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16. ABSTRACT

Green streets offer many potential benefits that include improving water quality, absorbing carbon (sequestration), and reducing urban heat island effects. This report summarizes: (1) the research team's analysis of 14 tools calculating green streets benefits; and (2) the results of applying the most promising calculators to a select group of green streets case studies. The researchers are affiliated with the Mineta Transportation Institute, which serves the California Department of Transportation ("Caltrans"). The report presents the results of the case study analyses, with an emphasis on carbon sequestration benefits and improvements to pedestrian levels of service (PLOS).

Trees absorb carbon dioxide and other pollutants from the air, reducing the costs of future climate change mitigations and medical care. Key findings obtained using i-Tree Design suggest that the monetary value (CO2 and air quality) of planting street trees is small but significant, with total estimated benefits from street trees on seven case study sites ranging from a low of $1,466 to a high of $9,420 over a 20-year period. On a per tree basis, the lowest benefits come from site 3A (Cherry Avenue in San Jose) with $10 per tree, and the highest come from site 1A (San Pablo Avenue in El Cerrito) at $175 per tree.

While the Landis PLOS method accounts for the benefits of short street tree spacings (i.e., a high number of trees) and of having a continuous biostrip or planter strip serving as a pedestrian buffer, the method does not appear to be sensitive to tree spacings, though it is very sensitive to buffers. Therefore, the importance of having a biostrip or planter strip buffer between the sidewalk and street traffic is also reflected in the PLOS findings in this study.

While the measurable benefits of a handful of street trees may seem small, this study suggests that using i-Tree Design to add together the trees planted by local and state agencies has the potential to provide a compelling picture of the carbon sequestration benefits across California. Similarly, the use of Highway Capacity Manual (HCM)-based pedestrian level of service methods by transportation professionals can bring significant gains in the appreciation of green streets' benefits.

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Analysis of the Benefits of Green Streets

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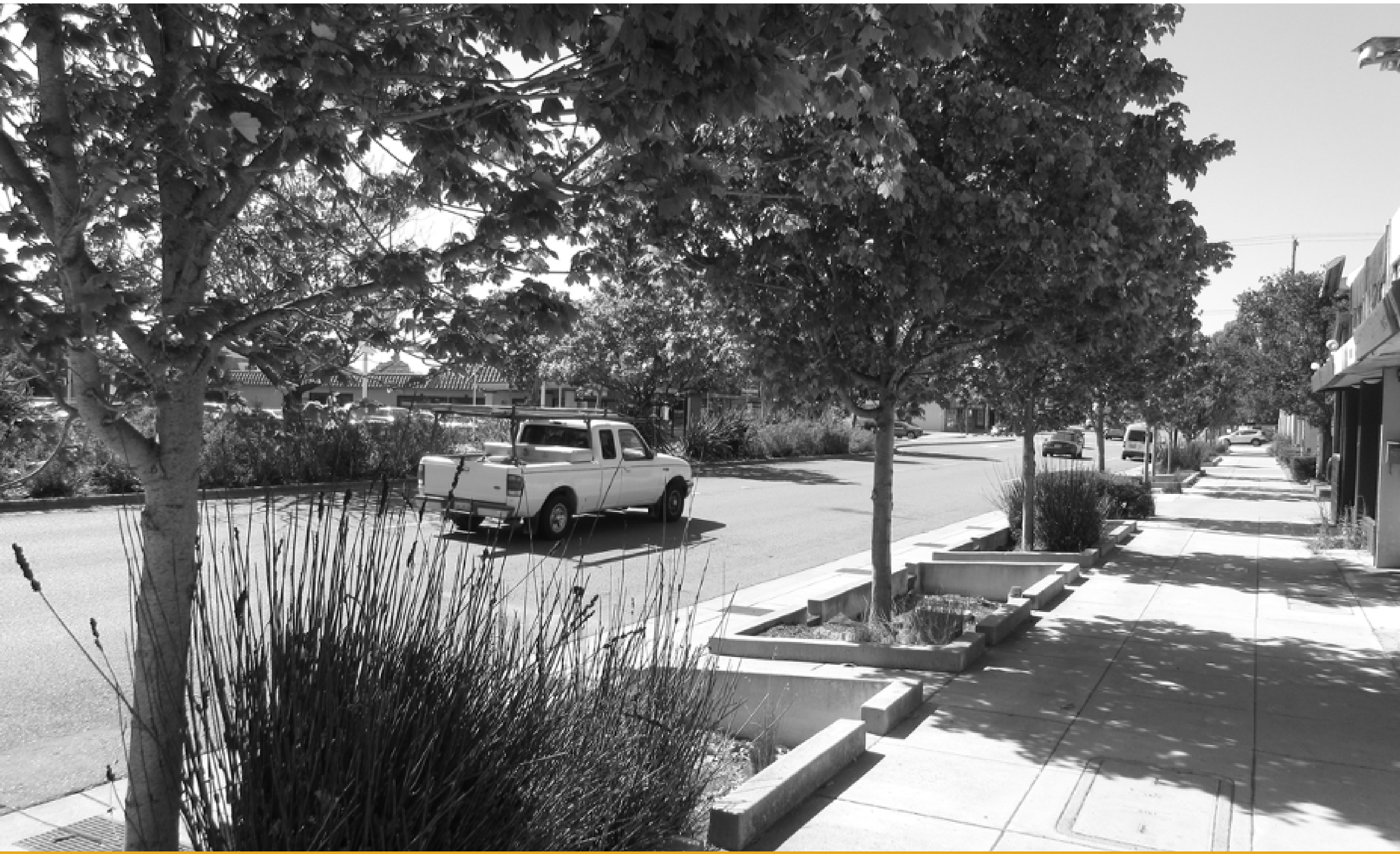

