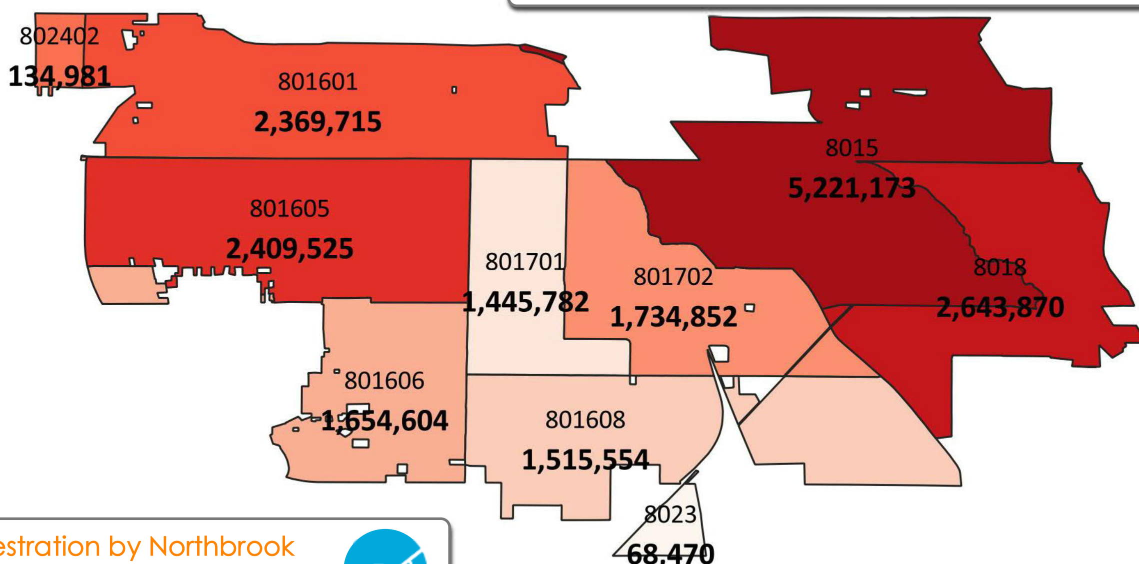
Pollution Absorption - Carbon

By volume, Carbon Dioxide pollution is the largest man-made emission contributing to Global Warming. Throughout the Village of Northbrook, 151,133 metric tonnes of CO_2 pollution is produced by vehicles. This is a volume of man-made greenhouse gas atmosphere equal to over 2.8 billion cubic feet annually.

Carbon Sequestration occurs throughout the growing season of all plants. Long-term carbon storage occurs within the tree/plant structure in the form of the plant material as well as below-grade in the form of soil carbon. 3.663 pounds of CO_2 sequestered produces 1 pound of carbon stored. The following diagrams are the annual carbon sequestration levels by neighborhood provided by the Village's Tree Canopy; the Village's lawns, grasses, and shrubs; the combined annual sequestration totals; sequestration per acre; and sequestration per household.

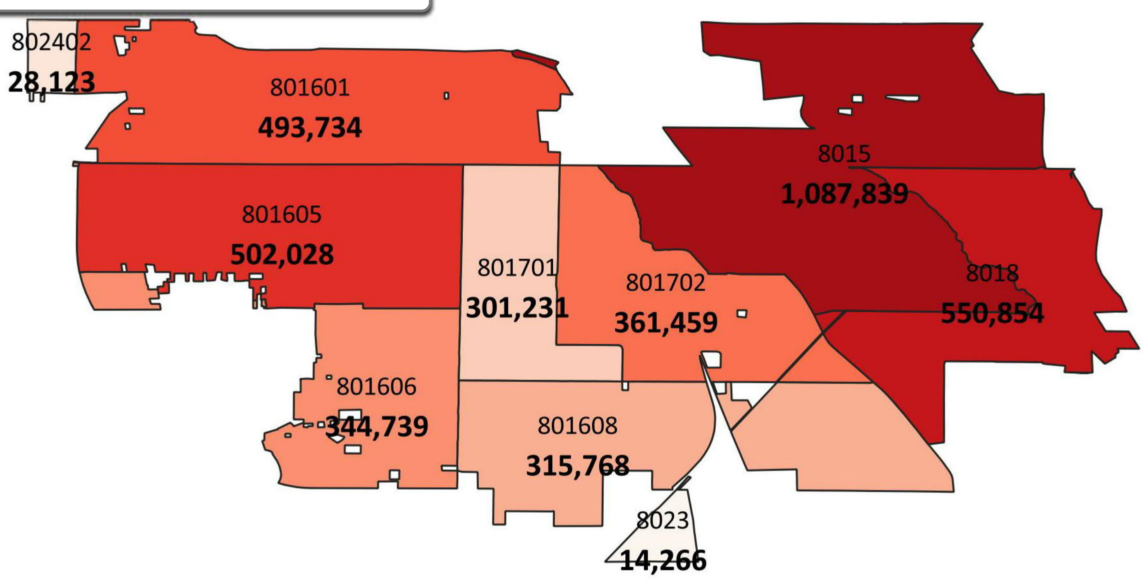
Carbon Sequestration by Northbrook Tree Canopy Annually

