Carmel-by-the-Sea, CA

Tree Canopy & Land Cover Assessment Summary Report

2023

CITY OF CARMEL-BY-THE-SEA, CALIFORNIA
INCORPORATED 1916

DAVEY Resource Group

Carmel-by-the-Sea, CA

Tree Canopy & Land Cover Assessment Summary Report

2023

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Executive Summary

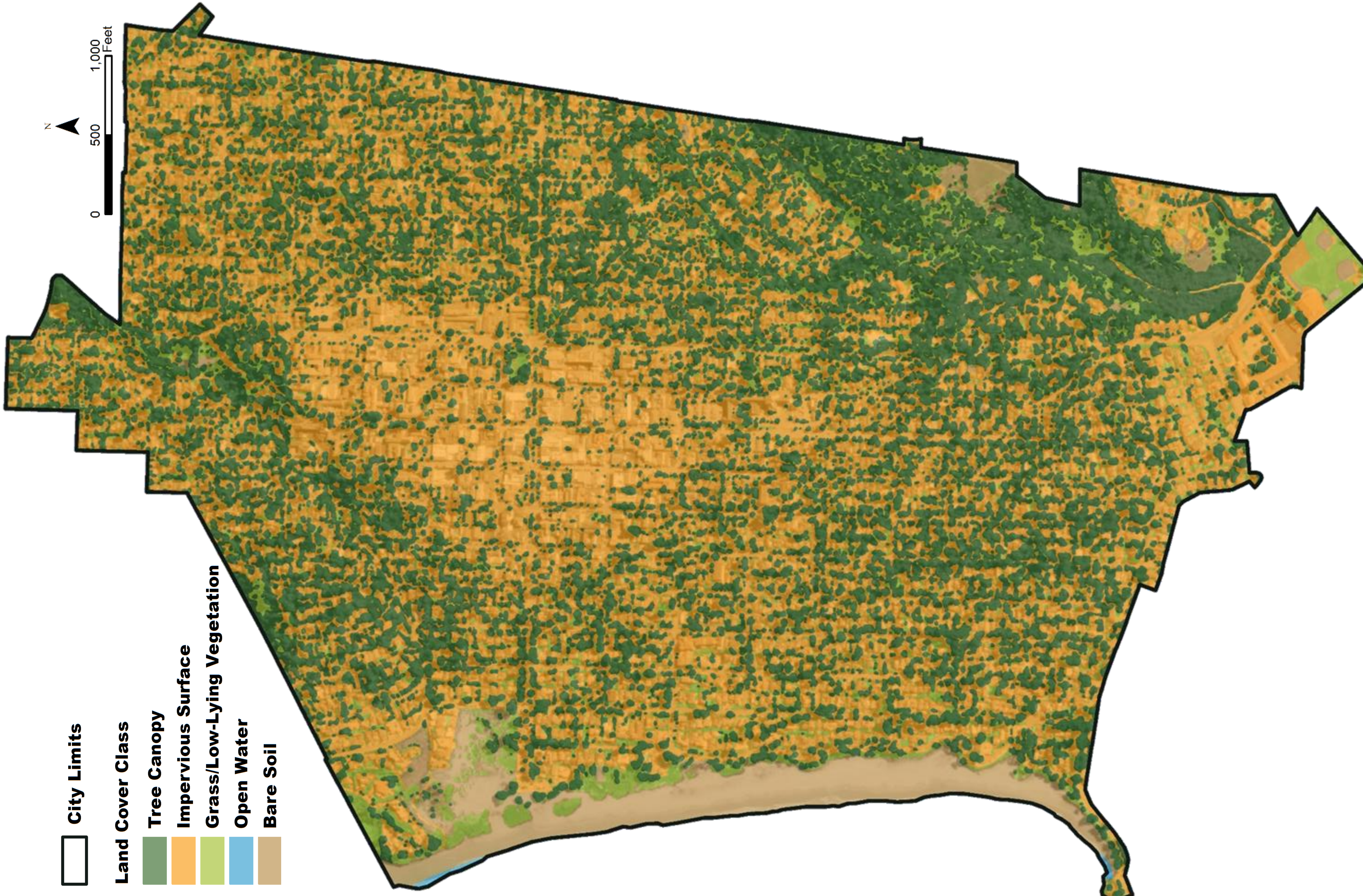
Urban forests and tree canopy cover provide vital environmental services and benefits to urban ecosystems, including reducing stormwater runoff and protecting water quality, sequestering atmospheric carbon, improving air quality, reducing energy consumption, supporting human health and welfare, and providing forage and habitat for wildlife. The benefits from the urban forest are directly related to the level of canopy cover and leaf surface area. Understanding the location and distribution of tree canopy is key to developing and implementing sound preservation and management strategies that promote the sustainability of Carmel-by-the-Sea's urban forest and the benefits it provides.

To evaluate tree canopy and its relationship with other primary land cover, the City of Carmel-by-the-Sea contracted with Davey Resource Group (DRG) in 2023 to conduct a comprehensive Land Cover Assessment. The Assessment, based on 2022 NAIP imagery, provides a birds-eye view of the entire urban forest and establishes a tree canopy baseline of known accuracy and classification methodology. This information provides important baseline values for the urban forest, including the amount and distribution of tree canopy as well as the benefits to air quality, stormwater, water quality, and carbon storage, which allows urban forest managers and planners to make informed decisions on canopy goals, maintenance, preservation, and planting plans. This report provides a summary and discussion on the key findings of this assessment.

Tree Canopy and Land Cover

Carmel-by-the-Sea encompasses 1.06 square miles (676.3 acres). The following information summarizes land cover in Carmel-by-the-Sea:

- 36% (243.3 acres) tree canopy, including trees and woody shrubs
- 45% (304.6 acres) impervious surfaces, including roads and structures
- 13.8% (93.3 acres) pervious surfaces, including bare soils and low-lying vegetation
- 0.1% (0.5 acres) open water
- Nearly 85% of canopy is in fair or better health
- 56.5% (137.6 acres) of tree canopy is on privately owned property
- 31.1 acres of tree canopy is in parks, trails, and open spaces for an average of 38.1%
- 133.0 acres of tree canopy in residential zoning (single and multi-family) for an average canopy cover of 35.6%
- Areas zoned as parkland have 31 acres of tree canopy and the highest level of canopy cover (37.9%) while areas zoned as Commercial have the lowest canopy cover (8.4%)
- 80.9 acres of possible planting sites including areas of existing bare soil and grass/low-lying vegetation, for an estimated canopy potential of 48%
- To date, Carmel-by-the-Sea's urban forest is storing 8,364 tons of carbon in woody and foliar biomass, valued at $1.4 million



Map 1: Tree Canopy and Primary Land Cover

Environmental Benefits

i-Tree *Canopy* (v7.1) was used to quantify the ecosystem benefits from Carmel-by-the-Sea's tree canopy cover (public and private trees) to air quality, stormwater runoff, and carbon sequestration. The dollar value of these benefits was calculated based on cost-modeling valuations from i-Tree *Eco* (v6.1.36). The analysis estimates that Carmel's tree canopy is annually providing nearly $151,719 in quantifiable benefits (Figure 1, Table 1), including:

- Removing 9 tons. of air pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM_{10}), valued at $48,285
- Reducing stormwater runoff by approximately 3.5 million gallons and avoiding 3,584 lb. of pollutants in stormwater runoff, valued at $31,228
- Sequestering an additional 423 tons of CO_2, valued at $72,206

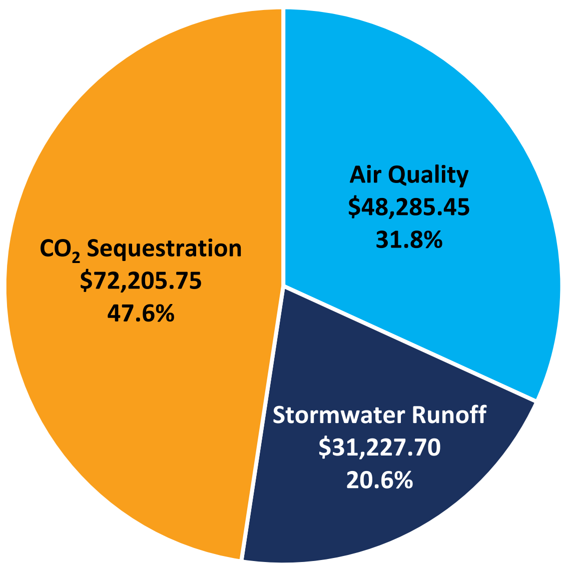


Figure 1: Annual Benefits Summary for Carmel-by-the-Sea

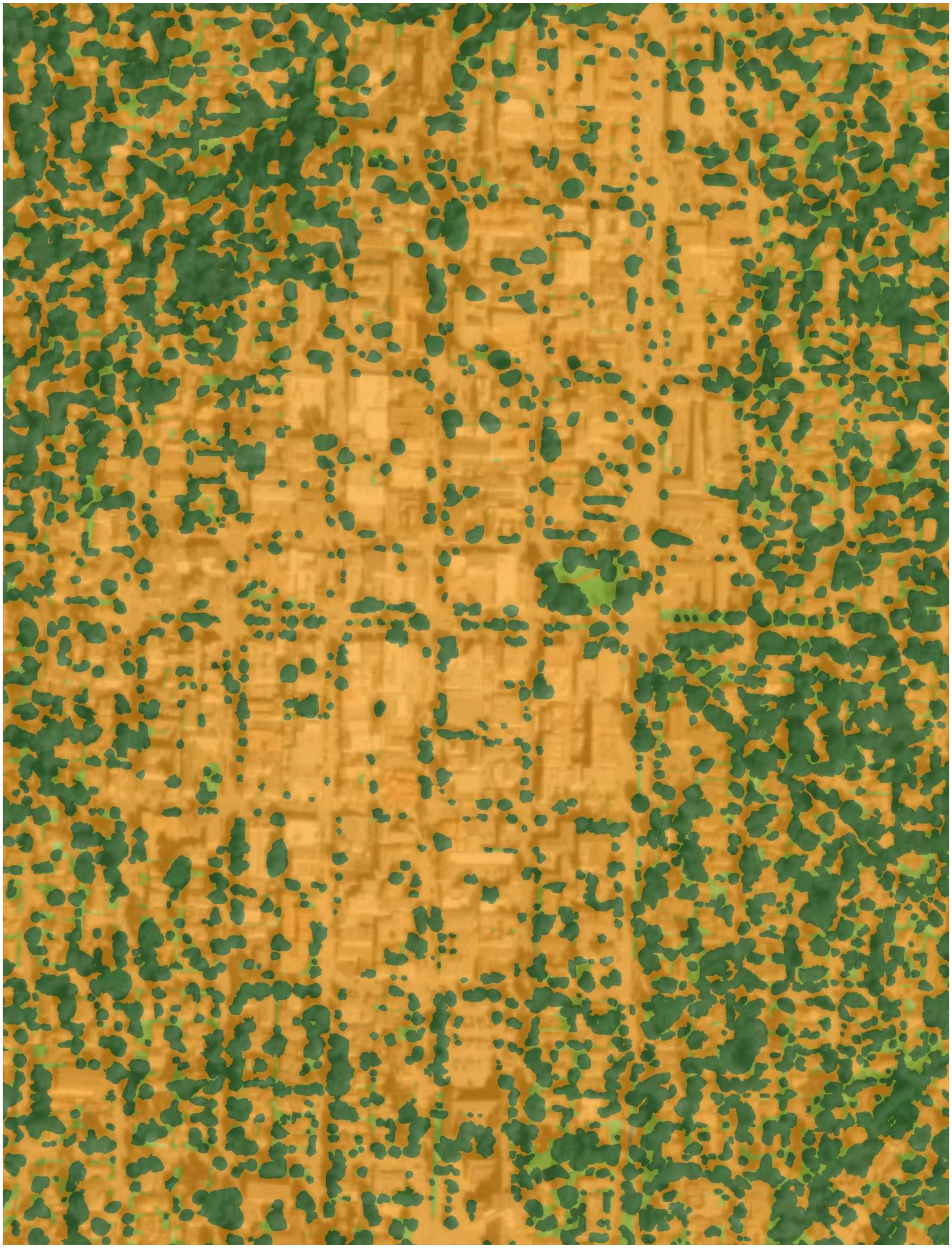
Table 1: Annual Environmental Benefits Summary