MINETA TRANSPORTATION INSTITUTE

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Mineta Consortium for Transportation Mobility

Founded in 1991, the Mineta Transportation Institute (MTI), an organized research and training unit in partnership with the Lucas College and Graduate School of Business at San José State University (SJSU), increases mobility for all by improving the safety, efficiency, accessibility, and convenience of our nation's transportation system. Through research, education, workforce development, and technology transfer, we help create a connected world. MTI leads the four-university Mineta Consortium for Transportation Mobility, a Tier 1 University Transportation Center funded by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology (OST-R), the California Department of Transportation (Caltrans), and by private grants and donations.

MTI's transportation policy work is centered on three primary responsibilities:

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MTI works to provide policy-oriented research for all levels of government and the p rivate sector to foster the development of optimum surface transportation systems. Research areas include: bicycle and pedestrian issues; financing public and private sector transportation improvements; intermodal connectivity and integration; safety and security of transportation systems; sustainability of transportation systems; transportation / land use / environment; and transportation planning and policy development. Certified Research Associates conduct the research. Certification requires an advanced degree, generally a Ph.D., a record of academic publications, and professional references. Research projects culminate in a peer-reviewed publication, available on TransWeb, the MTI website (http://transweb.sjsu.edu).

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REPORT 20-32

ANALYSIS OF THE BENEFITS OF GREEN STREETS

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EXECUTIVE SUMMARY

Green streets, as defined by the Environmental Protection Agency, are streets that incorporate different kinds of vegetation and permeable surfaces "…to slow, filter, and cleanse storm water run-off from impermeable surfaces."[1] Unlike traditional streets, green streets retain runoff at the source rather than discharging runoff off-site.[2] Green streets offer many other potential benefits that include improving water quality, absorbing carbon (sequestration), and reducing urban heat island effects.[3] This report summarizes: (1) the research team's analysis of 14 tools calculating green streets benefits; and (2) the results of applying the two most promising calculators to a select group of green streets case studies. The researchers are affiliated with the Mineta Transportation Institute (MTI), which serves the California Department of Transportation ("Caltrans"). The report presents the results of the case study analyses, with an emphasis on carbon sequestration benefits estimated using the i-Tree Design[4] calculator, and improvements to pedestrian levels of service estimated using a Highway Capacity Manual (HCM)-based (the "Landis") method.[5]

APPROACH

The MTI team developed a list of 14 calculators for use in measuring green street infrastructure benefits. From this list, three calculators were selected for testing in consultation with Caltrans:

1. i-Tree Design.[6]

2. Center for Neighborhood Technology's (CNT's) Green Values National Stormwater Management Calculator.[7]

3. Landis Pedestrian Level of Service (PLOS).[8]

Based on the lessons learned from a literature review and stakeholder discussions, the research team developed a list of potential case study sites. In total, 22 sites were identified, of which 11 were examples of "green" sites with at least one green street feature. Eleven matched-pair "non-green" sites were selected to be as close as possible to the green street sites in terms of highway/street design, surrounding characteristics (e.g., urban, suburban, rural small town), and traffic volumes, except that these sites had no green street features.