Village Total: **8.856** Million Pounds



Carbon Sequestration by Northbrook Grass and Greenspace Annually

Village Total: **11.117** Million Pounds



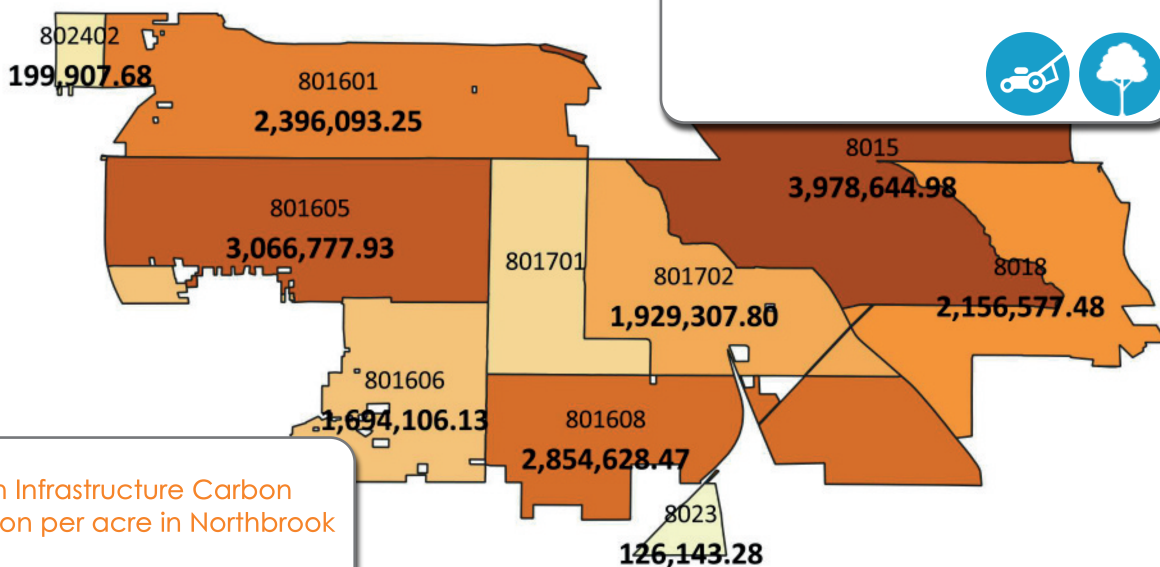
Landcover Impacts and Benefits

Total Green Infrastructure (Trees and Grass) Carbon Sequestration Annually

Village Total: 19.7 Million Pounds

Census Tract Low: 0.12M Pounds Tract 8023

Census Tract High: 3.97M Pounds Tract 8015

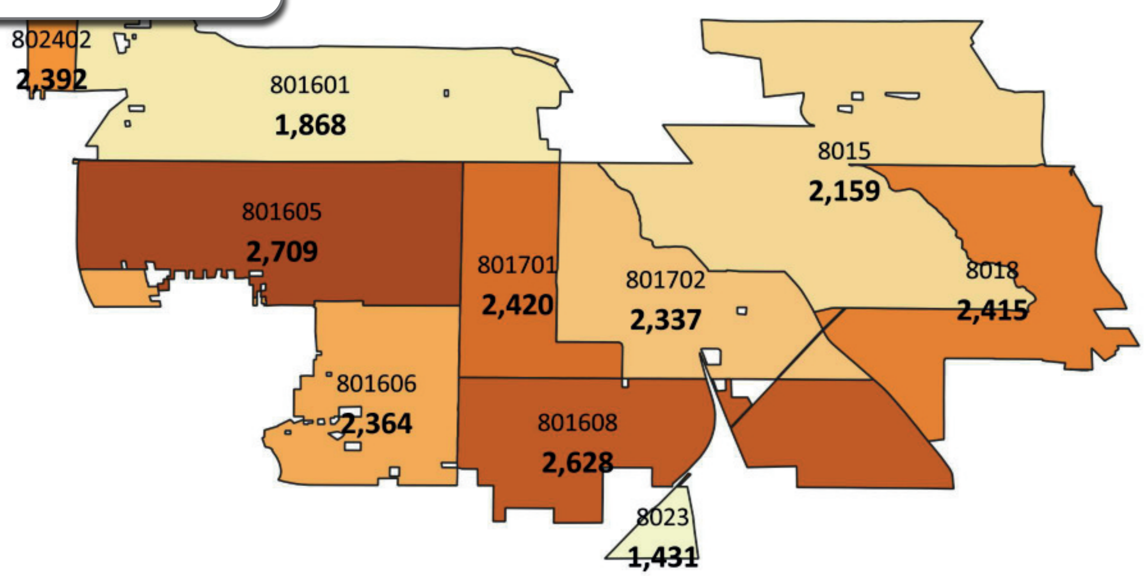


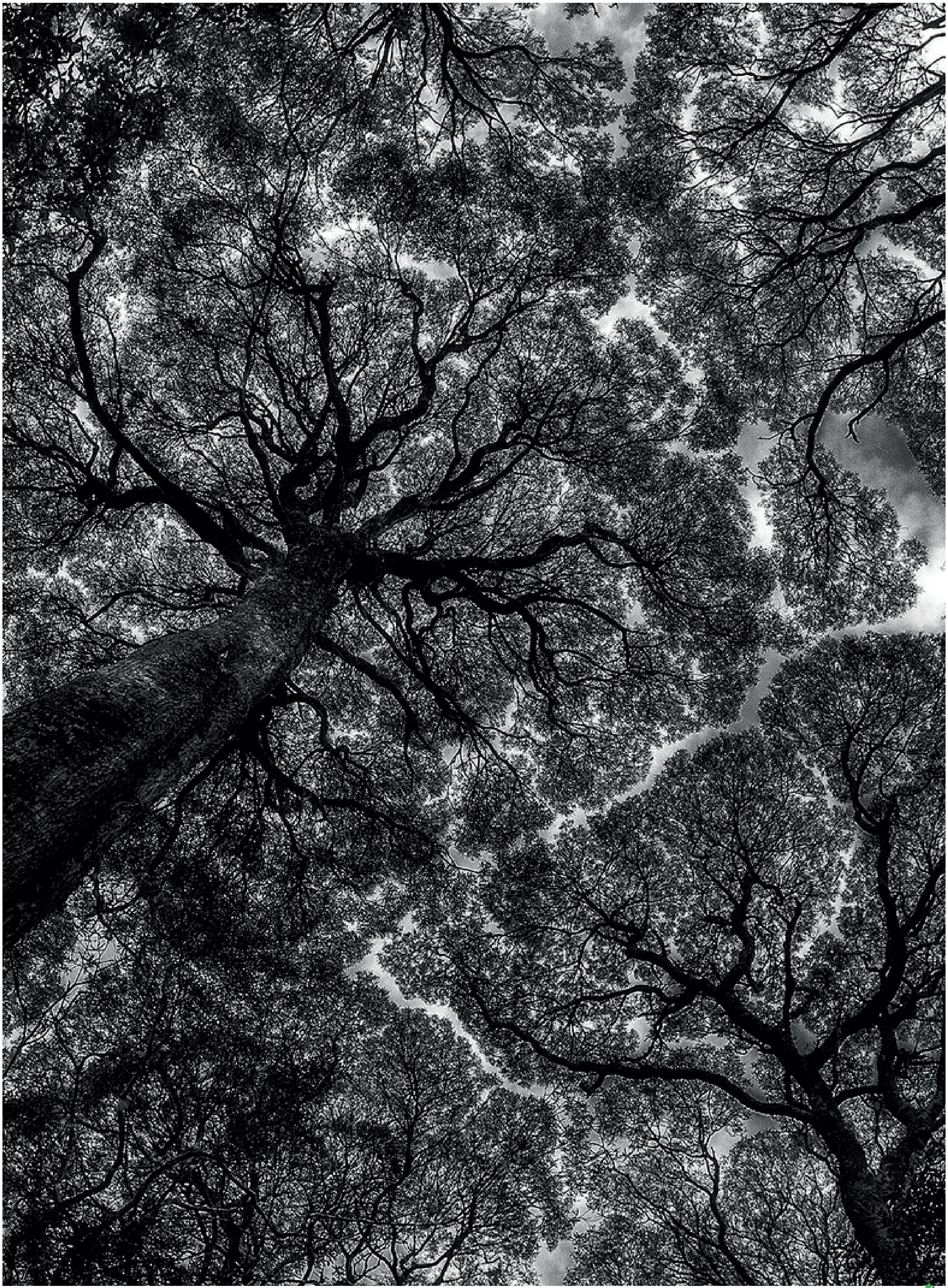
Total Green Infrastructure Carbon Sequestration per acre in Northbrook Annually

Village Average: 1,748 Pounds

Census Tract Low: 1,431 Pounds

Census Tract High: 2,709 Pounds





Section 04

Tree Canopy Economic Value

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Tree Canopy Economic Value

In recent years, several computer models have been developed by the USDA Forest Service and collaborators to assist cities in assessing the value and environmental benefits of their tree resources. Each of the benefits outlined in Section 3 of this report have economic benefit as well as environmental benefit.

Air Pollution Removal Values

The air pollutants estimated are the six criteria pollutants included in Section 3 of this report, defined by the U.S. Environmental Protection Agency (EPA); carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), and particulate matter (PM), which includes particulate matter less than 2.5 microns (PM2.5) and particulate matter greater than 2.5 and less than 10 microns (PM10).

Air pollution removal value estimates are based on procedures detailed in Nowak et al. (2014). This process used local tree cover, leaf area index, percent evergreen, weather, pollution, and population data to estimate pollution removal (g/m2 tree cover) and values ($/m2 tree cover) in urban and rural areas. Current i-Tree Canopy Annual Tree Benefit Estimate values per ton of pollution removed are: CO at $1,333.50; NO2 at $477.89; O3 at $2,443.66; PM2.5 at $91,955.05; SO2 at $163.18; PM10 at $6,268.44, and CO2 sequestration at $35.38.

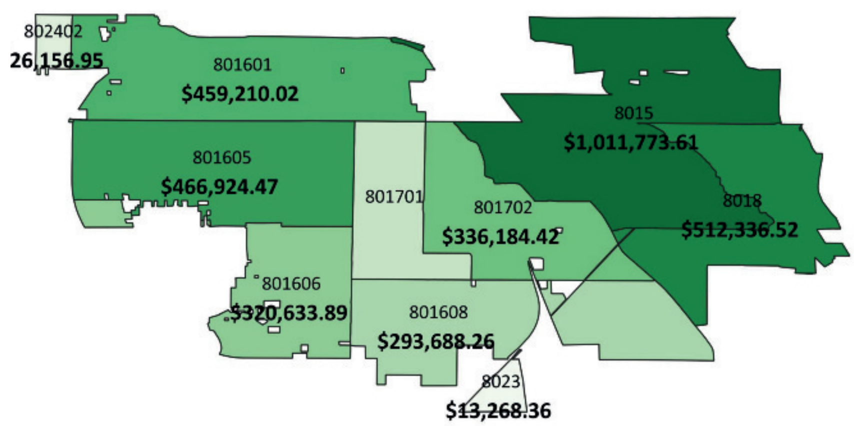
Building Energy Savings Values

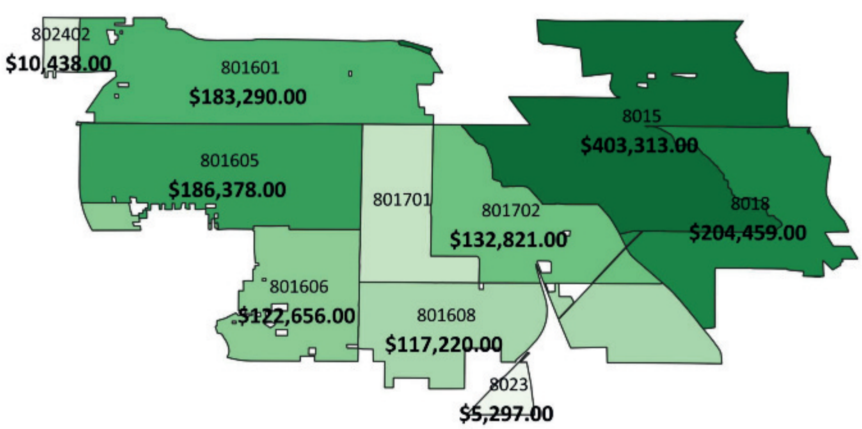
As outlined in Section 3 of this report, building energy savings values can be estimated using average energy affecting tree counts per acre, by community density type, established through the study "Residential building energy conservation and avoided power plant emissions by urban and community trees in the United States." Using these averages, we can estimate the total electrical and natural gas savings contributed by Northbrook's tree canopy.

Building energy savings values are then estimated using an average of $0.10 per kWH of electricity and $0.43 per Therm

Energy Savings Value Provided by Northbrook Tree Canopy Annually

Village Total: **$3,720,344**



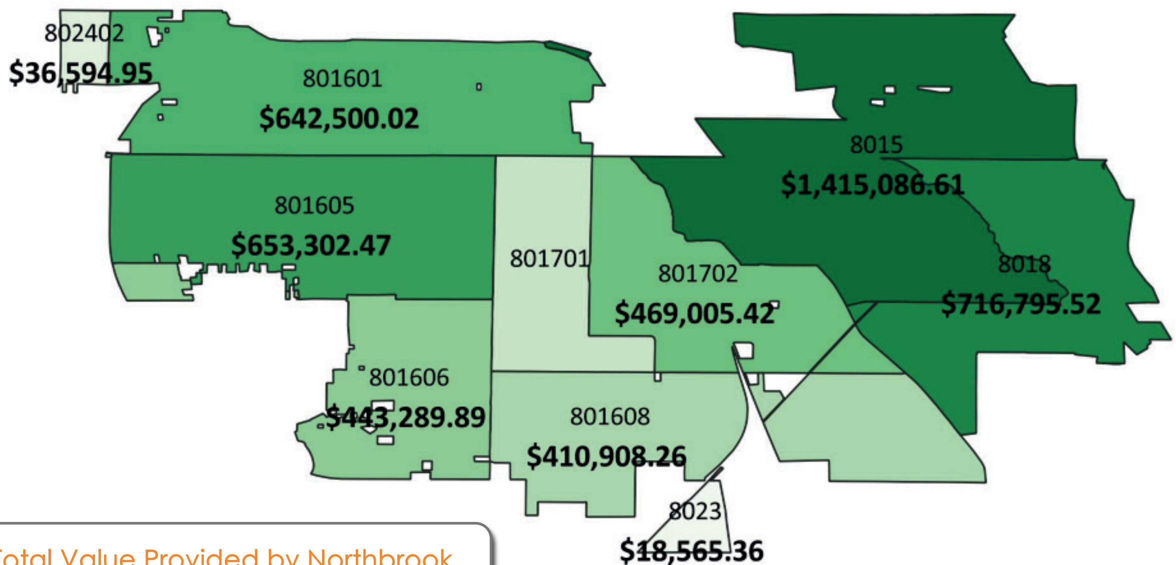


Air Pollution Value Provided by Northbrook Tree Canopy Annually

Village Total: **$1,477,354**

Tree Canopy Economic Value

Total Economic Value combines the total Air Pollution Removal value and Building Energy Savings values. It should be noted that the total land area encompassed by each neighborhood differs. Consequently, the total values shown do not necessarily represent tree canopy equity - ie a very large neighborhood with poor tree canopy coverage may still have a higher total tree canopy value than a small neighborhood with excellent canopy coverage. Tree Canopy value equity will be explored through “value per acre” and “value per household” assessments later in this Section.



Total Value Provided by Northbrook Tree Canopy Annually

Village of Total: $5,197,698

Tree Canopy Economic Value

Equity In Tree Canopy Economic Value

In terms of tree canopy coverage within the Village of Northbrook, equity can be viewed from two perspectives: geographic equity and social equity.