Environmental Benefit	Value	% of Total Benefit
CO_2 Sequestration	72,205.75	47.59
O_3	33,943.35	22.37
Stormwater Runoff	31,227.70	20.58
PM_{10}	13,616.09	8.97
CO, NO_2, SO_2	726.01	0.48
Total	**$151,718.90**	**100%**

Management Applications

Understanding the location and distribution of tree canopy is key to developing and implementing sound preservation and management strategies that promote the sustainability of Carmel-by-the-Sea's urban forest. The data, combined with existing GIS information and emerging research, enables managers to balance urban development with tree preservation and aids in identifying and assessing urban forestry opportunities. A spatial understanding of tree canopy and other primary land cover can help urban forest managers and city leaders align urban forestry objectives with community vision, including:

- Set canopy goals for the future urban forest based on zoning, land cover distribution, and community values.
    - Carmel-by-the-Sea has an existing tree canopy cover of 36% and the potential to support up to 48% canopy.
- Expand tree canopy on public property, by focusing planting efforts in parks, trails, and open space.
- Encourage tree planting and preservation on private property by incentivizing tree planting, expanding community education, and supporting activities and programs related to urban trees.
- Use priority planting maps to develop planting plans to meet canopy goals and to support stormwater management, preserve soil, and complement the existing urban infrastructure for the greatest impact and return on investment.
    - Create a planting plan and identify and prioritize planting spaces that increase environmental benefits and complement the existing urban infrastructure.
    - Use the tree planting placement model to identify priority planting site locations.
    - Maximize available resources and planting space by planting the largest statured tree that can be accommodated in a site.
- Incorporate trees into stormwater management strategies to capture and reduce runoff and lessen the impact of flood events on existing infrastructure.
- Preserve and protect existing trees and forest stands to sustain environmental benefits.
- Conduct a periodic land cover assessment to track changes in canopy.



A spatial understanding of tree canopy and other primary land cover can help urban forest managers and city leaders align urban forestry objectives with community vision.

Introduction

Carmel-by-the-Sea is a charming town located on the central coast of California. It is situated on the Monterey Peninsula, about 120 miles south of San Francisco and 350 miles north of Los Angeles. The town is bordered by the Pacific Ocean to the west and the Carmel River to the south. Its prime location makes it an ideal spot for enjoying the stunning coastal scenery, with plenty of opportunities for hiking, biking, and other outdoor activities.

Carmel-by-the-Sea has a Mediterranean climate, characterized by mild, wet winters and cool, dry summers. The average temperature in the summer months ranges from 55°F to 68°F (13°C to 20°C), while in winter, temperatures range from 45°F to 60°F (7°C to 15°C). The town receives most of its rainfall between November and April, with an average of 20 inches of precipitation per year. Coastal fog is also a common feature in the area, particularly during the summer months, which helps to keep the temperatures mild and comfortable. Overall, the town's mild climate makes it an ideal destination for outdoor activities throughout the year.

Individual trees and canopy play an essential role in the community of Carmel-by-the-Sea by providing many benefits, tangible and intangible, to residents, visitors, and neighboring communities. Research demonstrates that healthy urban trees can improve the local environment and lessen the impact resulting from urbanization and industry (Center for Urban Forest Research, 2017). Trees improve air quality, reduce energy consumption, help manage stormwater, reduce erosion, provide critical habitat for wildlife, and promote a connection with nature.

Tree Canopy Cover and Geographic Information Systems

Tree canopy cover is measured by the area of leaves, branches, and stems that cover the ground when viewed from above. Since trees provide benefits to the community that extend beyond property lines, this assessment includes all tree canopy within the borders of the community and does not distinguish between publicly-owned and privately-owned trees. To place tree canopy in context and better understand its relationship within the community, the assessment included other primary landcover classifications, including impervious surfaces (e.g., buildings, roads, parking lots), pervious surfaces (e.g., low-lying vegetation and bare soils), and water.

As communities focus more attention on environmental sustainability, community forest management has become increasingly dependent on geographic information systems (GIS). GIS is a powerful tool for urban forest mapping and analysis. Understanding the extent and location of the existing canopy is key to identifying various types of community forest management opportunities, including:

- Future planting plans
- Stormwater management
- Water resource and quality management
- Impacts and management of invasive species
- Preservation of environmental benefits
- Outreach and education

Using high-resolution aerial imagery (2022) and infrared technology, DRG remotely mapped tree canopy and other primary land cover (Map 1 and 2, Figure 2). The results of the study provide a clear picture of the extent and distribution of tree canopy within Carmel-by-the-Sea. The data developed during the assessment becomes an important part of the City's GIS database and provides a foundation for developing community goals and urban forest policies. With this data, managers can determine:

- Carmel-by-the-Sea's progress towards local and regional canopy goals
- Changes in tree canopy over time and in relation to growth and development
- The location and extent of canopy at virtually any level, including by land use, zoning, parks, and public or private parcels
- Potential planting space

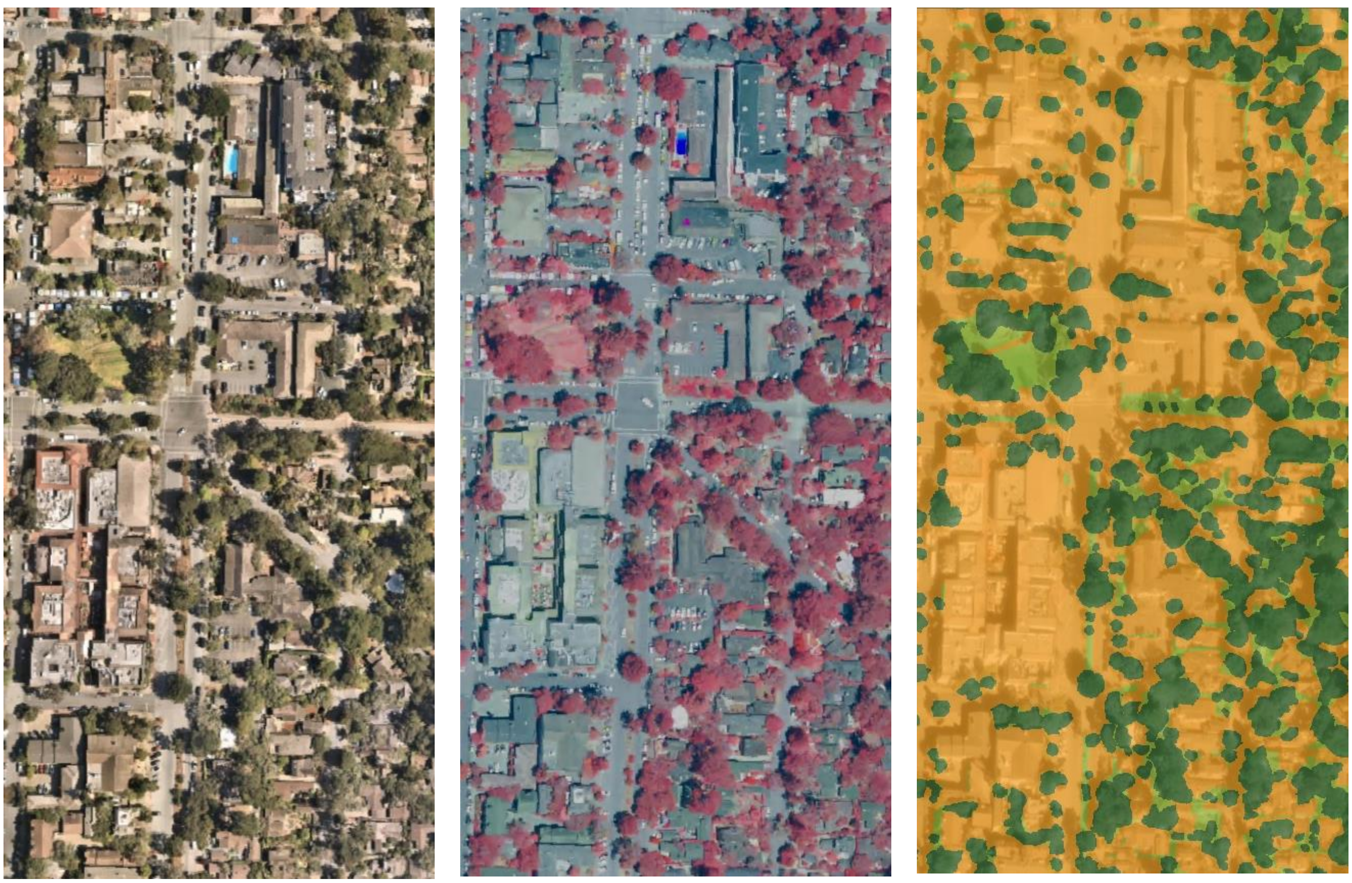


Figure 2: Land Cover Mapping

High-resolution aerial imagery (left) is used to remotely identify existing land cover. Infrared technology delineates living vegetation including tree canopy (middle). Remote sensing software identifies and maps tree canopy and other land cover (right).

Benefits of Tree Canopy

Urban forests continuously mitigate the effects of urbanization and development and protect and enhance the quality of life within the community. The amount and distribution of leaf surface area is the driving force behind the ability of the urban forest to produce benefits for the community (Clark et al, 1997). Healthy trees are vigorous, often producing more leaf surface area each year. Trees and urban forests provide quantifiable benefits to the community in the following ways:

Air Quality

Trees and canopy improve air quality in five fundamental ways:

- Reducing particulate matter (dust)
- Absorbing gaseous pollutants
- Providing shade and transpiration
- Reducing power plant emissions
- Increasing oxygen levels

Urban trees protect and improve air quality by intercepting particulate matter (PM_{10}), including dust, ash, pollen, and smoke. Particulates are filtered and held in the tree canopy. Trees and forests also absorb harmful gaseous pollutants like ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Shade and transpiration reduce the formation of O_3, which is created during higher temperatures. In fact, scientists are now finding that some trees may absorb more volatile organic compounds (VOC's) than previously thought (Karl et al, 2010). VOC's are a class of carbon-based particles emitted from automobile exhaust, lawnmowers, and other human activities. By reducing energy needs, trees also reduce emissions from the generation of power. Through photosynthesis, trees and forests increase oxygen levels.