Because green and non-green sites can be substantially different in terms of their development context, street and traffic characteristics, and other features, the initial test calculator output for three green street and three non-green street sites revealed that, for the most part, there little benefit was derived from comparing green to non-green sites as a way to test the capabilities and shortcomings of each calculator. As a result, the team employed additional tests using calculator runs based on hypothetical "before" conditions for three green street sites. These conditions were estimated based on the removal of all green street infrastructure elements from each green site and their replacement with non-green features similar to what is found at each non-green paired site.

Based on these calculator test findings and subsequent discussions with Caltrans, the research team decided to move forward with the analysis of the hypothetical before and after conditions for seven green street case study sites using the i-Tree Design and Landis PLOS calculators.

FINDINGS AND DISCUSSION

It is important to note that there are several potentially important benefits of green streets infrastructure that the two calculators used in this study, i-Tree Design[9] and Landis PLOS[10], are not designed to measure. Therefore, these case study findings should be considered as limited and suggestive rather than as definitive accounts of the total benefits at each site and the benefits of each green street infrastructure type.

In particular, the contribution of street trees and other vegetation to reducing the urban heat island effect; the stormwater filtering, runoff, and retention benefits of biostrips and other planters; and the benefits to bicyclists (which the Landis Bicycle LOS method does not measure[11]) are largely unaccounted for by the methods used here. Furthermore, any disbenefits (e.g., maintenance costs, safety issues, or possible impediments to future roadway expansions) of various green street infrastructure projects are not measured by these calculators, and therefore they are not discussed in-depth here.[12]

Finally, the case studies do not evaluate the benefits or costs of specific trees. Great care must be taken in the selection of trees, and a variety of factors not evaluated in this study should be considered. That being said, a number of conclusions were identified by comparing the calculators' results across the seven case studies.

Monetary Benefits of Trees

Trees absorb carbon dioxide and other air pollutants from the air, reducing the costs of future climate change mitigations and medical care. The monetary value of planting trees over a 20-year period is small but significant, according to analysis performed with the i-Tree Design calculator. The calculator measures these benefits in terms of air quality improvements and carbon dioxide (CO2) sequestration. The total estimated benefits from street trees over a 20-year forecast period on the seven case study sites range from a low of $1,466 for nine trees at site 9A (South Hope Street in Los Angeles) to a high of $9,420 for 56 trees at site 7A (CA 299 in Willow Creek).

On a per tree basis, the lowest benefits come from site 3A (Cherry Avenue in San Jose) with $10 per tree, and the highest come from site 1A (San Pablo Avenue in El Cerrito) at $175 per tree. CO2 sequestration accounts for the bulk of monetary value from trees for all sites in this study analyzed using i-Tree Design, except for site 5A (Woodman Avenue in Los Angeles). Based on these findings, it is reasonable to conclude that the age of trees makes a real difference in the benefits provided, with larger, more mature trees providing air quality benefits, while younger, fast-growing trees quickly add vegetative mass that absorbs and retains CO2.

PLOS Benefits of Pedestrian Buffers

While the Landis PLOS method accounts for the benefits of short street tree spacings (i.e., a high number of trees) and the benefits of having a continuous biostrip or planter strip serving as a pedestrian buffer, the method does not appear sensitive to tree spacings, while it is very sensitive to buffers. For example, site 5A (Woodman Avenue in Los Angeles) has two “after” segments; both have 40-foot average tree spacings, but only one has a five-foot-wide planter strip sidewalk buffer. The segment without a buffer shows no change in PLOS score (from which the letter grade is derived), while the segment with a buffer (but having the same average tree spacing) shows an improvement in the PLOS score. The importance of having a biostrip or planter strip buffer between the sidewalk and street traffic is also reflected in the PLOS findings for the other six cases in this study.

POTENTIAL FOR FURTHER RESEARCH AND WIDER USE

The report concludes that i-Tree Design’s ease of use, sensitivity to a range of tree and environmental characteristics, and scalability—it can be used to analyze one tree or many trees—make it a useful candidate to serve as a common frame of reference and analysis for a variety of potential users within Caltrans and other state departments, as well as local and federal government agencies. With modest effort, it seems possible to use i-Tree Design (or some other application from the i-Tree Suite) as a common tool for both state and local agencies within California, and in doing so, to foster additional green streets interagency cooperation and collaboration.