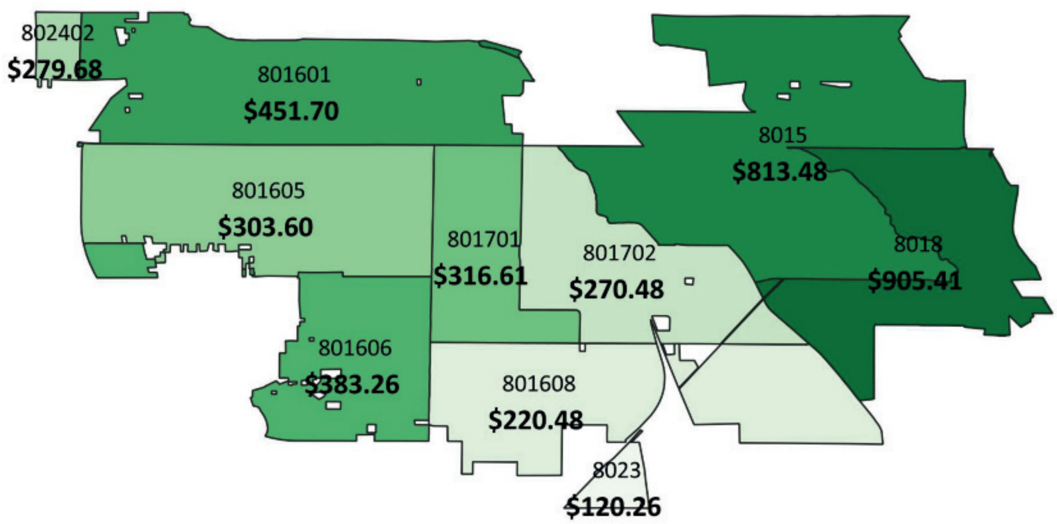
Geographic equity relates to the degree of equitable distribution of tree canopy economic value across land area and is represented in Tree Canopy Economic Value per Acre. Social equity relates to the degree of equitable distribution of tree canopy economic value across the population of the Village of Northbrook and is represented in Tree Canopy Economic Value per Household.

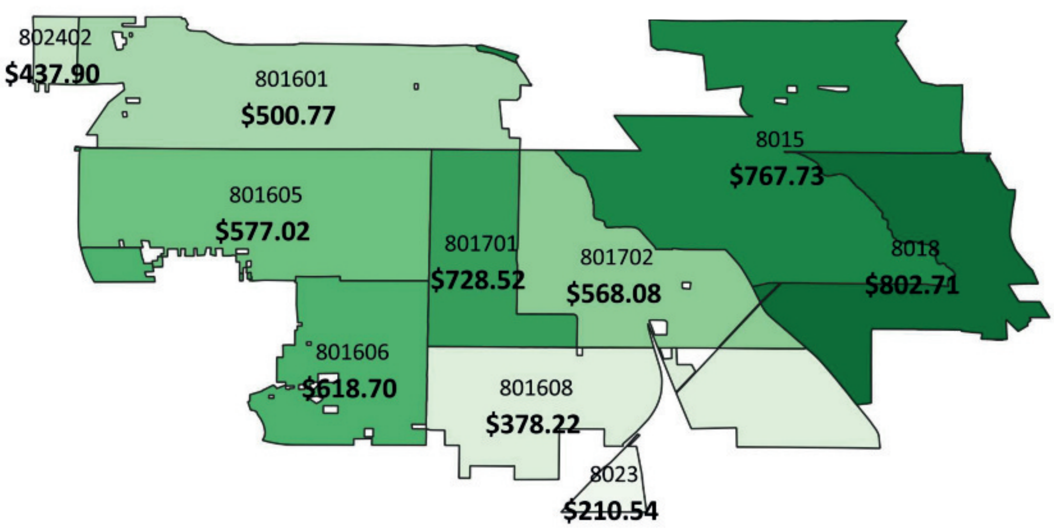
Northbrook Tree Canopy Economic Value per Acre

Village Average:	$612/Acre
Census Tract High:	$803/Acre Tract 8018
Census Tract Low:	$210/Acre Tract 8023

Northbrook Tree Canopy Economic Value Per Household

Village Average:	$420/Household
Census Tract High:	$905/Household Tract 8018
Census Tract Low:	$120/Household Tract 8023





Section 05

Findings

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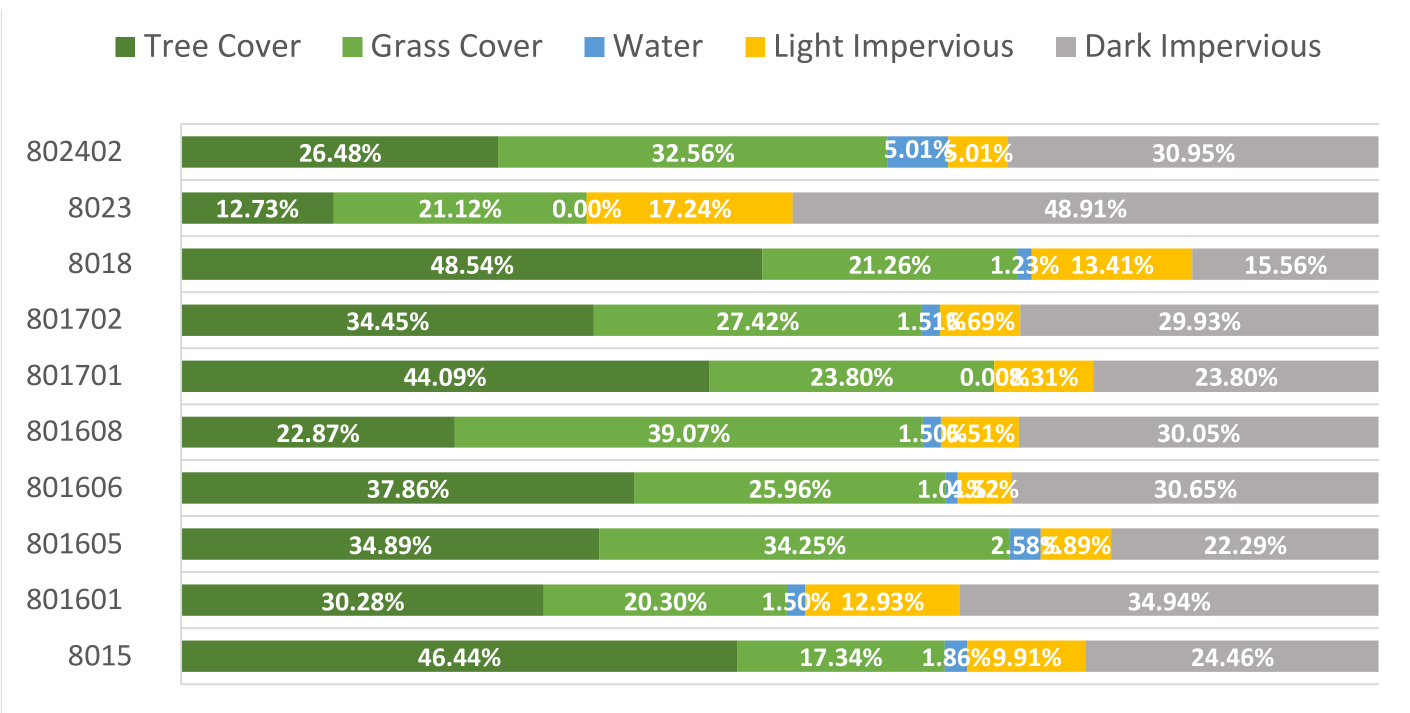
Findings

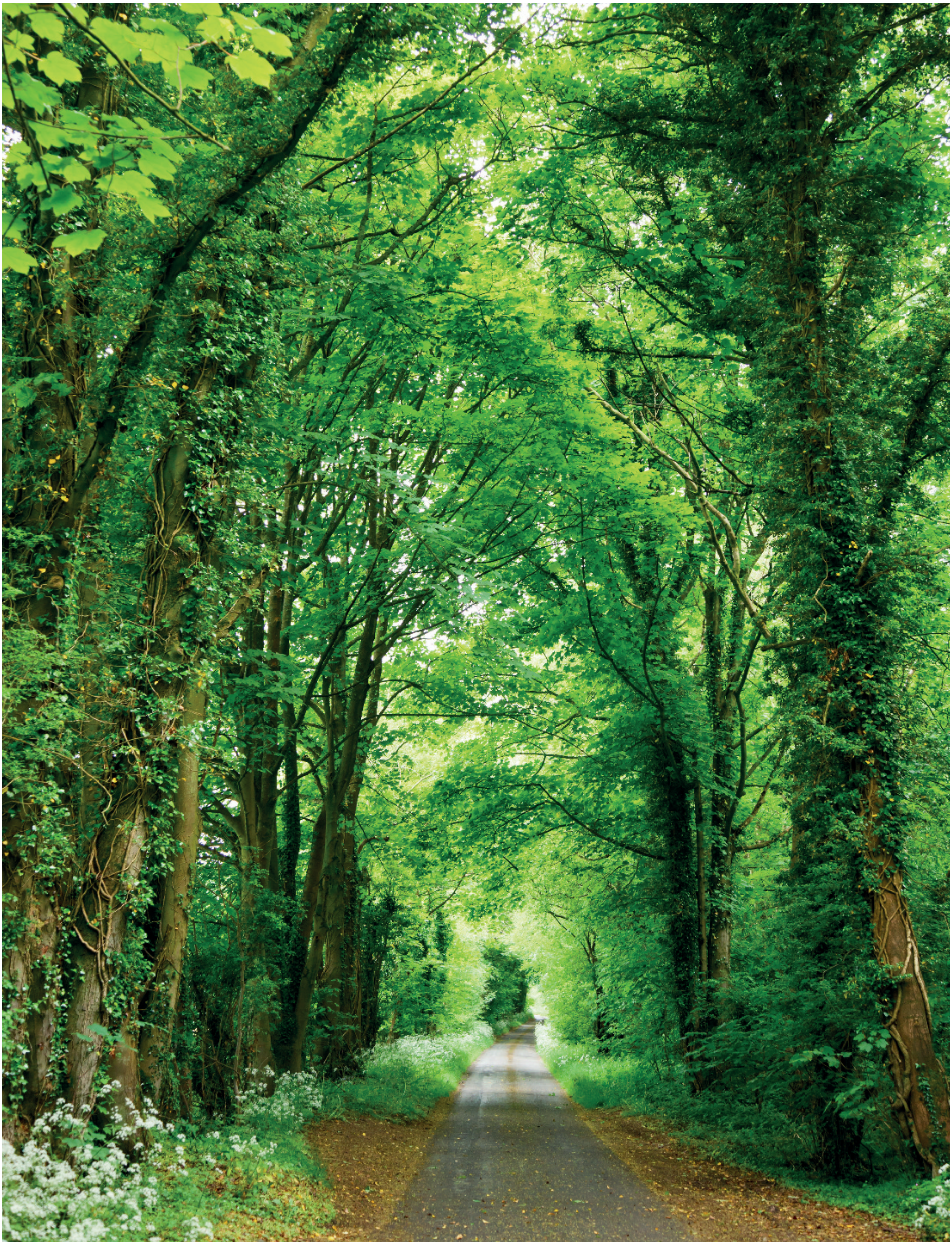
The health of the Village's green infrastructure and the impacts of impervious land cover affect everyone in the Village of Northbrook and Village policies and actions should consider needs of the entire community. As with all planning efforts landcover planning benefits from analysis in order to assist in establishing priorities for efforts. An effort to structure a prioritization should not be seen as an attempt to discard the need to address or improve land cover impacts for any neighborhood of the Village - whether or not it is defined as one of the "priority" neighborhoods. Prioritization, however, is necessary to ensure the greatest impact and effectiveness of limited Village resources.