Annually, trees in Carmel-by-the-Sea remove 18,029 lb. of air pollutants for a total value of $48,285, including: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM_{10}) (Figure 3).

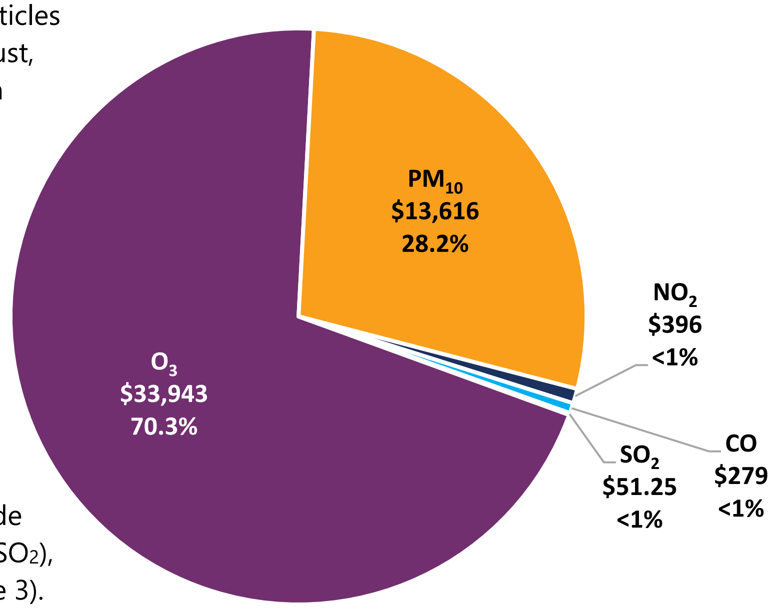


Figure 3: Annual Benefits to Air Quality

Carbon Reduction

Trees and canopy directly reduce CO_2 in the atmosphere through growth and sequestration of carbon as woody and foliar biomass. When trees die and decay, they release much of the stored carbon back to the atmosphere. In urban environments, most trees that die are removed and chipped or disposed of as firewood, releasing stored carbon. Thus, carbon storage is an indication of the amount of carbon that can be gained and lost over the course of a tree's lifecycle through growth and decomposition. Indirectly, trees and forests reduce CO_2 by lowering the demand for energy and reducing the CO_2 emissions from the consumption of natural gas and the generation of electric power.

Purchasing emission allowances (offsets) has led to the acceptance of carbon credits as a commodity that can be exchanged for financial gain. Some communities are exploring the concept of planting trees to develop a carbon offset (or credit) or to track progress toward climate action goals. i-Tree tools can be used to estimate the GHG and carbon sequestration benefits of tree planting projects (Urban and Community Forestry Program Quantification Methodology, 2020).

To date, the urban forest in Carmel-by-the-Sea is storing 8,364 tons of carbon (CO_2) in woody and foliar biomass, valued at nearly $1.4 million. Annually, Carmel-by-the-Sea's trees sequester an additional 423 tons of carbon valued at $72,206.

Stormwater Reduction

Trees and canopy improve and protect the quality of surface waters, such as creeks, rivers, lakes and bays, by reducing the impacts of stormwater runoff through:

- Interception
- Increasing soil capacity and rate of infiltration
- Reducing soil erosion

Trees intercept precipitation in their canopy, which acts as a mini reservoir (Xiao et al, 1998). During storm events, this interception reduces and slows runoff (Figure 4). In addition to catching stormwater, canopy interception lessens the erosive impact of raindrops on bare soil. Root growth and root decomposition increase the capacity and rate of soil infiltration by rainfall and snowmelt (McPherson et al, 2002). Each of these processes greatly reduces the flow and volume of stormwater runoff, avoiding erosion and preventing sediments and other pollutants from entering local creeks and waterways.

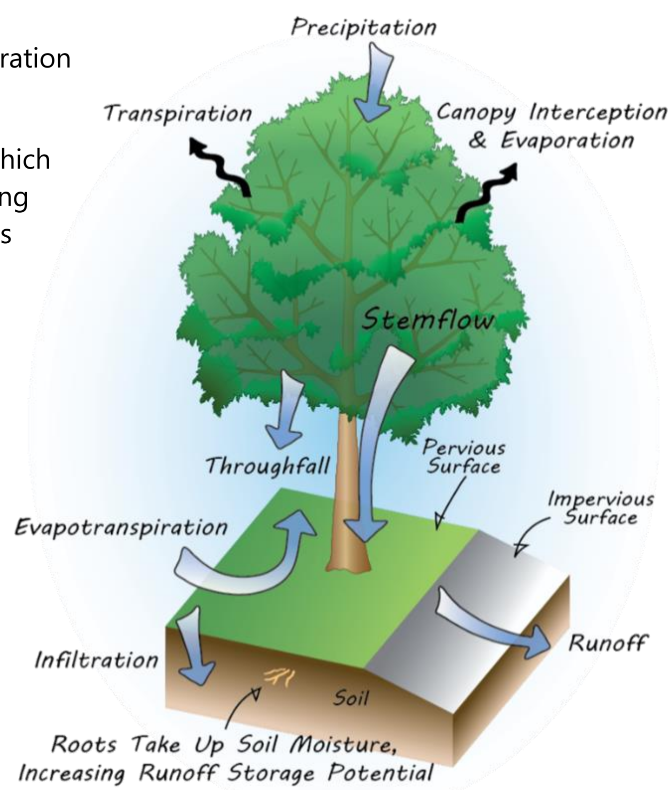


Figure 4: How Trees Reduce Stormwater Runoff

Surface runoff is a cause for concern in many urban areas as it contributes to the pollution and flooding of streams, wetlands, rivers, lakes, and oceans. Figure 4 illustrates the benefits of trees to reducing stormwater runoff. When rain falls on impervious surfaces it cannot permeate into the soil. Instead, it collects into flows and runoff. The runoff picks up sediment, trash, oil, bacteria, and other contaminants from paved surfaces and carries this non-point source pollution to bodies of water. Along with pollutants, stormwater runoff can produce flows with large volumes of water in a short period of time, causing flooding and erosion.

During precipitation events, some portion of the precipitation is intercepted by vegetation (trees, shrubs, grass, other vegetation). Some of the water is temporarily held by leaves and bark and later evaporates or gradually infiltrates into the soil, which slows and reduces the movement of water off site. The portion of the precipitation that reaches the ground and does not infiltrate into the soil or falls on impervious surfaces, becomes surface runoff (Hirabayashi, 2012). In urban areas, higher levels of impervious surfaces increase the amount of surface runoff and the cost of infrastructure a community must invest in to manage stormwater for the safety of residents and property.

Annually, the urban forest in Carmel-by-the-Sea is reducing stormwater runoff by 3.5 million gallons, valued at $31,228 (Appendix B).

Energy Savings

Urban trees and forests modify climate and conserve energy in three principal ways:

- Shading dwellings and hardscape
- Transpiration
- Wind reduction

Shade from trees reduces the amount of radiant energy absorbed and stored by hardscapes and other impervious surfaces, thereby reducing the heat island effect, a term that describes the increase in urban temperatures in relation to surrounding locations. Transpiration releases water vapor from tree canopies, which cools the surrounding area. Through shade and transpiration, trees and other vegetation within an urban setting modify the environment and reduce heat island effects. Temperature differences of more than 9°F (5°C) have been observed between city centers without adequate canopy cover and more vegetated suburban areas (Akbari et al, 1997).

Trees reduce wind speeds relative to their canopy size and height by up to 50%. Trees also influence the movement of warm air and pollutants along streets and out of urban canyons. By reducing air movement into buildings and against conductive surfaces (e.g., glass and metal siding), trees reduce conductive heat loss from buildings, translating into potential annual heating savings of 25% (Heisler, 1986). Reducing energy needs has the bonus of reducing carbon dioxide (CO_2) emissions from fossil fuel power plants.

Aesthetics and Socioeconomics

While perhaps the most difficult to quantify, the aesthetic and socioeconomic benefits from trees may be among their greatest contributions, including:

- Beautification, comfort, and aesthetics
- Shade and privacy
- Wildlife habitat and ecosystem health
- Opportunities for recreation
- Creation of a sense of place and history
- Human health

Many of these benefits are captured as a percentage of property values, through higher sales prices where individual trees and forests are located.

Calculating Tree Benefits

While all these tree benefits are provided by the urban forest, it can be useful to understand the contribution of just one tree. Individuals can calculate the quantifiable benefits of individual trees to their property by using the National Tree Benefit Calculator or with i-Tree *Design*. (design.itreetools.org).

Calculate My Tree Benefits

Land Cover

Overall Canopy

Carmel-by-the-Sea encompasses an area of approximately 1.06 square miles (676.3 acres). More than 243 acres are covered by tree canopy, for an average canopy cover of 36% (Figure 5). In addition to tree canopy, Carmel-by-the-Sea's land cover includes 45% impervious surface, 13.8% grass and low-lying vegetation, 5.1% bare soil, and 0.1% open water (Figure 5, Table 2).