A similar argument can be made for the Landis PLOS method. HCM-based methods (such as the Landis method) are already a common standard for the transportation industry. Hence, teaching and advocating for Caltrans and other transportation professionals to use these methods to capture the pedestrian benefits of green streets infrastructure (as done here with pedestrian buffers and street trees) would likely require little effort and would yield significant gains in the appreciation of green streets’ benefits.

I. INTRODUCTION

City, county, state, and federal governments are increasingly looking to sustainable streets to accommodate and balance the transportation needs of growing populations.[13] Sustainable streets include two primary components: complete streets and green streets improvements within the street right-of-way (ROW).

According to Caltrans,

> A complete street is a transportation facility that is planned, designed, operated, and maintained to provide safe mobility for all users, including bicyclists, pedestrians, transit vehicles, truckers, and motorists, appropriate to the function and context of the facility. Every complete street looks different, according to its context, community preferences, the types of road users, and their needs.[14]

In the United States alone, approximately 25 percent of cities have some type of complete street policy in place.[15]

Green streets, as defined by the Environmental Protection Agency, are streets that incorporate different kinds of vegetation and permeable surfaces "…to slow, filter, and cleanse storm water run-off from impermeable surfaces."[16] Unlike traditional streets, green streets retain runoff at the source rather than discharging runoff off-site.[17] Green streets offer many potential benefits that include improving water quality, absorbing carbon, and reducing urban heat island effects.[18]

While being distinct concepts, complete streets and green streets have similarities. Green streets and complete streets share elements that can be integrated into one another, and additionally, participants in active transportation modes (associated with complete streets) tend to be more aware of green streets infrastructure.[19] In fact, these two categories are complementary and overlapping to such a degree that some have made the case that they should be thought of as part of as a single approach to building more sustainable streets.[20]

The literature review explores common elements of green street and complete street definitions. This is followed by a more focused review of green street types, their social and environmental benefits, evaluation methods, performance metrics, and performance research findings.

Using key findings from the literature review and drawing on discussions with Caltrans stakeholders, the research team developed a method for identifying, screening, and selecting green street case studies for further analysis.

II. CASE STUDY IDENTIFICATION, SCREENING, AND SELECTION

Based on the lessons learned from the literature review and stakeholder discussions, the research team developed a list of potential case study sites. In total, 22 sites were identified, of which 11 were examples of “green” sites with at least one green street feature, while 11 were matched-pair “non-green” sites selected to be as close as possible to the green street sites in terms of highway/street design, surrounding characteristics (e.g., urban, suburban, rural small town), and traffic volumes, except that these sites had no green street features.

Because green and non-green sites can vary substantially in terms of their development context, street and traffic characteristics, and other features, the initial test-runs of the calculator for three green street and three non-green street sites found that, for the most part, there was little benefit from comparing green to non-green sites as a way to test the capabilities and shortcomings of each calculator. As a result, the research team conducted additional tests using calculator runs based on hypothetical “before” conditions for three green street sites. Hypothetical “before” conditions were estimated based on the removal of all green street infrastructure elements from each green site and replacement with non-green features similar to what is found at each non-green paired site.

After further discussions, as well as analysis and development of green streets benefits calculation methods, the list of case study sites was reduced to seven green sites. Table 1 lists and describes these final case study sites.

Table 1. List of Final Case Study Analysis Sites

Site No	Street Name	From	To	City Name	Green?	Green Features
1A	San Pablo Avenue	Lincoln	Eureka	El Cerrito	Yes	· Biostrips east side of street (pedestrian buffer). · Street trees.
3A	Cherry Avenue	SR 85 Overpass	Almaden Expressway	San Jose	Yes	· Biostrips (new) on both sides of street for most of segment. (pedestrian buffer). · Street trees (new).
5A	Woodman Avenue	Saticoy Street	Lanark Street	Panorama City/ Los Angeles	Yes	· Biostrips in median separating frontage road on West side of street. (Path weaves between Woodman-adjacent & adjacent to side street on west side). · Street trees.
7A	SR 299	Walnut Way	Willow Road	Willow Creek	Yes	· Street trees. · Planter buffer strip on both sides of street.
8A	SR 299	Court Street	Bremer Street	Weaverville	Yes	· Street trees. · No pedestrian buffer.
9A	South Hope Street	West 12th Street	West 11th Street	Los Angeles	Yes	· Biostrips on east side of street but only 1/2 of block. · Street trees.
11A	Lakeside Drive	Madison Avenue	West Grand Avenue	Oakland	Yes	· Biostrips on east side of street. Biostrip serves as buffer between bike lanes/sidewalk and street. · Street trees in buffer between street and bike lanes.