To assist in prioritization, in the following pages, this report reviews the community Green Infrastructure and Impervious Surface data through "filters" in order to arrive at a recommended prioritization of neighborhoods for policy action. These "filters" are based on the land coverage information detailed in Section 2 of this report.

Side-By-Side Comparison

The bar chart below provides a side-by-side comparison of the of land cover data detailed in Section 2, by Census Tract.





Findings

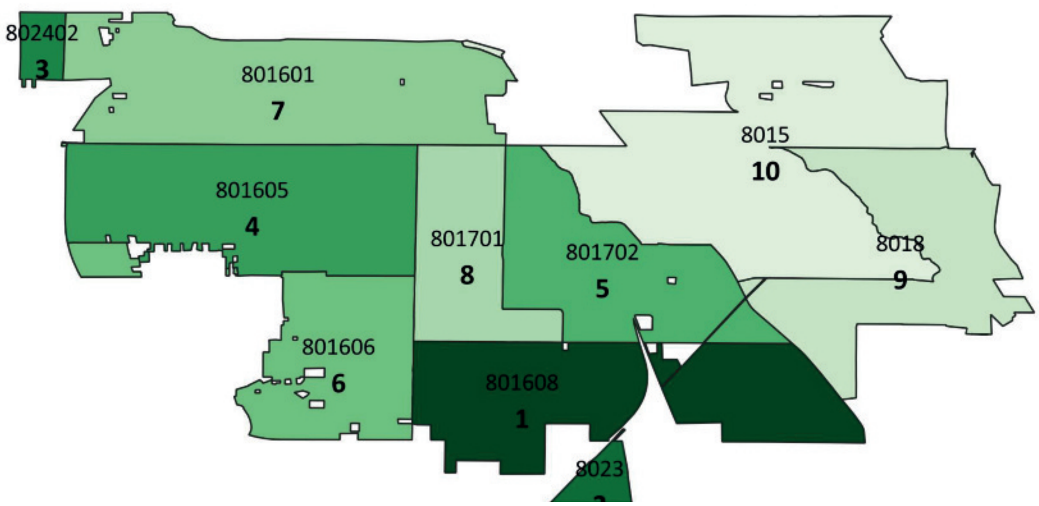
Review Criteria - Green Infrastructure

Prioritization of locations for increased green infrastructure included in this report is based on an equity approach. This approach reviews a range of land cover and demographic characteristics of each neighborhood in an "Environmental Equity Index". This process is based on procedures developed by the USDA Forest Service.

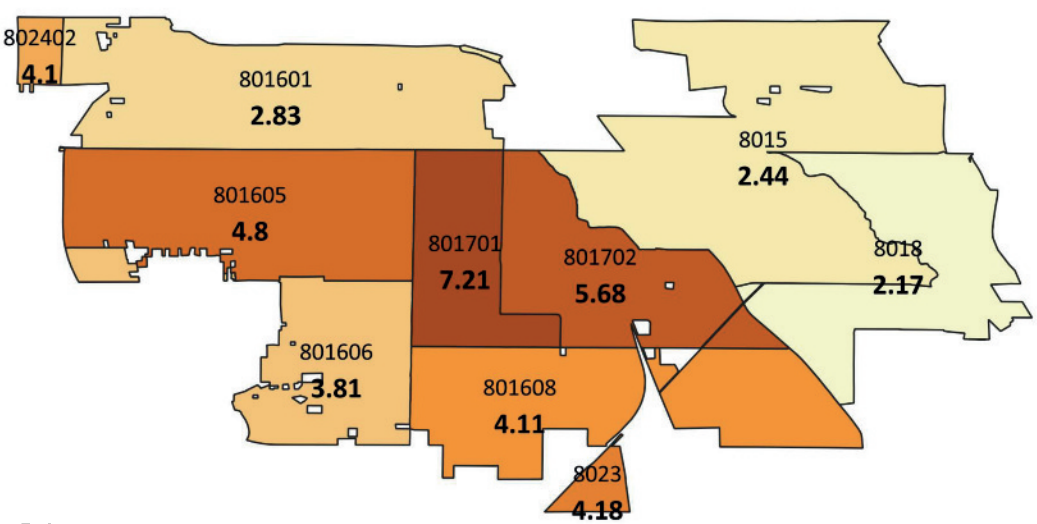
To determine the best locations to plant trees, tree canopy and impervious cover maps developed for this report's Section 2 were used in conjunction with U.S. Census data to produce an index of priority planting areas by neighborhood. Index values were produced for each neighborhood with higher index values relating to higher priority of the area for tree planting. This index is a type of "environmental equity" index with areas with higher human population density, higher economic stress, lower existing tree cover, and higher total tree canopy potential receiving the higher index value. The criteria used to make the index were:

- Tree Stock Potential Levels: Tree stock potential level refers to the ratio of additional tree canopy potential to the total area of potential tree canopy and existing tree canopy coverage. Higher tree stock potential levels represent higher potential and priority for tree planting.
- Population Density: the greater the population density, the greater the priority for tree planting. Population densities shown are estimates based on US Census data by tract. Many census tracts overlap more than one neighborhood. For overlapping census tracts, the population within that census tract was assumed to be evenly distributed with portions of census population attributed to Northbrook neighborhoods in proportion to census tract's land area within each neighborhood.
- Economic Stress Density: The social, economic, and environmental benefits of a robust tree canopy are a benefit to all community residents, however, those living under economic stress are both more likely to live in areas with lower tree canopy coverage as well as those for whom the benefits have the largest positive impacts. Higher economic stress density values represent higher potential for increasing environmental equity of tree canopy cover.
- Tree Canopy per Capita: Lower existing tree canopy per capita means a neighborhood has a higher potential for added benefit for increased tree canopy. Higher index values relate to higher potential for increased trees per capita.

Northbrook - Priority Tree Canopy Increase Based on Tree Stock Potential
(Lower values represent higher opportunity)



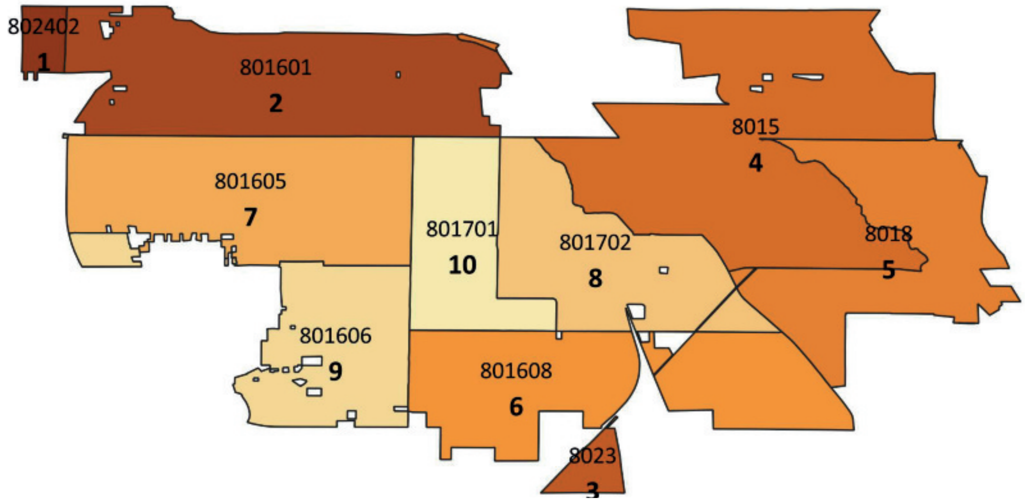
Northbrook - Priority Tree Canopy Increase Based on Population Density
(Lower values represent higher opportunity)



Findings

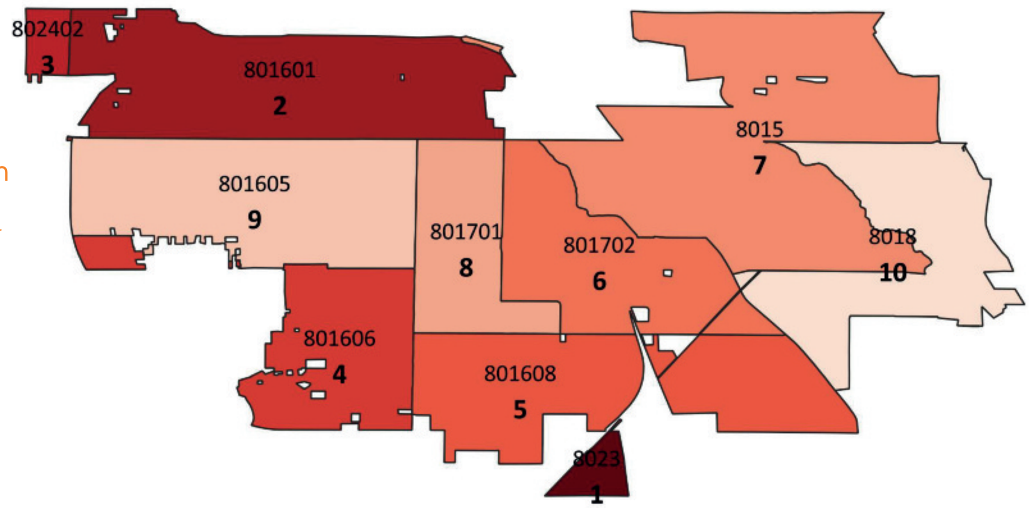
Northbrook - Priority Tree Canopy Increase Based on Low Income Population

(Lower values represent higher opportunity)