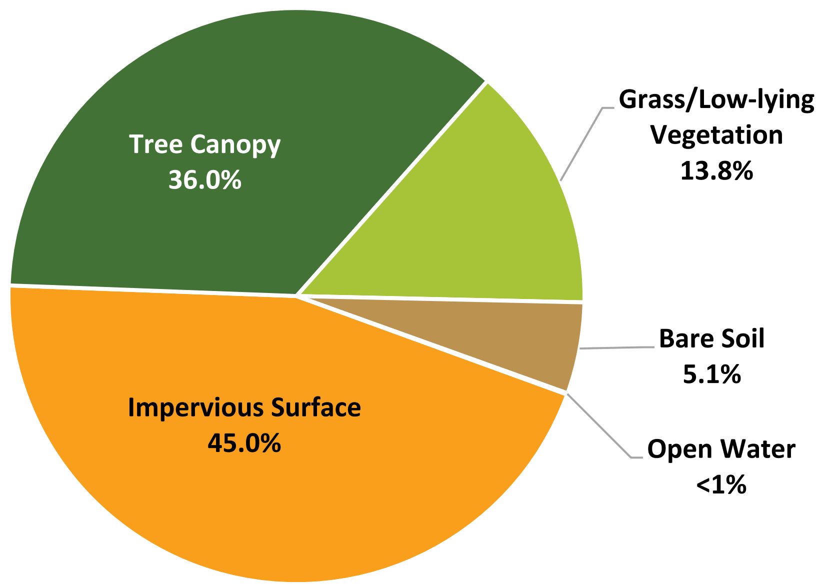
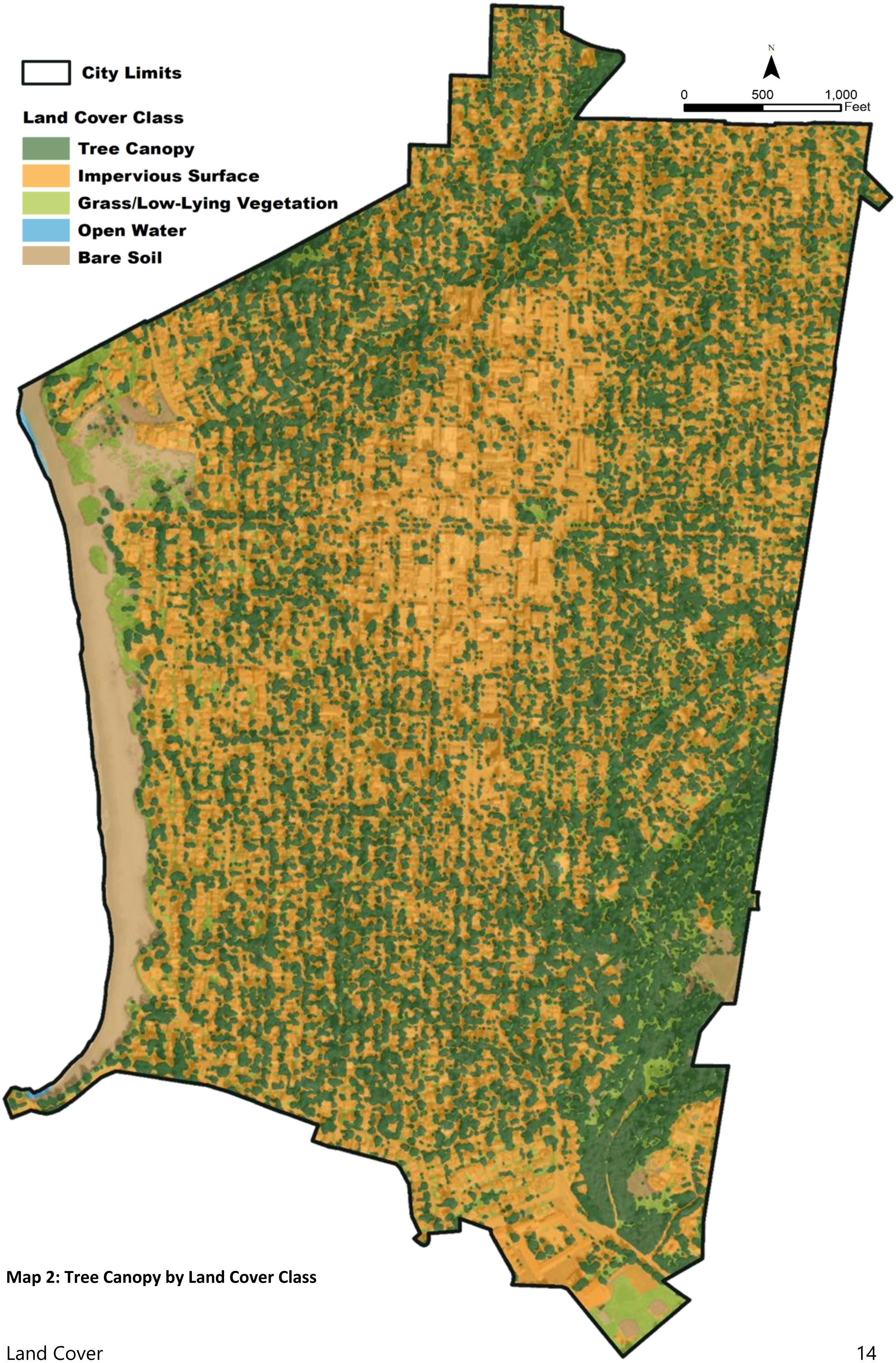


Figure 5: Carmel-by-the-Sea Land Cover

Table 2: Carmel-by-the-Sea Land Cover Classification Summary

Land Cover Class	Acres	% of Land Cover
Impervious Surface	304.56	45.03
Tree Canopy	243.26	35.97
Grass/Low-lying Vegetation	93.29	13.79
Bare Soil	34.70	5.13
Open Water	0.50	0.07
Total Acres	**676.31**	**100%**



Map 2: Tree Canopy by Land Cover Class

Tree Canopy by Parks

Carmel-by-the-Sea has 9 areas designated as parks, trails, and open space that cover a total of 81.7 acres (Table 3). Together, parks, trails, and open space include 31.1 acres of tree canopy for an average canopy cover of 38.1%. Unnamed Open Space 1 has the highest level of canopy cover at 71.1% followed by Mission Trail Park at 69.3% and Picadilly Park, which is quite small at 0.1 acres, and a canopy cover of 65.8%. Not surprisingly, Carmel Beach has the lowest level of canopy cover at just under 7% and very little opportunity for additional tree planting.

As the second largest park, Mission Trail Park (34.4 acres) has the most canopy acres (23.8 acres). Mission Trail Park also has 0.9 acres of impervious surfaces and 7.0 acres of grass/low-lying vegetation. Mission Trail Park is part of the 34-acre Mission Trail Nature Preserve that features three miles of hiking trails and a native plant garden. The preserve includes a Monterey pine forest, coast live oak woodland, wetlands, a willow riparian corridor, and a coastal prairie. Tree canopy in the park provides much needed habitat for birds and wildlife.

Table 3: Canopy Cover in Carmel-by-the-Sea's Parks, Trails, and Open Space

Parks	Acres	Canopy Acres	Canopy %	Impervious Acres	Grass/Low-lying Veg. Acres	Bare Soil Acres	Open Water Acres	Potential Canopy %
Carmel Beach	39.63	2.75	6.95	0.59	7.10	28.70	0.48	17.95
Mission Trail Park	34.38	23.83	69.31	0.93	6.96	2.67	0.00	69.46
Forest Hill Park	3.90	2.55	65.28	0.36	0.76	0.23	0.00	72.30
PacRep at the Forest Theater	1.57	0.63	40.40	0.67	0.23	0.04	0.00	56.84
Unnamed Open Space 1	1.12	0.80	71.09	0.04	0.28	0.00	0.00	96.21
Devendorf Park	0.63	0.34	52.92	0.04	0.26	0.00	0.00	53.00
First Murphy Park First Murphy House	0.28	0.11	39.14	0.11	0.06	0.00	0.00	61.31
Picadilly Park	0.10	0.06	65.81	0.02	0.01	0.00	0.00	74.55
Unnamed Open Space 2	0.08	0.02	29.09	0.03	0.02	0.00	0.00	59.70
Total	**81.68**	**31.09**	**38.06%**	**2.80**	**15.68**	**31.63**	**0.48**	**44.57%**

Map 3: Carmel-by-the-Sea Parks

Tree Canopy by Zoning Class

Zoning reflects the community's land classification plan and parameters for growth in specific areas (Map 4). Zoned areas encompass nearly 500 acres in Carmel-by-the-Sea and tree canopy cover varies widely across zoning designations. Examining tree canopy cover by zoning can provide additional perspective on canopy and establishing canopy goals and determining where to target new tree plantings.

Single-Family Residential zoning covers the greatest area (367 acres) and has an average canopy cover of 36%. Areas zoned for Parkland have the highest tree canopy cover (37.9%) and the potential to support up to 44.9% canopy cover (Table 4, Figure 6). Commercial zoning has the lowest canopy cover at 8.4%. Commercial areas also have a high percentage of hardscape (90.6%) and the lowest potential for canopy cover at 10.3%.

Table 4: Tree Canopy by Zoning

Zoning Class	Acres	Canopy Acres	Canopy %	Impervious Acres	Grass/Low-lying Veg. Acres	Bare Soil Acres	Open Water Acres	Potential Canopy %
Parkland	81.61	30.96	37.94	2.90	15.68	31.69	0.46	44.85
Single Family Residential	366.95	132.00	35.97	170.50	61.66	2.75	0.04	52.40
Cultural and Theatrical	4.91	1.10	22.46	3.58	0.23	0.00	0.04	27.12
Multi-Family Residential	7.06	0.95	13.42	5.54	0.49	0.00	0.00	20.09
Residential Limited Commercial	17.84	2.32	12.99	14.59	0.93	0.00	0.00	18.18
Commercial	21.47	1.80	8.39	19.46	0.43	0.00	0.00	10.30
Total	**499.84**	**169.13**	**33.84%**	**216.84**	**80.09**	**34.36**	**0.49**	**47.43%**

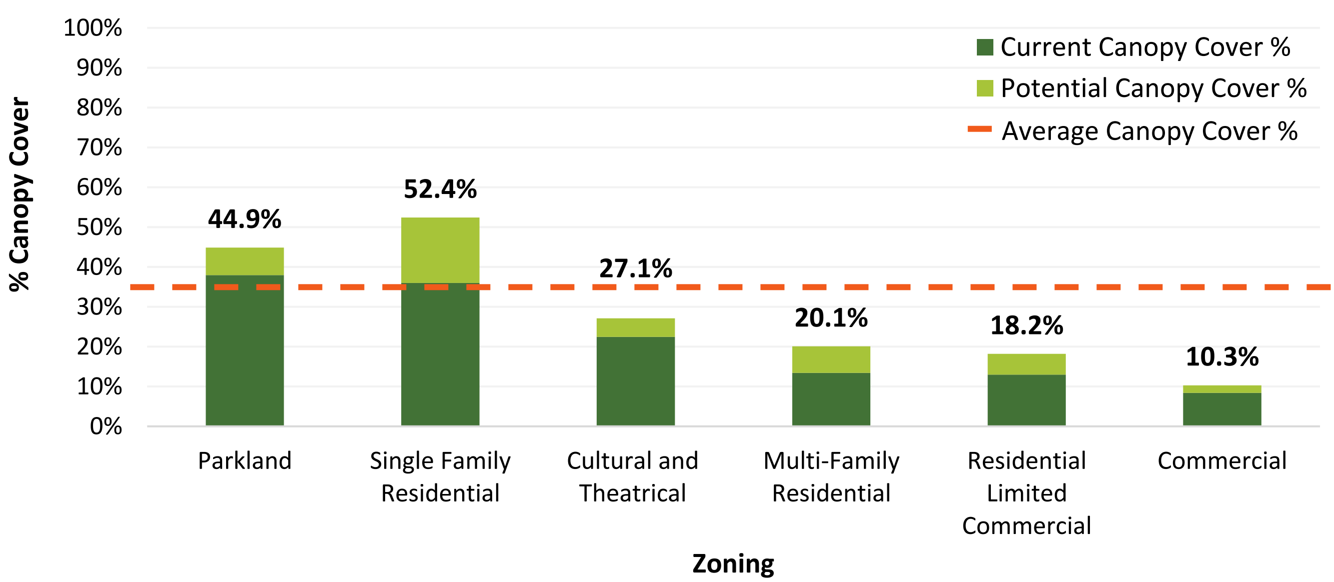


Figure 6: Current and Potential Canopy Cover by Zone

Map 4: Zoning in Carmel-by-the-Sea

Tree Canopy by Public Versus Private Land

The urban forest is comprised of all trees in the city, including trees on publicly and privately owned properties. Mapping tree canopy by land ownership can help managers better understand the distribution of the urban forest and serve as a baseline to monitor where canopy change is occurring. Nearly 57% (137.6 acres) of Carmel-by-the-Sea's tree canopy is on privately owned property (Table 5, Figure 7). Private lands also have the greatest potential for canopy at 48.6%. Overall, the average canopy cover on privately owned lands is 33.4%. On publicly owned lands the average canopy cover is 40%.

Table 5: Canopy Cover in Public and Private Land

Land Ownership	Acres	Canopy Acres	Canopy %	Impervious Acres	Grass/Low-lying Veg. Acres	Bare Soil Acres	Open Water Acres	Potential Canopy %
Private Land	412.09	137.55	33.38	50.45	15.53	0.64	0.00	48.64
Public Land	264.22	105.71	40.01	36.58	11.09	12.14	0.18	47.22
Total	**676.31**	**243.26**	**35.97%**	**87.03**	**26.62**	**12.78**	**0.19**	**48.08%**

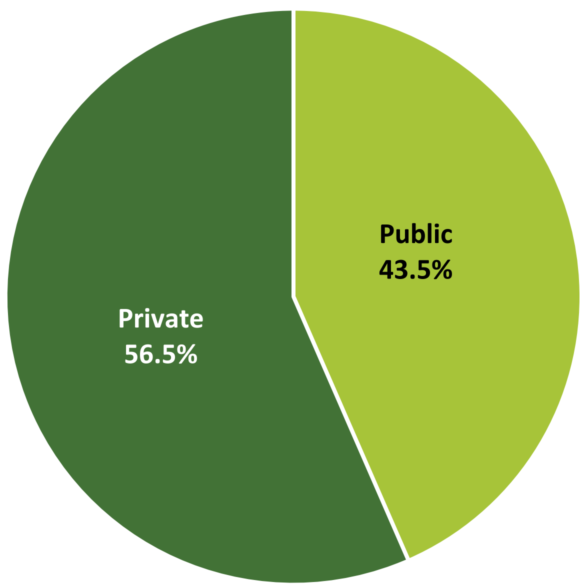


Figure 7: Canopy Cover Distribution Between Public and Private Land

Tree Canopy in Comparison with Other Communities

Communities vary in acreage, land use, and population, but comparison can be beneficial for providing context to the percentage and distribution of canopy cover in Carmel-by-the-Sea. Carmel-by-the-Sea's canopy cover falls in the top range among communities in Northern California with known canopy cover (Figure 8).

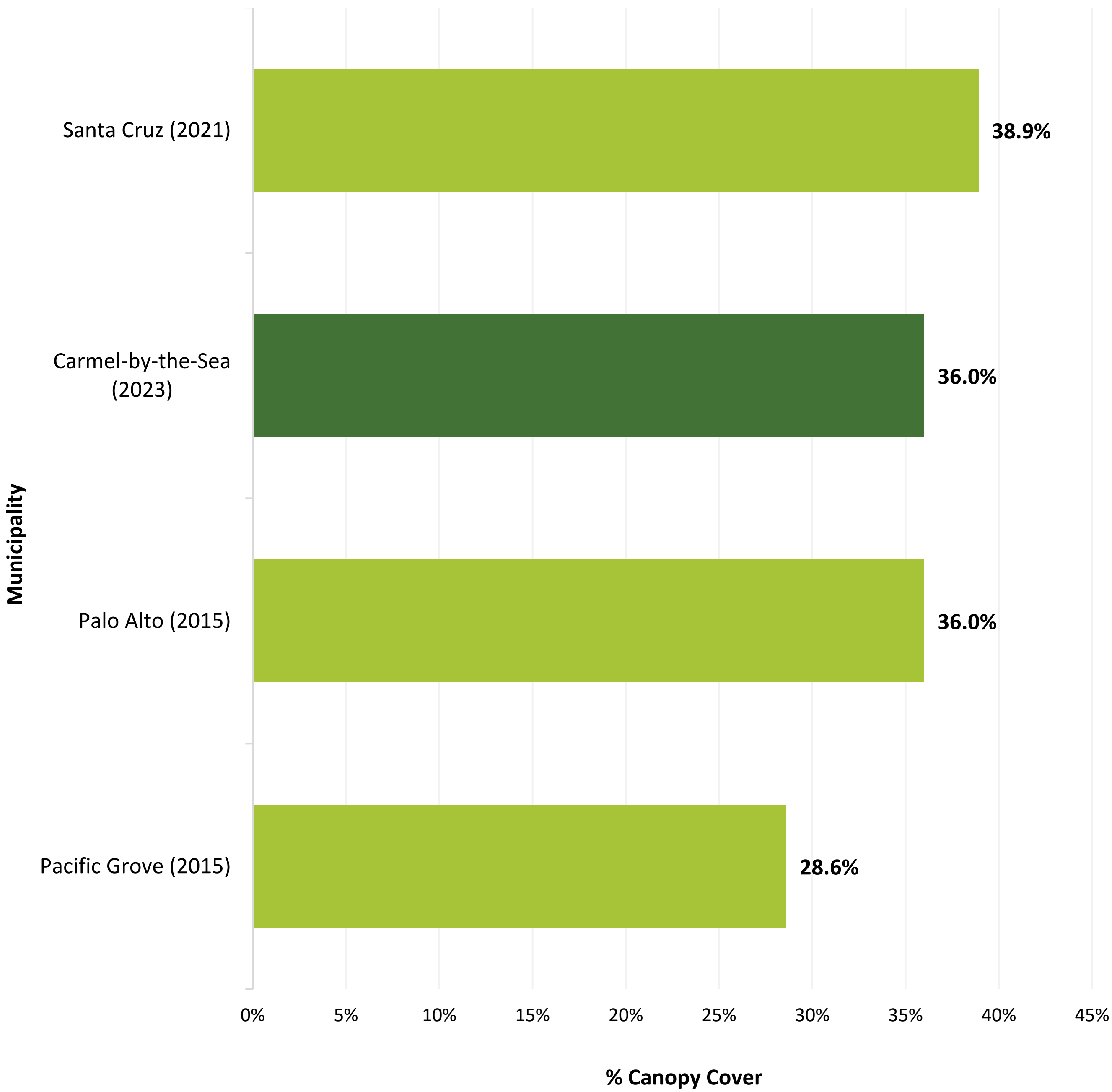


Figure 8: Canopy in comparison with other communities

Tree Canopy Health

Canopy health can be determined using near-infrared imagery and Normalized Difference Vegetation Index (NDVI) transformation. NDVI values are averaged over time to establish normal growing conditions in a region. Further analysis can characterize the health of vegetation relative to the established normal condition and classify plant condition from very good to declining. This important baseline data can help managers to better understand and evaluate forest health over time. The data can also be used as a comparison if emerging pests or disease become an issue. There are many biotic and abiotic factors that can impact the health of tree canopy, including drought, soil disturbances, pests, and disease. Where patterns of decline are apparent, a follow up field visit can help determine next steps.

In Carmel-by-the-Sea, more than 84% of tree canopy is in fair or better condition (Figure 9, Table 6). Healthy trees are vigorous, often producing more leaf surface area each year. In areas where the canopy appears to be in poor health (11.6%), field assessments and sampling (e.g., soil, foliar, pest/disease) can help to identify health factors and treatment protocols. Approximately 0.4% of canopy could not be classified due to shadows in the imagery.

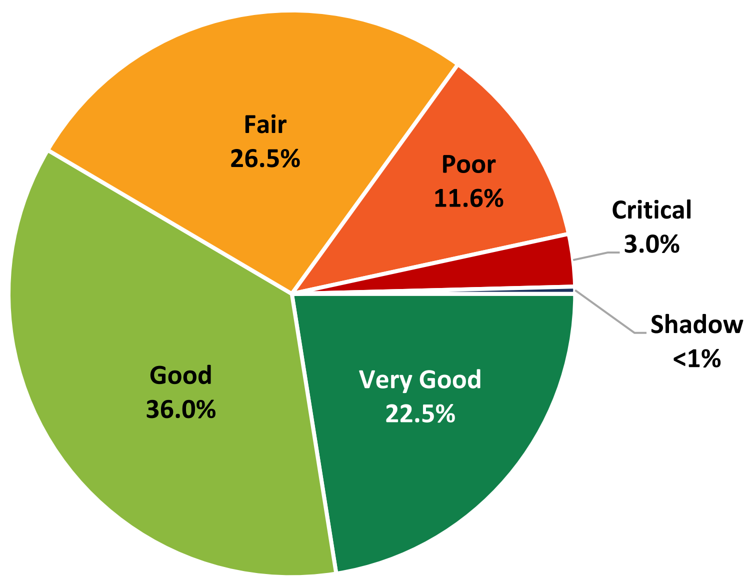
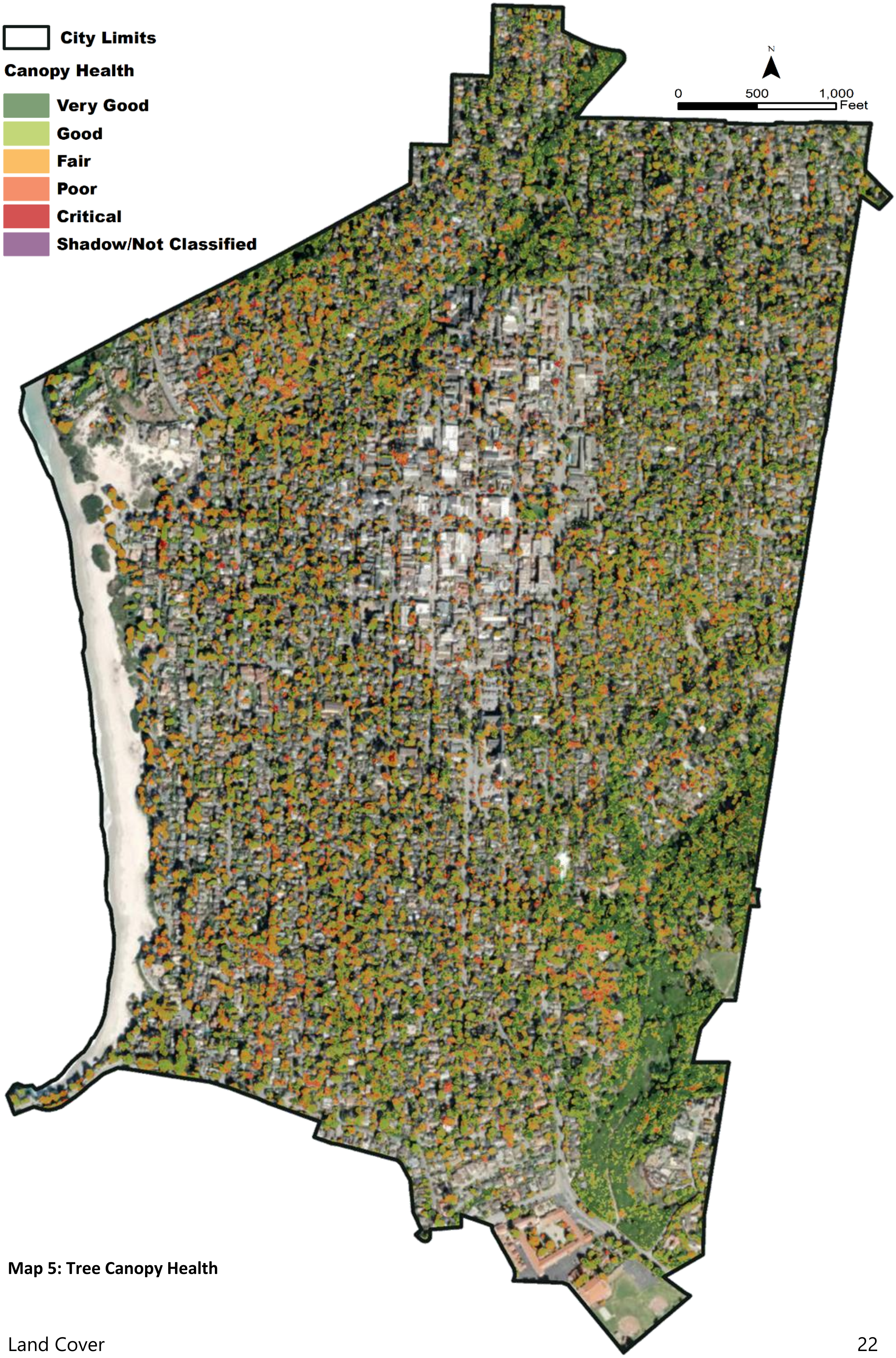