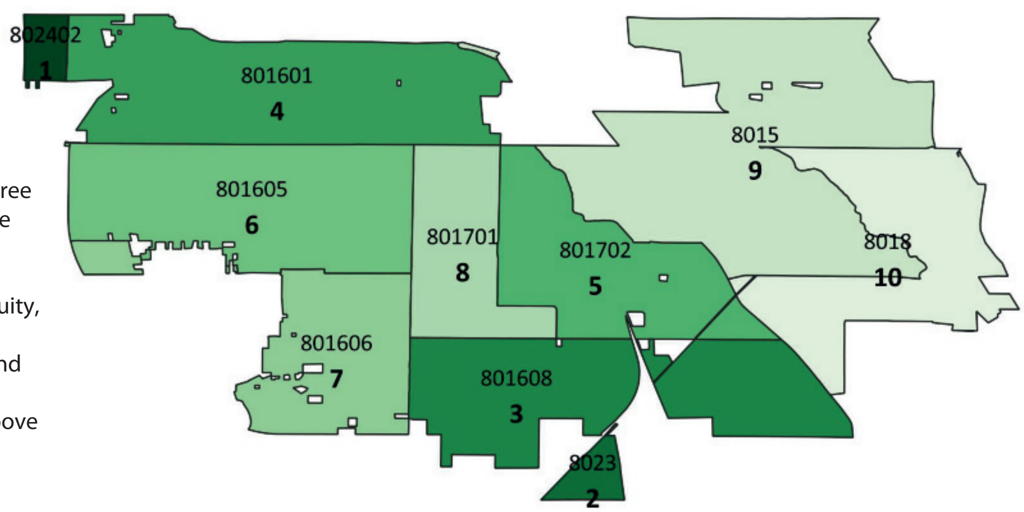
Northbrook - Priority Tree Canopy Increase Based on Heat Island Mitigation Need

(Lower values represent higher opportunity)



Northbrook - Weighted Priority Tree Canopy Increase

(Lower values represent higher Priority)



The weighted prioritization for tree canopy increase looks to balance the potential for increased tree canopy with the opportunity to improve tree canopy benefit equity, potential to positively impact as many households as possible, and the need for mitigation of heat island impacts. The priorities above are weighted as follows:

Potential for new trees: 20%
Population density: 20%
Low Income Population (equity adjustment): 30%
Heat Island mitigation need: 30%

Section 06

Recommendations

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Recommendations

As summarized at the end of this Section, this report recommends goals for

- Lawns and Grasslands
- City Wide Tree Canopy
- Heat Island Mitigation

The following are detailed recommendations for Village Wide Tree Canopy coverage goals for the Village of Northbrook from the research documented in this report.

Recommendations - Tree Canopy Coverage Goal for 2040

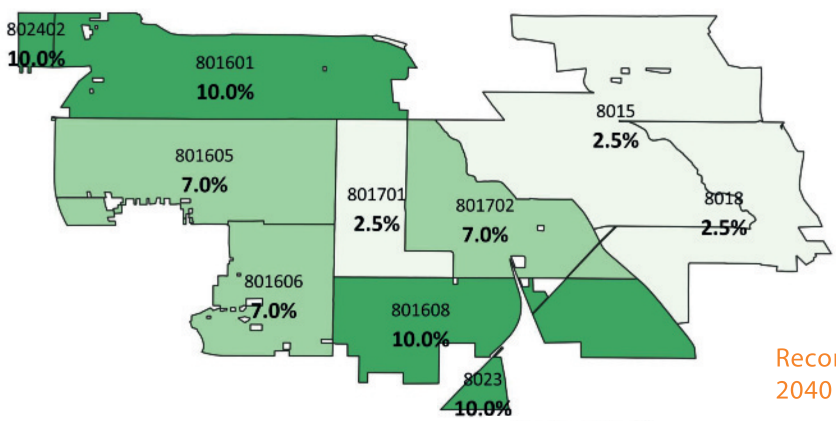
Total tree canopy coverage goals are central to long-range land cover goal recommendations for the Village of Northbrook. In support of an "Environmental Equity" approach to tree canopy goalsetting, as outlined in the Findings Section of this report, identification of long-term tree canopy coverage goals includes consideration of each neighborhood's Tree Stock value (the amount of existing tree canopy compared to available land for tree canopy coverage), population densities, economic stress densities, and heat island mitigation need.

The recommended goals for 2040 Tree Canopy coverage are based on individual neighborhood calculations, corresponding to the neighborhood prioritizations outlined in the Findings Section of this report. 2040 Tree Canopy goals are first calculated as Tree Stock goals, that is, goals calculated against the total potential Tree Stock area (existing tree canopy area + existing lawn/grass/shrub area), with a progressive percentage increase goal based on neighborhood prioritization. As the total Tree Stock area (potential tree canopy) varies by neighborhood, the resulting Tree Canopy percentage varies for each neighborhood.

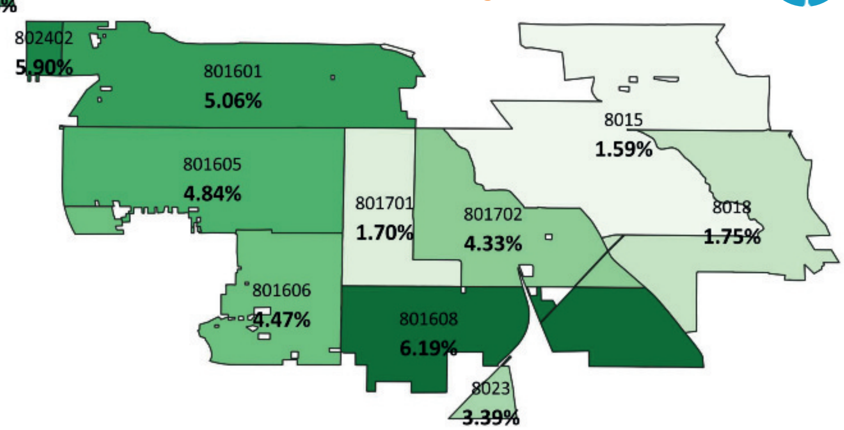
The recommended Tree Stock increase goals are:
For neighborhoods in the top 1/3rd Neighborhood Priority Ranking: 10%
For neighborhoods in middle 1/3rd Neighborhood Priority Ranking: 7%
For neighborhoods in bottom 1/3rd Neighborhood Priority Ranking: 2.5%

The recommended long-term (2040) increase in Tree Stock values, and the increase in Tree Canopy coverage those represent by neighborhood are shown below.

Recommendations
Tree Stock Increase Goal for 2040



Recommendations
2040 Increase target over current UTC



Recommendations

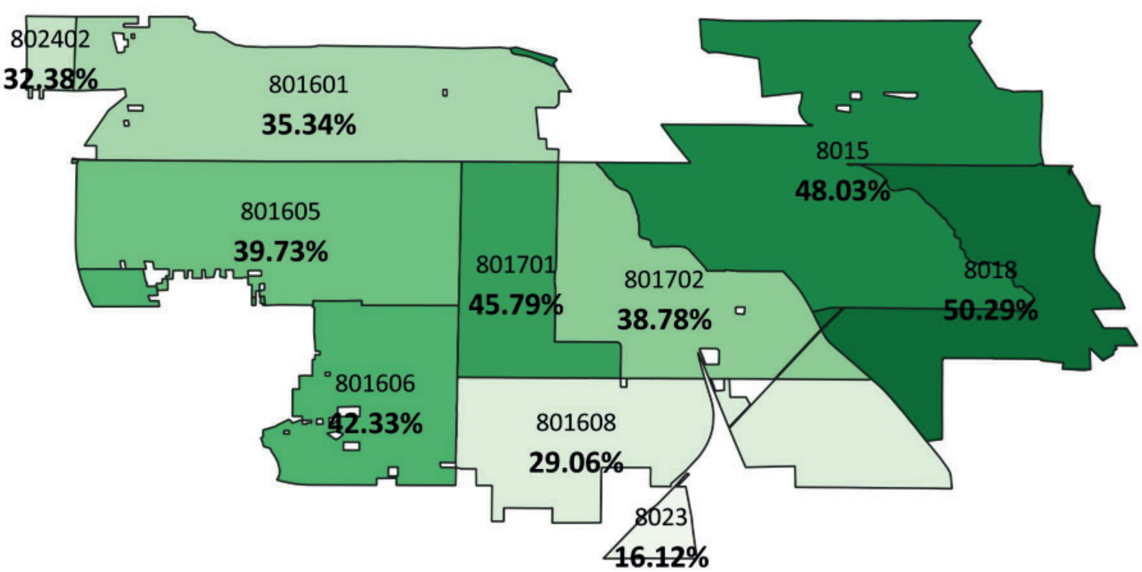
Recommendations

Tree Canopy Coverage as Neighborhood Percentage Goal for 2040 (CT)

The resulting projected Tree Cover Canopy for 2040 as percentage of total neighborhood area, based on the recommendations on the previous page, are shown to the Right.

City Wide Average 2040 Tree Canopy Coverage Goal (CT)

40.8% Total



Recommendations

New Tree Plantings Needed to Achieve Tree Canopy Coverage Goal for 2040

While it is easy to think of the long range Tree Canopy coverage goals for each nieghborhood in terms of planting trees, it is critical that Tree Canopy enhancement goals include a combination of tree protection, tree maintenance, and tree planting in order to be fully realized and efficiently implemented.

A common calculation used to determine the new tree planting requirements in order to meet the long-range Tree Canopy coverage goals, while recognizing the impacts of tree canopy growth and mortality was established by a 2002 Report to North East State Forester Association by Luley and Bond. That report offers the following conceptual analysis for increasing UTC:

$$CB + CG - CM + CN = CT$$

Where:
CB= the existing Tree Canopy;
CG= the growth of existing Tree Canopy (protection and maintenance);
CM= Tree Canopy mortality or loss due to natural and man -induced causes.
CN= Tree Canopy increase from new trees (planting); and
CT= total Tree Canopy Result (or goal)

Recommendations

Translating Tree Canopy Coverage Goal To New Tree Planting - Growth Rates (CG)

Consideration of tree canopy growth rate is important in anticipating long-range tree canopy goals and annual new planting needs. According to a 2014 USDA report, the average growth rate for non-managed forests is 2% while the average growth rate for managed forests is 2.5% annually.

Translating Tree Canopy Coverage Goal To New Tree Planting - Mortality Rates (CM)

As with growth rate, consideration of tree canopy mortality is necessary for long-range Tree Canopy planning. According to the 2014 USDA report, the average mortality rate for non-managed forests is 1.86% while the average mortality rate for managed forests is 1.5% annual. There are few studies exploring mortality rates for trees in urban and suburban settings, those studies that exist indicate a range from 2.7% for general suburban trees and 3.5% to 14% for street trees*. As many trees in the Village of Northbrook exist in forest type setting on publicly owned land and much of the balance are general suburban trees observed regularly and likely seen as having value, we recommend using a mortality rate of 1.5%.

Ash Tree Mortality

Ash trees are projected to be significantly impacted by the infestation of the Emerald Ash Borer insect. Long-term tree canopy planning for the Village of Northbrook should anticipate substantial (complete for all non-treated trees) Ash tree mortality within the next 10-15 years.

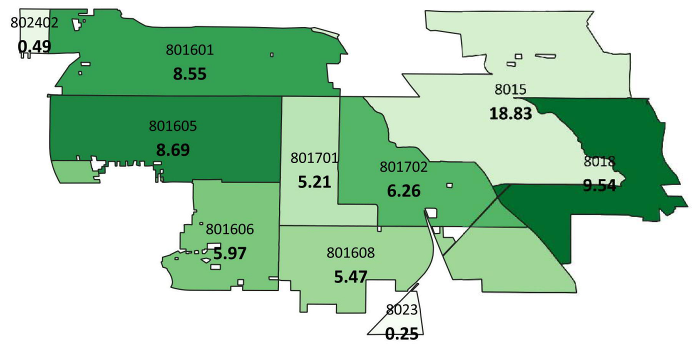
The exact extent of Ash trees Village-Wide has not been surveyed, however, according to a 2012 study by Whittier College, (Potential impacts of emerald ash borer invasion on biogeochemical and water cycling in residential landscapes across a metropolitan region) for the potential long-term impact on community-wide tree canopy, we recommend an estimated extent of Ash trees throughout the Village of Northbrook of up to 19% of the existing tree canopy.

We recommend a detailed tree species study be conducted to identify the Village wide canopy make-up by species. Until that detailed information is available, this report will use an assumed average Village-Wide ash tree coverage of 10%, for an an additional annualized tree canopy loss of 0.667% due to potential Emerald Ash Borer loss over 15 years. With this Ash tree mortality adjustment, the total recommended tree canopy mortality rate for long-range tree canopy planning is 2.13%

*How Many Trees Are Enough? Tree Death and the Urban Canopy https://scenariojournal.com/article/how-many-trees-are-enough/

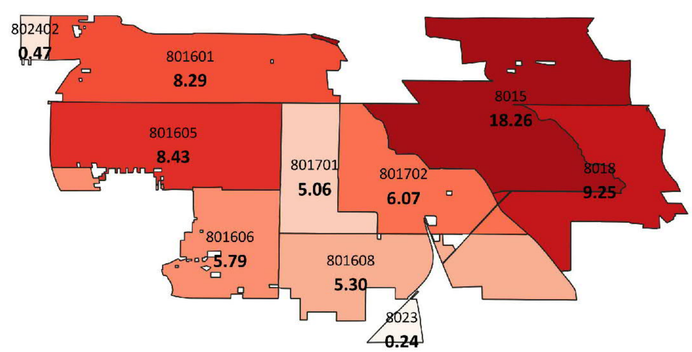
Total Estimated Annual Growth of Existing Tree Canopy in Acres (CG)

Village Total: **70** Acres Annually



Total Estimated Annual Mortality of Existing Tree Canopy (CM)

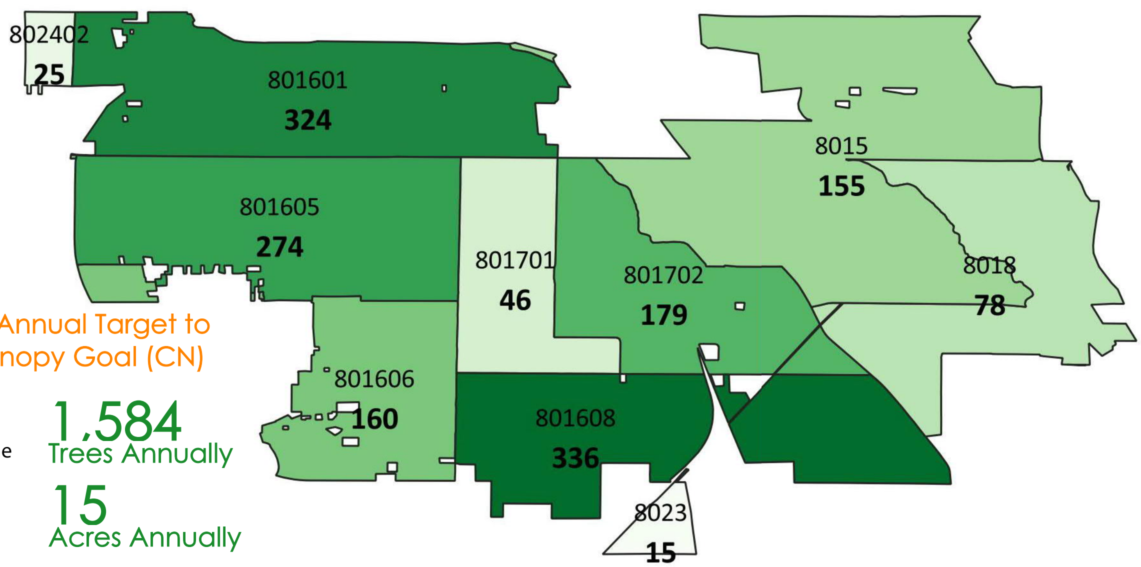
Village Total: **68** Acres Annually



Recommendations

Translating Tree Canopy Coverage Goal To New Tree Planting - New Tree Planting Annual Target (CN)

Using the new planting requirement calculation method (CB + CG - CM + CN = CT) with the previously defined values for existing tree canopy (CB), growth rates (CG), mortality rates (CM), and the 2040 Tree Canopy (CT) goals by neighborhood the required number of new trees to be planted to meet that goal can be identified. The map below shows the annual new tree count required to meet the 2040 tree canopy goals for each neighborhood.



New Tree Planting Annual Target to Meet 2040 Tree Canopy Goal (CN)

Village-Wide Total:

Note, Acreage represents the canopy coverage at year of planting, with an assumed new tree crown radius of 5’.

1,584
Trees Annually

15
Acres Annually

Annual Path to 2040 Tree Canopy Cover Goal

The chart below shows the Village wide average values for year beginning canopy cover (CB), annual growth rate (CG), mortality rate (CM), the new tree planting targets (CN) and the year end tree canopy goal (CT) for each year through the 2040 goal.

Year	CB (acres)		CG (acres)		CM (acres)		CN (acres)		CT (acres)	Canopy Cover %
2021	3147	+	69	-	67	+	15	=	3164	37.3%
2022	3164	+	70	-	68	+	15	=	3181	37.5%
2023	3181	+	70	-	68	+	15	=	3198	37.7%
2024	3198	+	70	-	68	+	15	=	3214	37.9%
2025	3214	+	71	-	69	+	15	=	3231	38.1%
2026	3231	+	71	-	69	+	15	=	3248	38.3%
2027	3248	+	71	-	69	+	15	=	3264	38.5%
2028	3264	+	72	-	70	+	14	=	3281	38.6%
2029	3281	+	72	-	70	+	14	=	3298	38.8%
2030	3298	+	73	-	70	+	14	=	3314	39.0%
2031	3314	+	73	-	71	+	14	=	3331	39.2%
2032	3331	+	73	-	71	+	14	=	3348	39.4%
2033	3348	+	74	-	71	+	14	=	3364	39.6%
2034	3364	+	74	-	72	+	14	=	3381	39.8%
2035	3381	+	74	-	72	+	14	=	3398	40.0%
2036	3398	+	75	-	72	+	14	=	3414	40.2%
2037	3414	+	75	-	73	+	14	=	3431	40.4%
2038	3431	+	75	-	73	+	14	=	3448	40.6%
2039	3448	+	76	-	74	+	14	=	3464	40.8%
2040	3464	+	76	-	74	+	14	=	3481	41.0%

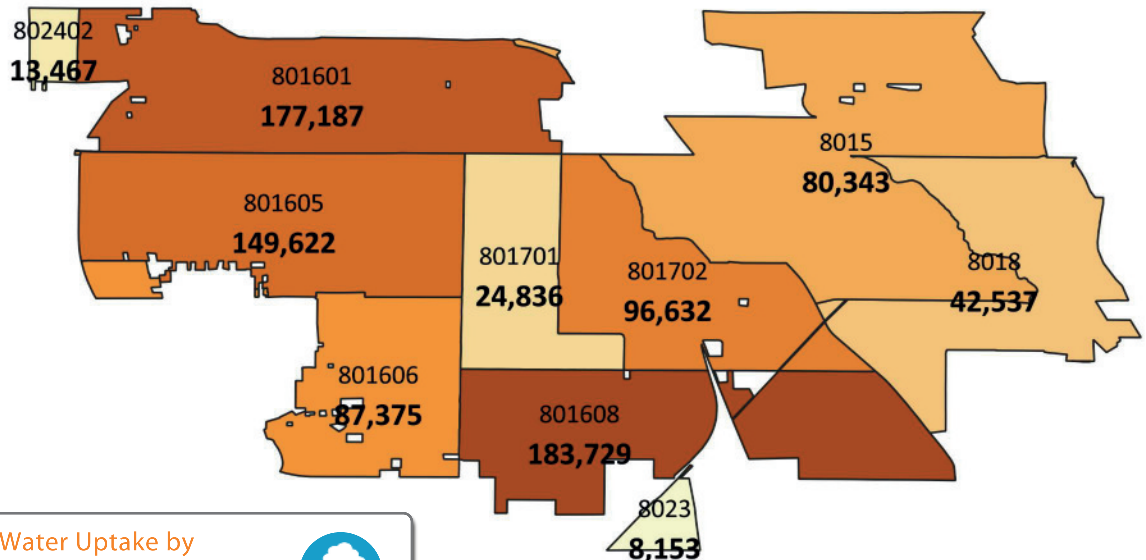
Recommendations

Calculating Benefits of 2040 Tree Canopy Coverage Goal

Using the same calculations as those used in Section 3, the maps below, and on the next page, illustrate the value of the added annual benefits of the 2040 Tree Canopy Coverage Goal.