Figure 9: Summary of Canopy Health

Table 6: Summary of Canopy Health

Health Rating	Acres	% Canopy
Very Good	54.69	22.49%
Good	87.48	35.98%
Fair	64.43	26.50%
Poor	28.28	11.63%
Critical	7.26	2.99%
Shadow	0.99	0.41%
Total	**243.14**	**100%**



Map 5: Tree Canopy Health

Tree Planting Opportunities

To identify tree planting opportunities in Carmel-by-the-Sea, canopy data was used to conduct three different analyses: possible planting, priority planting, and tree placement modeling (Appendix B).

Possible Planting

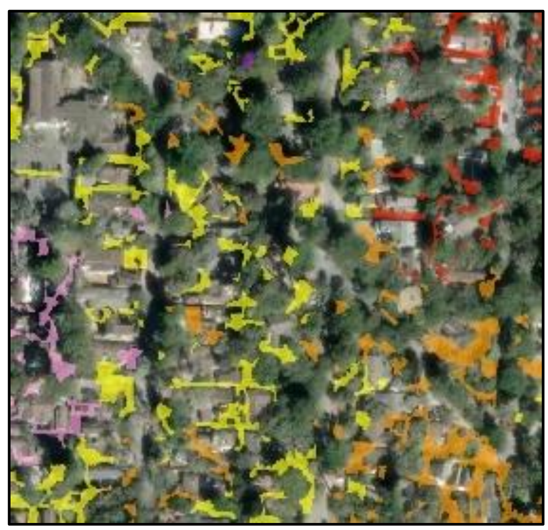
Areas of the city where additional tree canopy is possible were identified, including grass, low-lying vegetation, and bare soil. Some locations were excluded because they are not suitable or realistic planting locations due to soil quality and/or conflicts with the intended use of the site. Examples of this include areas designated and intended to be open and free from trees and canopy cover such as Carmel Beach and sports fields. The analysis identified 80.9 acres where additional trees could be planted, including 2.1 acres in commercial areas and 78.8 acres in residential areas (Map 6).

Including existing canopy (243.3 acres) there are a total of 324.2 acres with the potential to support tree canopy. If all possible sites are planted and existing trees are preserved, canopy cover could be increased to 48%. This analysis did not consider additional factors that might further inform the potential for canopy cover, including:

- Expansion of tree canopy over existing impervious surfaces, from the growth of newly planted and/or existing young trees
- Planned removal of trees and tree canopy for other land use
- Reclamation of existing impervious surfaces for new planting space

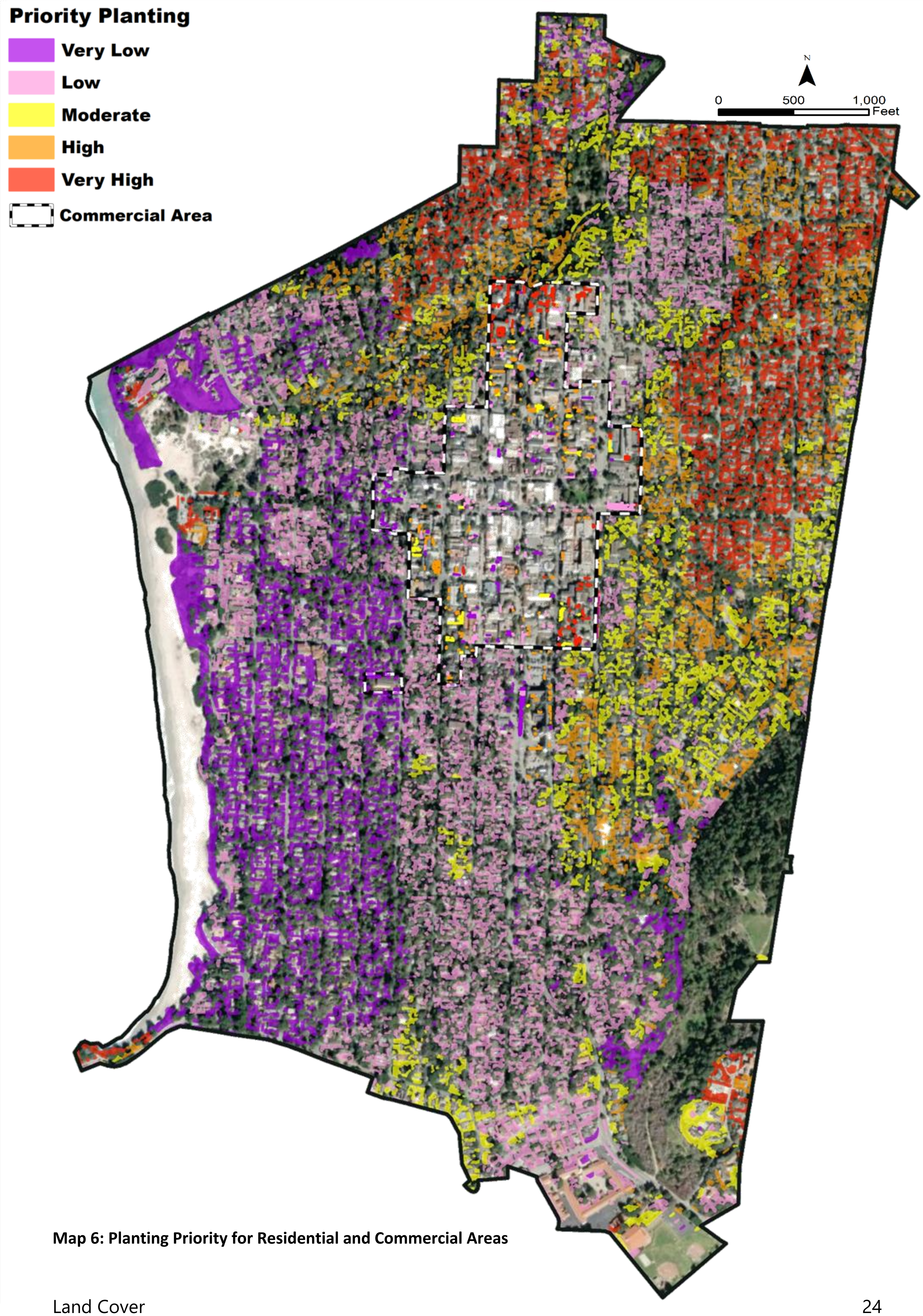
Priority Planting

Planting trees in some sites can be more beneficial for reducing stormwater runoff and preventing soil loss. To prioritize these locations, DRG assessed environmental factors, including proximity to hardscape, canopy fragmentation, soil permeability, slope, and potential for soil erosion factor (K-factor) (Table 7). Residential areas were prioritized to optimize stormwater capture and reduce canopy fragmentation. Commercial areas were prioritized to optimize stormwater capture and where soil conditions are conducive to planting trees.



Priority Planting Close-Up

Many trees in the community are mature and over time, as they reach the end of their useful life, they will need to be removed. As a result, losses in tree canopy should be anticipated over the next decade or so. The priority planting analysis can help identify areas where new tree planting will provide the greatest benefits for reducing stormwater runoff and soil erosion along with mitigating canopy loss. The analysis identified 21.6 acres of possible planting areas as high or very high priority (Table 8 and Map 6).



Map 6: Planting Priority for Residential and Commercial Areas

Table 7: Factors Used to Prioritize Planting Sites in Residential and Commercial Areas

Dataset	Source	Weight
	Residential	
Proximity to Hardscape	Land Cover Assessment	0.4
Distance to Canopy	Land Cover Assessment	0.3
Soil Permeability	Natural Resource Conservation Service	0.1
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.1
Slope	National Elevation Dataset	0.1
	Commercial	
Proximity to Hardscape	Land Cover Assessment	0.5
Soil Permeability	Natural Resource Conservation Service	0.17
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.17
Slope	National Elevation Dataset	0.16

Table 8: Priority for Possible Planting Areas by Residential and Commercial

	Residential (acres)	Commercial (acres)
Very High	11.11	0.53
High	9.54	0.45
Moderate	13.55	0.30
Low	21.24	0.45
Very Low	23.35	0.41
Total	**78.79**	**2.14**

Tree Placement

A tree placement model was used to estimate the number of large, medium, and small stature trees[1] that can be planted based on possible planting space. Where a possible planting site in the public rights-of-way includes an existing stump, this information is noted in the database. Possible planting sites on private property may also have stumps; however, the city does not track this data. The model identified 888 planting sites on public rights-of-way in residential and commercial areas, including 46 sites with existing stumps (Table 9 and 11, Figure 10 and 11). A total of 2,832 possible planting sites are located on private property.

Within residential areas, 10% of possible planting sites could accommodate a large stature tree, whereas within commercial areas only 4% of possible sites were appropriate for a large tree. Nearly 27% of possible planting sites in residential areas and more than 47% of possible sites in commercial areas are in planting areas classified as high or very high priority. Forty-six possible planting sites have an existing stump, 44 of which were in residential areas.