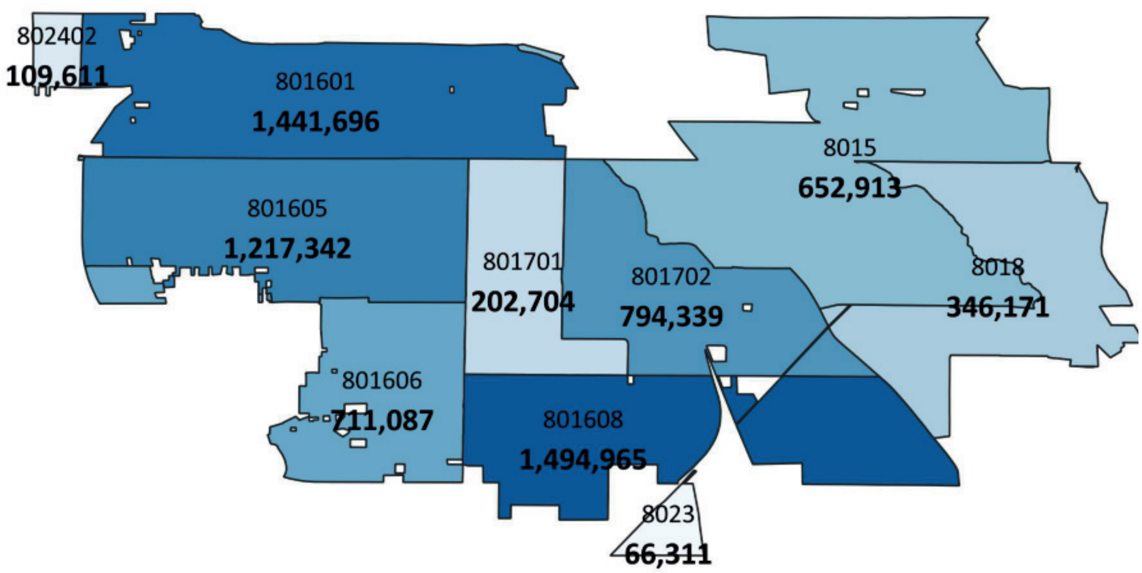
Additional Annual Carbon Sequestration by Achieving 2040 Tree Canopy Goal

Village Total: **0.864** Million Pounds



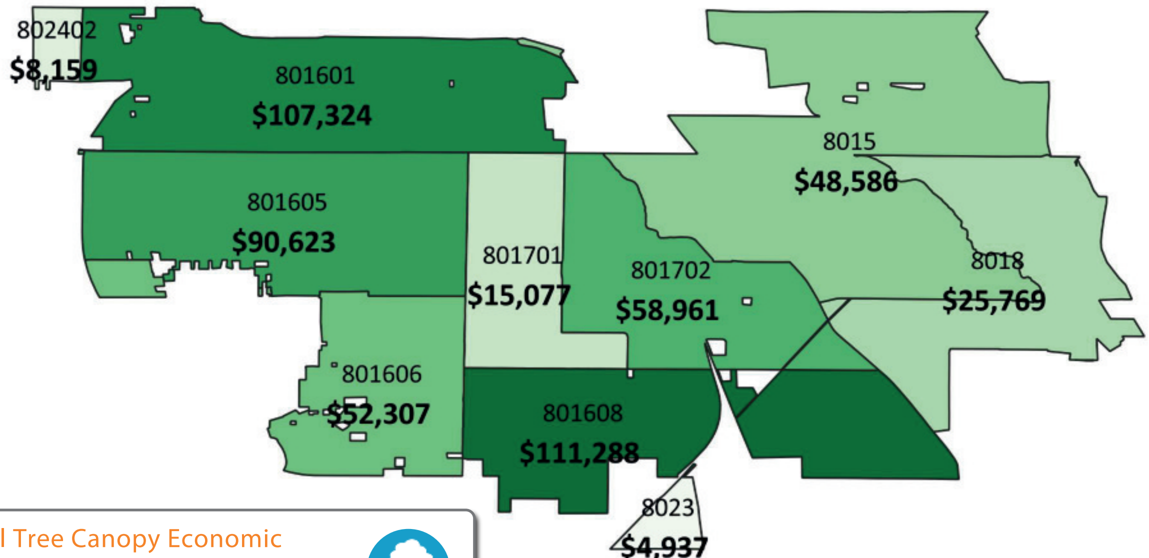
Additional Annual Water Uptake by Achieving 2040 Tree Canopy Goal

Village Total: **7.037** Million Gallons



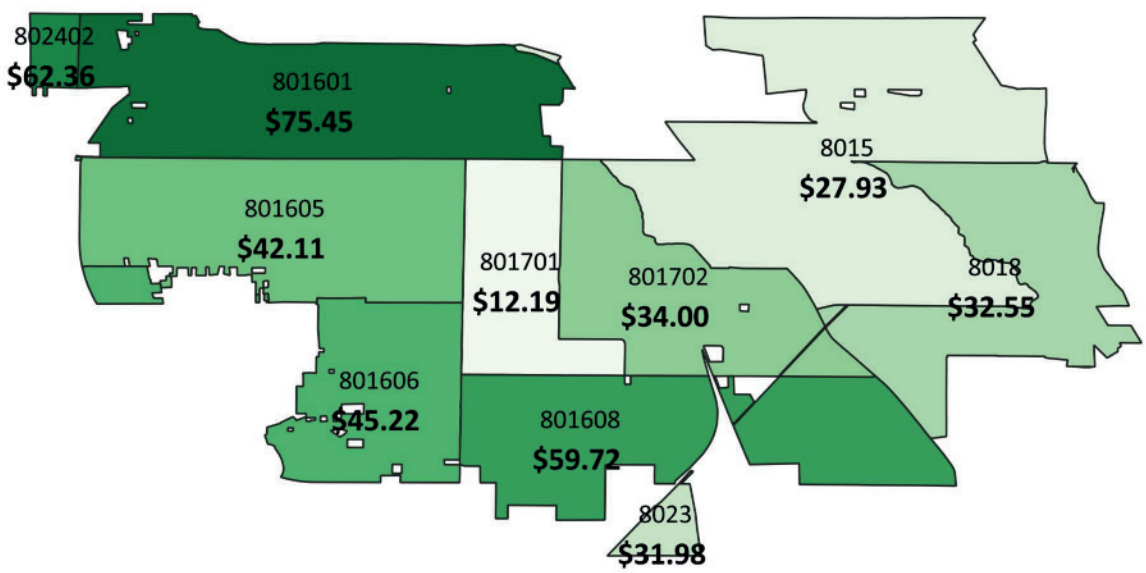
Total Increase in Annual Value of Tree Canopy Benefits by Achieving 2040 Goal

Village Total: **$523,100**



Increase in Annual Tree Canopy Economic Value per Household by Achieving 2040 Goal

Village Total: **$42.25**
Per Household



Recommendations

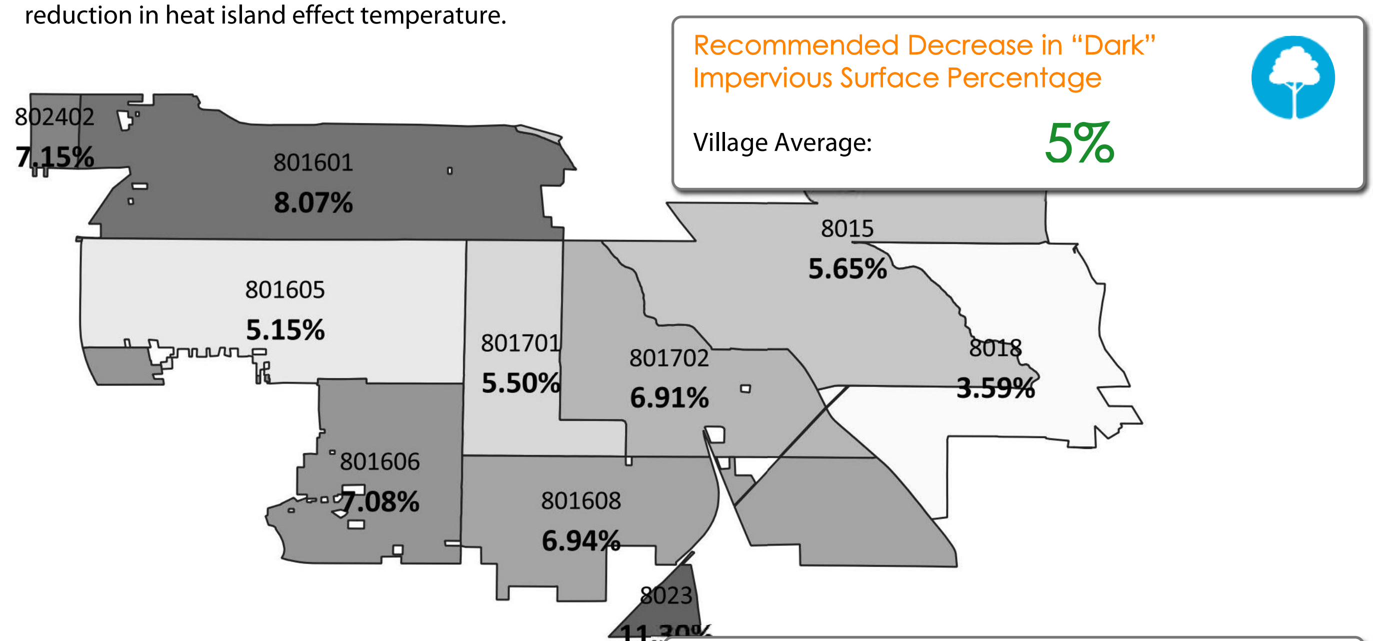
Recommendations - Heat Island Reduction Goal for 2040

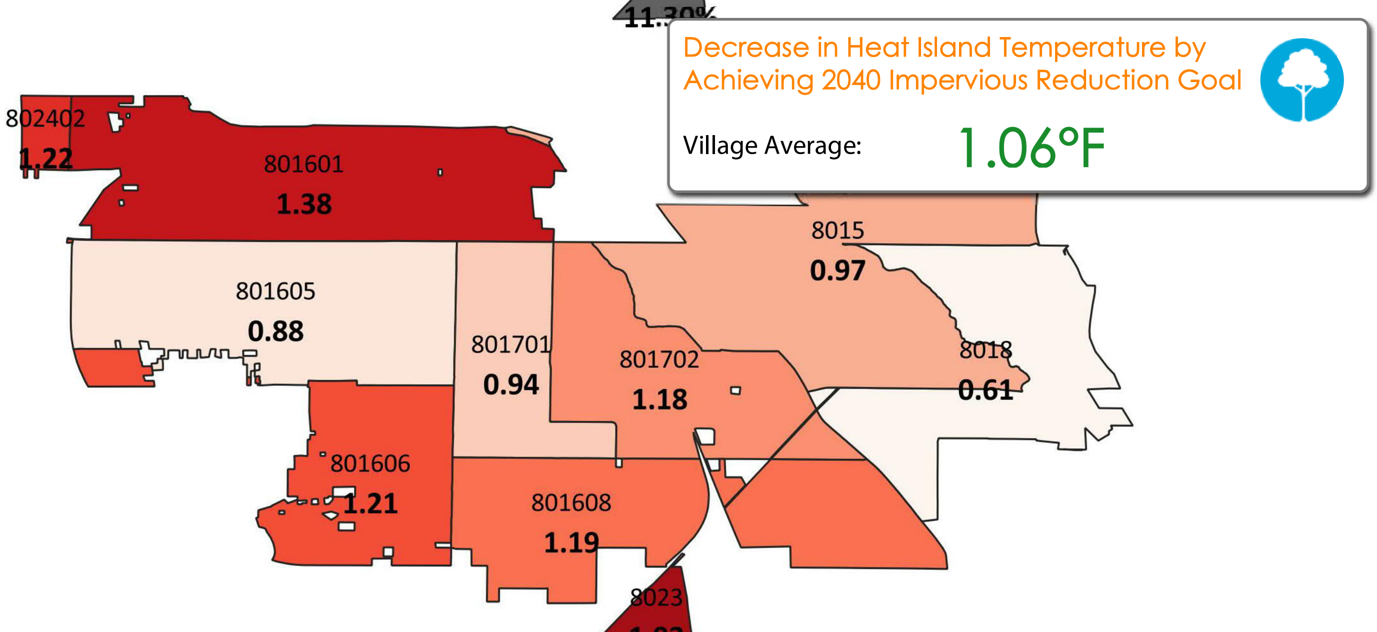
As described in Section 4 of this report, the quantity and type of impervious surfaces throughout the village contribute to heat island effects. Through reduction of impervious surfaces, especially dark surfaces with high energy absorption, the Village can mitigate future heat island effects.