[1] Tree stature is based on the diameter of estimated canopy spread at maturity: small (15 feet), medium (30 feet), and large (50 feet)

Table 9: Possible Planting Sites in Residential Areas

Priority	Total Sites	Private Sites	Public Sites	Public Sites with Stumps	Total Tree Polygon Acres
Very High	500	392	108	11	4.31
High	468	350	118	11	4.14
Moderate	643	510	133	11	5.92
Low	986	794	192	6	9.28
Very Low	1,024	728	296	5	13.55
Total	**3,621**	**2,774**	**847**	**44**	**37.20**

Table 10: Possible Planting Sites in Commercial Areas

Priority	Total Sites	Private Sites	Public Sites	Public Sites with Stumps	Total Tree Polygon Acres
Very High	28	22	6	0	0.21
High	19	10	9	1	0.15
Moderate	16	11	5	0	0.13
Low	15	7	8	1	0.15
Very Low	21	8	13	0	0.10
Total	**99**	**58**	**41**	**2**	**0.74**

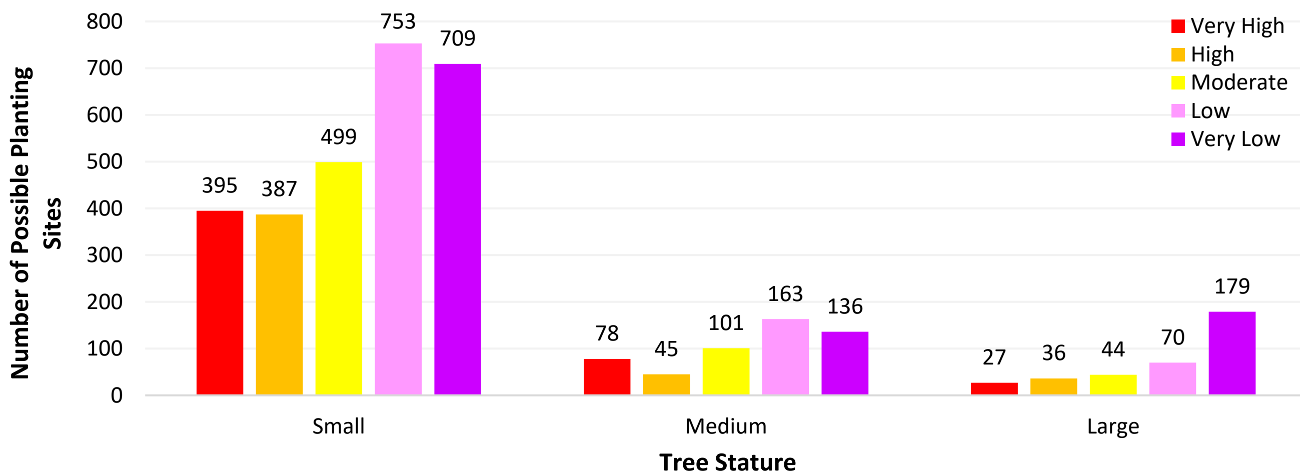


Figure 10: Priority for Possible Planting Sites in Residential Areas

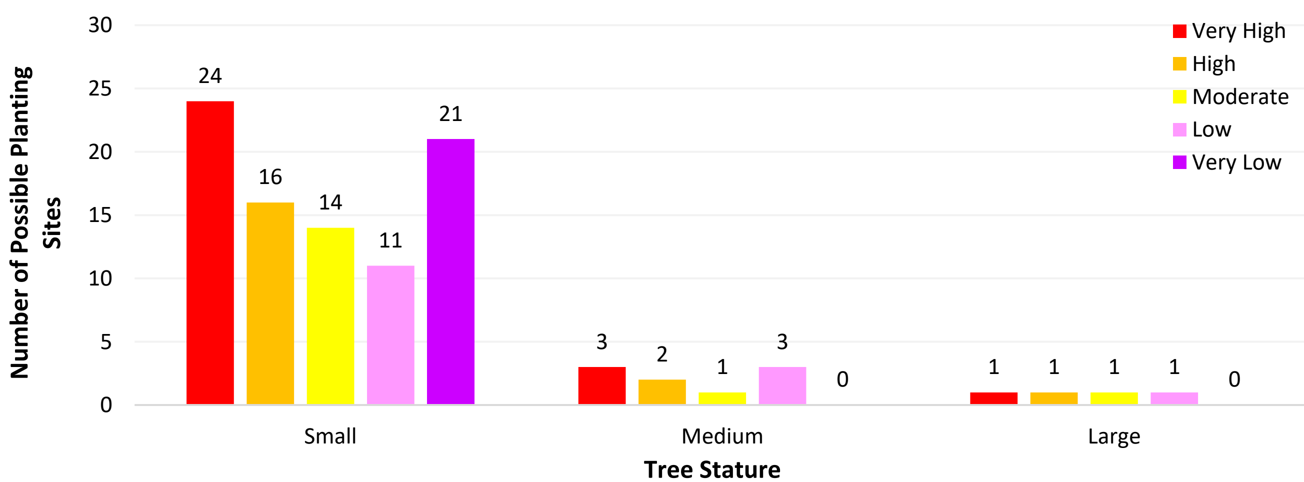


Figure 11: Priority for Possible Planting Sites Commercial Areas

Conclusion

Carmel-by-the-Sea's Tree Canopy and Land Cover Assessment establishes a new baseline for monitoring tree canopy cover throughout the community and augments the City's GIS database with a landcover layer that identifies the location and extent of existing canopy and possible planting sites. This data can be used in conjunction with other geographic layers to further prioritize planting plans and strategically manage canopy cover by zoning class, census tracts, parks, schools, parcels or other boundaries. The data provides a foundation for developing urban forest management strategies and measuring the success of those strategies over time.

Currently, Carmel-by-the-Sea has an overall average canopy cover of 36%. Considering there are nearly 81 acres of possible planting sites, there is the potential to increase canopy cover up to 48%, if all possible sites are planted.

Based on this assessment, urban forest managers have the following opportunities:

- Identify canopy goal(s) based on zoning, land cover distribution, and community values.
- Replace and expand canopy by planting trees in parks, trails, and open spaces, as these areas have 5 acres of possible planting sites.
- Encourage tree planting and preservation on private property by incentivizing trees and through community education and support for activities and programs related to the urban forest.
    - Incentivize tree preservation and planting on private property through tree planting campaigns and other activities and programs aimed at increasing awareness of the value and benefits of trees and canopy cover.
    - Support volunteer activities and initiatives that help the community realize tree planting and canopy goals.
    - Support and augment policies that protect private trees and mitigate replacement of trees that require removal.
- Use priority planting maps to develop planting plans that support canopy goals, stormwater management, soil preservation, and complement existing infrastructure for the greatest impact and return on investment.
    - Use tree placement modeling to optimize the potential for possible planting sites. Where possible, planting large stature trees will result in the greatest benefits.
    - Prioritize planting sites that do not have an existing stump.
    - Remove existing stumps to increase possible planting space.
    - Incentivize tree planting on private property, particularly in areas of high and very high priority.
- Periodically reassess canopy cover (e.g., every 10 years) to track changes and trends.
- Preserve and protect existing trees to maximize and sustain environmental benefits.

In Carmel-by-the-Sea there are 375 acres zoned as residential that include 134 acres of tree canopy for an average canopy cover of 35.6%

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There are 81.7 acres in Carmel-by-the-Sea dedicated to parks, trails, and open space with an average canopy cover of 38.1%.

Appendix B: Methodology

Calculating Benefits

Air Quality

The i-Tree *Canopy* v7.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree *Canopy* was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree *Canopy* application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; US EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree *Canopy*, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree *Canopy*. Those canopy percentages were matched by placing random points within the i-Tree *Canopy* application. Benefit values were reported for each of the five listed air pollutants.

Carbon Storage and Sequestration

The i-Tree *Canopy* v7.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree *Canopy* was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.

To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree *Canopy*. Those canopy percentages were matched by placing random points within the i-Tree *Canopy* application. Benefit values were reported for carbon storage and sequestration.

Stormwater

The i-Tree *Hydro* v6.1 Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree *Hydro* was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent version (v6.1) allows users to report hydrologic data on the city level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree *Hydro* v6.1 manual (http://www.itreetools.org).

To calculate ecosystem services for the study area, land cover percentages derived for the project area and all municipalities that were included in the project area were used as inputs into the model. Precipitation data from 2005-2012 was modeled within the i-Tree *Hydro* to best represent the average conditions over an eight-year time period. Model simulations were run under a Base Case as well as an Alternate Case. The Alterative Case set tree canopy equal to 0% and assumed that impervious and vegetation cover would increase based on the removal of tree canopy. Impervious surface was increased 4% based on a percentage of the amount of impervious surface under tree canopy and the rest was added to the vegetation cover class. This process was completed to assess the runoff reduction volume associated with tree canopy since i-Tree Hydro does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons to retrieve the overall volume of runoff avoided by having the current tree canopy.

Through model simulation, it was determined that tree canopy decreases the runoff volume in the project area by 3,469,744 gallons per year using precipitation data from 2005-2012. This equates to approximately 14,265 gallons per acre of tree canopy (3,469,744 gals/243.23 acres).

To place a monetary value on storm water reduction, the cost to treat a gallon of storm/waste water was taken from McPherson et al 1999. This value was $0.01 per gallon. Tree canopy was estimated to contribute roughly $1,579,828 to avoided runoff annually to the project area.

Land Cover Extraction and Accuracy Assessment

Davey Resource Group, Inc. utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely-sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by each UTC city, and custom ArcGIS® tools were used to aid in the final manual editing, quality checking, and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflow

1. Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.
2. Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows). Water samples are not always needed since hydrologic data are available for most areas. Training data for impervious features were not collected because the City maintained a completed impervious layer.
3. Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.
4. Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to

represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.

5. Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.
6. Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc. to update features.
7. Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.
8. Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.
9. Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.
10. Input canopy, impervious, bare soil, and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.
11. Thoroughly inspect final land cover dataset for any classification errors and correct as needed.
12. Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1. Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.
2. Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the number of small features that could result in incorrect classifications and also helps computer performance.
3. The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.
4. The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve the best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process will be completed using ArcGIS® to identify, clean, and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions will be edited at a 1:2000 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

To test for accuracy, random plot locations are generated throughout the city area of interest and verified to ensure that the data meet the client standards. Each point will be compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points will be classified as either correct or incorrect and recorded in a classification matrix. Accuracy will be assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics are calculated using a custom Excel® spreadsheet.

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. ***Random Point Generation***—Using ArcGIS, 1,000 random assessment points are generated.
2. **Point Determination**—Each point is carefully assessed by the GIS analyst for likeness with the aerial photography. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 12) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same, then the point is counted as a correct classification. Likewise, if the CODE and TRUTH are not the same, then the point is classified as incorrect. In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins.
3. ***Classification Matrix***—During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is

presented in Table 11. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Table 11).

Table 11: Classification Matrix

		Classification Data							
	Classes	**Tree Canopy**	**Impervious**	**Grass/Veg**	**Bare Soils**	**Water**	**Row Total**	**Producer's Accuracy**	**Errors of Omission**
Reference Data	**Tree Canopy**	370	11	8	0	0	389	**95.12%**	**4.88%**
	Impervious	4	418	2	0	0	424	**98.58%**	**1.42%**
	Grass/Veg	6	13	116	2	0	137	**84.67%**	**15.33%**
	Bare Soils	0	0	0	46	0	46	**100.00%**	**0.00%**
	Water	0	0	0	0	4	4	**100.00%**	**0.00%**
	Column Total	380	442	126	48	4	1,000		
	User's Accuracy	**97.37%**	**94.57%**	**92.06%**	**95.83%**	**100.00%**		**Overall Accuracy**	**95.40%**
	Errors of Commission	**2.63%**	**5.43%**	**7.94%**	**4.17%**	**0.00%**		**Kappa Coefficient**	**0.9287**

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

Overall Accuracy – Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((370+418+116+46+4)/1,000 = 95.40%).

User's Accuracy – Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [370/380= 97.37%]).

Producer's Accuracy – Probability of a reference pixel being correctly classified (correct land cover classifications divided by the row total [370/389 = 95.12%]).

Kappa Coefficient – A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

Errors of Commission – A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 2.63% of the area classified as canopy is most likely not canopy.