We recommend a goal to reduce "dark" impervious surfaces by an average of 5% throughout the Village by 2040. To achieve this, we recommend the following sub-goals:

1) Decrease dark roofing through conversion to Green Roof systems 10% of Village Roof stock
2) Decrease dark roofing through conversion to "cool roof" systems 30% of Village Roof stock
3) Decrease dark pavement through conversion to "cool pavement" systems 10% of Village pavement stock
4) Decrease dark pavement through conversion to "pervious pavement" systems 2% of Village pavement stock
5) Decrease impact of dark pavement through increase in parking tree canopy coverage 5% of City pavement stock (assumes 15-20% coverage of all parking areas).

The graphics below illustrate the effective reduction in "dark" impervious surface cover percentage and the resulting reduction in heat island effect temperature.





Recommendations

Recommendations - Goals

Based on the 2040 Tree Canopy Cover and 2040 Heat Island Reduction goals outlined in the previous pages, we offer the recommended Goals below.

Lawns and Grasslands

L1: Increase pollinator supportiveness of lawns and grasslands in Village of Northbrook
L2: Increase Carbon Sequestration values of lawns and grasslands in Village of Northbrook

Tree Canopy

T1: Promote Heat Island awareness and education among residents and businesses
T2: Increase tree canopy coverage city-wide to meet long-term canopy goals for each neighborhood (see page 6-2 and 6-3)
T3: Increase resilience of Northbrook tree canopy
T4: Increase carbon sequestration potential of new plantings
T5: Improve tree canopy mortality rates
T6: Create economic development potential in support of tree canopy health and expansion
T7: Increase stormwater retention and reduce water runoff
T8: Create strategic compatibility between Village wide tree canopy and renewable energy goals

Heat Island Mitigation

H1: Promote Heat Island awareness and education among residents and businesses
H2: Decrease Heat Island impacts of pavement in Northbrook
H3: Decrease Heat Island impacts of buildings in Northbrook

Section 07

Conclusions and Next Steps

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Conclusions and Next Steps

Conclusions

The Village of Northbrook's tree canopy coverage is higher than the average for cities throughout the United States, however, the Village's tree canopy achieves only the 38th percentile when compared to the Village's primary comparison cohort. The existing tree canopy provides significant value for the Village. Annually, trees in Northbrook remove over 8.8 million pounds of man-made pollutants from the community's air, reduce the Village's electric use by over 19 million kWH, and save over 4 million therms of natural gas. The full value of the Village's green infrastructure is not possible to calculate, however, the economic value of these air quality and energy benefits for residents and businesses in Northbrook total over $5 million annually.

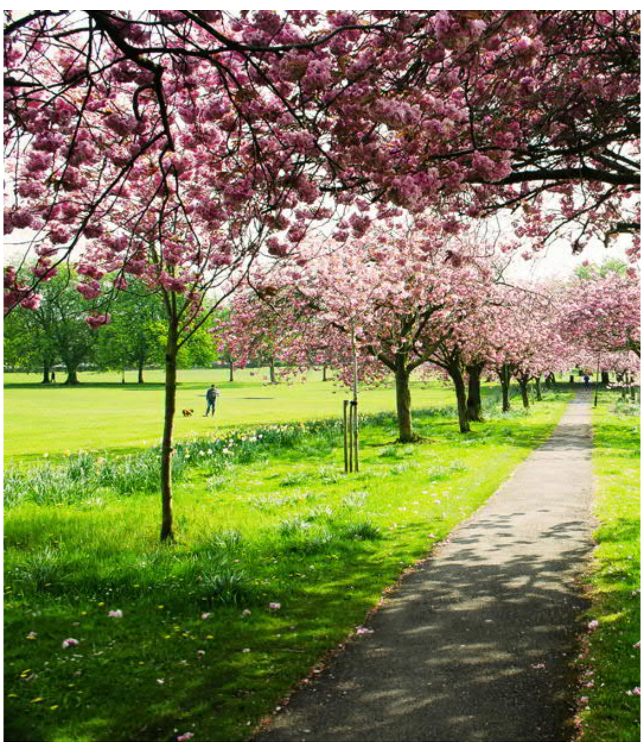
Even with a strong existing green infrastructure, the Village has the potential for more. Using research from the University of Minnesota, this study indicates that the Village of Northbrook has a heat island impact of at least 3-4 degrees in daytime and 4-6 degrees in nighttime temperature increase. Meanwhile, even with the significant pollution absorption services the Village's green infrastructure provides, only a fraction of the man-made air quality impacts occurring in the Village are mitigated. Consequently, increases in green infrastructure offer significant reward potential for the Village.

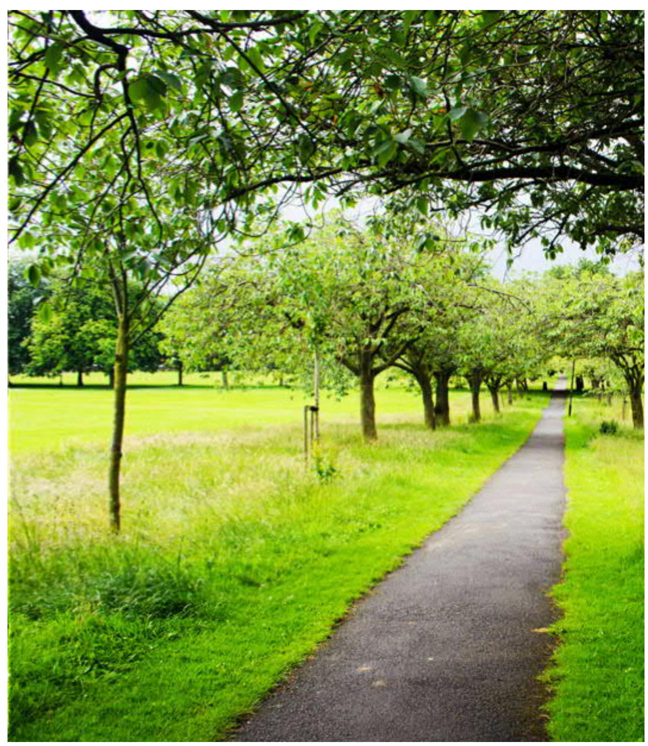
Primary Goals

Section 6 of this report provided a range of recommended goals for the Village of Northbrook. The overarching goals recommended in this report are:

1) To increase the tree canopy coverage throughout the Village, particularly in the Priority Neighborhoods identified in Section 6, to an average of at least 40.8% Village-wide by 2040.
2) Decrease the quantity of "dark" impervious surfaces throughout the Village by an average of at least 5% by 2040.

The percentage targets identified for both of these goals are intended to be achievable goals - in both instances, exceeding the percentage goals would be ideal.





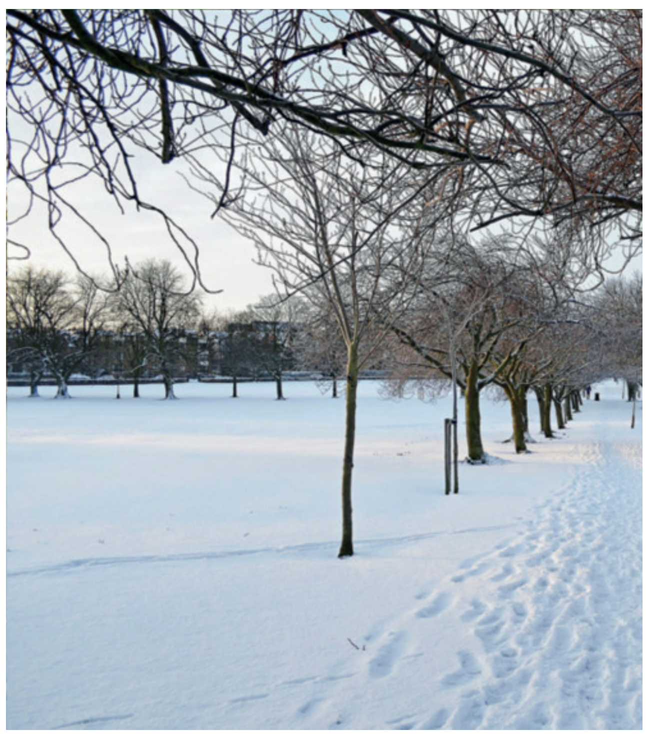
Conclusions and Next Steps

Next Steps

We recommend that the Village of Northbrook implement the recommended goals and select strategies into the Village's Climate Action Plan. This effort should focus on expanding, refining and applying select strategies included in this report. An implementation planning effort should focus on a community outreach process to develop support for the finalized strategies as well as to begin the process of developing public awareness and engagement in implementing the adaptation strategies.

Specific recommended next steps are:

1) Integrate appropriate content, findings, and recommendations from this report into the Village's Climate Action Plan.
2) Conduct a Vilalge-wide pollinator habitat assessment and pollinator corridor master plan
3) Conduct a detailed tree species distribution study/survey.
4) Conduct a Tree Survey and Carbon Sequestration update at regular intervals (3-5 years) to report on progress and adjust long-term goals and strategies accordingly.
5) In coordination with the Climate Action Plan, develop strategies to address Heat Island Abatement



Appendix A1

iTree Technical Notes

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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

Lindgren, BW and GW McElrath. 1969. Introduction to Probability and Statistics. Macmillan Co. London
Hodges, JL and EL Lehmann. 1964. Basic Concepts of Probability and Statistics. Holden-Day, Inc. San Francisco.
Thompson, S. K. 2002. Sampling, second edition. John Wiley and Sons, Inc., New York, New York.

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