Errors of Omission – A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the matrix below, we can conclude that 4.88% of all canopy classified is actually classified as another land cover class.

Allocation Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less-than-optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

Confidence Intervals – A confidence interval is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

Table 12: Confidence Intervals

95% Confidence Intervals

Landcover Assessment

Class	Acres	%	Lower Bound	Upper Bound
Tree Canopy	243.23	36.0%	34.1%	37.8%
Impervious	304.65	45.0%	43.1%	47.0%
Grass/Veg	93.22	13.8%	12.5%	15.1%
Bare Soils	34.71	5.1%	4.3%	6.0%
Water	0.50	0.1%	0.0%	0.2%
Total	676.31	100.0%		

Statistical Metrics Summary:

Overall Accuracy =95.4%
Kappa Coefficient = 0.9287
Allocation Disagreement = 3%
Quantity Disagreement = 2%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	97.4%	96.5%	98.2%	95.1%	94.0%	96.2%
Impervious	94.6%	93.5%	95.6%	98.6%	98.0%	99.2%
Grass/Veg	92.1%	89.7%	94.5%	84.7%	81.6%	87.7%
Bare Soils	95.8%	92.9%	98.7%	100.0%	100.0%	100.0%
Water	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Priority Planting

Summary

This project was conducted to assess priority planting locations for Carmel-by-the Sea, CA. Data sources were sought across the board to analyze a variety of factors that can contribute to accessing tree canopy needs. Analysis included data sets from the city of Carmel-by-the-Sea, US Department of Agriculture, and United States Geological Survey. The resulting analysis found plantable areas in both public and private properties across the town.

Description

To help the census tract in the city of Carmel-by-the-Sea increase its canopy coverage, an urban tree canopy assessment was conducted by the town to assess land cover using 2022 aerial imagery. The study was completed in 2023. An analysis to identify the most suitable locations was conducted by analyzing each planting location to assign a priority ranking for stormwater.

Each data source utilized the most current version available and described in the subsequent sections. Stormwater uses the most recent NAIP imagery, soil data, hydrography data, and elevation data.

Methodology

In order to create a priority planting plan, the locations for planting must first be determined. Planting location polygons were created by taking all grass/open space and bare ground areas and combining them into a single dataset. Non-feasible planting areas such as agricultural fields, recreational fields, major utility corridors, airports, etc. were restricted and noted as a query-able attribute in the final GIS dataset. This layer was reviewed and approved by the city of Carmel-by-the-Sea before the analysis proceeded. The remaining planting space was consolidated into a single feature and then, exploded to multipart features creating separate, distinct polygons for each location. The final step broke polygons up again to note planting restrictions as their own feature.

Stormwater:

To identify and prioritize planting potential based on the stormwater analysis, locations were assessed with several environmental features, including proximity to hardscape, proximity to canopy, soil permeability, slope, and soil erosion factor. These factors are based on numerous historic projects completed by DRG for stormwater analysis. Each factor was assessed using data from various sources and analyzed using separate grid maps. Values between zero and four (with zero having the lowest priority) were assigned to each grid assessed. A value of zero indicates that this classified piece of information yielded little or no overall value within the dataset. The grids were overlain with the values averaged to determine the priority levels at an area on the map. A priority ranging from Very Low to Very High was assigned to areas on the map based on the calculated average of all grid maps using quantile classification breaks within ArcGIS. This step of the process was completed to statistically subset data evenly into five classes of increasing importance. Areas of higher potential for runoff and erosion were considered higher priority due to their ability to diminish water quality within urban areas.

Once the process of identifying priority was completed, the development of planting strategies will be the next step in the process. While available planting sites may ultimately be planted over the next several decades, the trees that are planted in the next few years, should be planned for areas in most need, and where they will provide the most benefits and return on investment given a particular set of circumstances and desires to fulfill certain obligations to the community. The city of Carmel-by-the-Sea can choose to target individual factors like heat islands for certain projects or select from the composite ranking to get the most return on investment across the board.

Table 13: Priority Weighting Scheme

Dataset	Source	Weight
	Residential	
Proximity to Hardscape	Land Cover Assessment	0.4
Distance to Canopy	Land Cover Assessment	0.3
Soil Permeability	Natural Resource Conservation Service	0.1
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.1
Slope	National Elevation Dataset	0.1
	Commercial	
Proximity to Hardscape	Land Cover Assessment	0.5
Soil Permeability	Natural Resource Conservation Service	0.17
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.17
Slope	National Elevation Dataset	0.16

Weighted Overlay Equation for stormwater priority:

("Impervious Distance" * 0.40) + ("Soil Permeability" * 0.10) + ("Soil Erosion" * 0.10) + ("Canopy Distance" * 0.30) + ("Slope Percent" * 0.10)

Weighted Overlay Equation for stormwater priority:

("Impervious Distance" * 0.50) + ("Soil Permeability" * 0.17) + ("Soil Erosion" * 0.17) + ("Slope Percent" * 0.16)

Stormwater

Distance to Hardscape

Source: Carmel-by-the-Sea Urban Tree Canopy Assessment

Data: Distance to Impervious

Distance to hardscape is derived by selecting the impervious surfaces data from the Carmel-by-the-Sea landcover layer. This impervious raster is used as an input layer into the Euclidean Distance tool within ArcGIS to create a layer that measures straight-line distance from each impervious surface location within the town. These distances are grouped into five classes from 0 - 4 with 4 being the closest to impervious surfaces and, therefore, the highest priority. The further a location is from an impervious surface, the lower the ranking it receives. A ranking of 0 is given to locations that are currently represented as impervious surfaces in the land cover data while the value of 4 indicates that the open area next to the impervious surface is available for planting trees to reduce the amount of runoff and sedimentation.

Table 14: Distance to Hardscape Ranking

Distance to Hardscape	
Rank	Distance to Impervious (ft)
0	0
1	Over 100
2	51 - 100
3	26 – 50
4	1 – 25

Distance to Canopy

Source: Carmel-by-the-Sea Urban Tree Canopy Assessment

Data: Distance to Canopy

Distance to canopy is derived by selecting the tree canopy data from the Carmel-by-the-Sea landcover layer. This canopy raster is used as an input layer into the Euclidean Distance tool within ArcGIS to create a layer that measures straight-line distance from each canopy location within the town. These distances are grouped into five classes from 0 - 4 with 4 being the closest to Canopy and therefore the highest priority. The further a location is from the canopy, the lower the ranking it receives. A ranking of 0 is given to locations that are currently occupied by tree canopy and not plantable. Higher values in this ranking will prioritize areas that have small gaps that can be filed in order to increase tree canopy closure, which has great impact of wildlife habitat by providing larger corridors to support a variety of different species.

Table 15: Distance to Canopy Ranking

Distance to Canopy	
Rank	Distance to Canopy (ft)
0	0
1	Over 200
2	101 - 200
3	51 - 100
4	1 - 50

Soil Permeability

Source: Natural Resource Conservation Service – USDA Web Soil Survey

Link: *https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx*

Data Attribute: Hydrologic Soils Group (HSG)

Soil Permeability is found by analyzing the Hydrologic Soils Group (HSG) information from the USDA Soil Surveys. This data is classified into four classes: A, B, C and D. Group A soils have a high infiltration rate, Group B has a moderate infiltration rate, Group C has a slow infiltration rate, and Group D has a very slow infiltration rate. The remaining values are classified as W denoting water. These areas are typically larger bodies of water such as ponds, lakes or rivers. The rankings range from 0 - 4 with 4 being the highest priority. A ranking of 4 is given to the D classification due to its low infiltration rate. Planting in these locations will increase stormwater uptake and therefore, reduce the amount of runoff. Lower rankings are given to the A, B and C classes as these classes have higher infiltration rates where water is able to percolate through the soil without creating surface runoff leading to an decrease in harmful pollutants and sediment into streams and stormwater infrastructure over time. The W class is given a 0 ranking because these areas are classified as water and have no bearing of runoff.

Table 16: Soil Permeability Ranking

Soil Permeability - HSG	
Rank	Threat
0	W
1	A
2	B
3	C
4	D

Soil Erosion

Source: Natural Resource Conservation Service – USDA Web Soil Survey

Link: *https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx*

Data Attribute: K-factor

Soil Erosion is found by analyzing the K-factor information from the USDA Soil Surveys. This data is classified into decimal numbers that range from 0.02 – 0.69. The higher numbers within this range mean that the area is more susceptible to sheet and rill erosion by water. Remaining values are given a value of 0 of which can represent water, quarries, pits, and other harder surface types. Water features are typically ponds, lakes and rivers. Rankings for this data are based on the susceptibility to erosion. A 0 ranking is given to areas that have little to no risk of erosion. The ranking increases as the risk of erosion increases with the highest ranking being 4. Planting in these priority areas will help decrease erosion vulnerability.

Table 17: Soil Erosion (K-factor) Ranking

Soil Erosion – K-factor	
Rank	**K-factor (expressed as whole numbers)**
0	0 - 10
1	45250
2	21 - 30
3	31 - 37
4	Over 38

Slope

Source: National Elevation Dataset – USDA Geospatial Data Gateway

Link: *https://datagateway.nrcs.usda.gov/*

Data: DEM

Slope is calculated by using the Digital Elevation Model (DEM) from the USDA and finding the slope percent rise of the DEM. The Percent Rise results were grouped into five classes from 0 - 4 with 4 being the highest priority as shown below. The rankings for this data are based on the percent rise of the area. The larger the percent rise of the land, the higher the planting priority. A ranking of 0 is given to areas of no percent rise and the rankings then increase as the percent rise increase with the highest ranking being 4. Planting trees on areas of high percent rise can help decrease stormwater runoff.

Table 18: Slope Ranking

Slope – Percent Rise	
Rank	**Percent Rise**
0	0
1	0 - 3
2	44991
3	45089
4	Over 12

Tree Placement

Summary

The purpose of this feature class is to create a planting placement guide for Carmel-by-the-Sea, California. This layer identifies possible locations for tree placement based on the placement analysis.

Description

To help Carmel-by-the-Sea, California increase its canopy coverage by community, an urban tree canopy assessment was conducted to determine the current land cover. This landcover was used to find the most suitable locations to plant trees. These locations were narrowed down to exclude areas within 5 feet of existing trees or 5ft existing impervious surface.

Use Limitations

As determined by the Carmel-by-the-Sea, California

Data Quality

Planting sites and their tree sizes are generalized based on data derived from the Priority Planting analysis and the Tree Placement model. No field verification of planting sites was conducted. Before planting, the City will need to conduct site assessments to ensure planting locations can adequately sustain planting trees.

Lineage

This process uses the priority planting areas to create points for tree placement. Grids area created over the designated area and points are placed within these grids within the priority planting areas. The size of the trees are determined by the size that is able to fit within both the grid and the planting area. The model places large trees first and then uses the remaining area to place medium trees and then again for small trees.

Fields

ET_X - X coordinate

ET_Y - Y coordinate

BUFF_DIST - The radius of the crown

Crown Size - The size (small, medium, large) of the tree crown

UNIQUEID - unique identifying number

Zone – If the tree placement point falls into a residential or commercial area

Priority - Stormwater priority rank