III. PRELIMINARY CALCULATOR EVALUATION

Based in part on the literature review conducted for this project, the MTI team developed the following list of potential calculators for use in measuring green street infrastructure benefits. Calculators shown in *italics* were **not** included in the evaluation due to prima facie shortcomings.

- i-Tree Design (U.S. Forest Service)
- i-Tree Harvest (U.S. Forest Service)
- i-Tree Planting (U.S. Forest Service)
- i-Tree Hydro (U.S. Forest Service)
- *Greenhouse Gas Equivalencies Calculator*
- Center for Urban Forestry Research (CUFR) Tree Carbon Calculator (CTCC)
- EPA National Stormwater Calculator
- Center for Neighborhood Technology (CNT) Green Values National Stormwater Management Calculator
- *Water Quality Index Calculator (WQI Calculator)*
- Tool for Heat Island Simulation (THIS)
- Highway Capacity Manual (HCM 2010) Pedestrian and Bicycle Level of Service (PLOS) Methods
- Landis 2000 Pedestrian and Bicycle Level of Service (PLOS/BLOS) Method[21]
- Mineta Bicycling Level of Traffic Stress
- *Botma Method for BLOS on Off-Street Paths*

The research team, in consultation with Caltrans, selected the following three calculators for calculator testing:

1. i-Tree Design Calculator (U.S. Forest Service).
2. CNT Green Values National Stormwater Management Calculator.
3. Landis 2000 Pedestrian and Bicycle Level of Service (PLOS/BLOS) Method.

A summary of the evaluation findings for these three calculators is provided below.

I-TREE DESIGN CALCULATOR

i-Tree Design is an online calculator created by the U.S. Forest Service to allow entry-level users to make simple estimations of the benefits provided by individual trees and groups of trees. The calculator is a component of a larger, peer-reviewed software suite designed to provide urban and rural forestry analysis and benefits assessment tools. i-Tree Design is specifically designed for understanding the value provided to a community by individual trees or a small population of trees.[22] The user provides simple inputs of each tree's location (tree icons are placed on an photographic aerial map using click-and-drag mouse commands), species (selected from a drop-down menu), size (in diameter breast-height or "DBH"), and a qualitative assessment of its health condition ("dead or dying" through "excellent"). Outputs provide estimates of each tree's benefits in terms of greenhouse gas sequestration (pounds of CO2), air quality improvements (savings in USD from criteria pollutants removed), and stormwater interception (stormwater runoff savings in USD and gallons).

i-Tree Design Evaluation Highlights

- Very simple data input requirements.
- Easy to learn and operate. Easy-to-use online map-based interface allows user to place individual trees on a site map/photo.
- Requires data entry for each individual tree, which could be somewhat cumbersome if many trees need analyzing.
- Output estimates for stormwater given in "intercepted" (gallons) are for tree effects only and do not address other aspects of soil retention or filtration.
- Designed for use at a small (parcel-level) scale of analysis, but is appropriate for use in smaller, main street or highway applications.

CNT GREEN VALUES NATIONAL STORMWATER MANAGEMENT CALCULATOR

The Green Values National Stormwater Management Calculator is an online tool created by the Center for Neighborhood Technology (CNT) for analysts working on a "single site or a campus of buildings." The calculator allows users to compare the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater practices,[23] and it includes additional benefits measures relevant to green streets analysis: (1) Reduced Air Pollutants, (2) Carbon Dioxide Sequestration, (3) Tree Value from Reduced Runoff, (4) Groundwater Replenishment, (5) Total Suspended Solids and Total Phosphorus Removal, (6) Reduced Treatment Benefits, (7) Erosion Prevention, (8) Flood Protection, (9) Property Value Increases from Trees, (10) Reduced Stormwater Nuisances from Raingardens, and (11) Reduced Need for Road Salt on Permeable Pavements.[24]

Overall, the calculator measures a wide variety of benefits in categories of interest to this study. However, this wide scope comes at a cost, since "casting such a wide net" almost inevitably means that each benefit category is measured at a relatively superficial level.

Green Values Calculator Evaluation Highlights

- Detailed inputs and comprehensive outputs for soil and vegetative runoff and retention estimates.
- Input requirements are detailed but easy to understand.
- Provides green infrastructure interventions as pre-set inputs (checkboxes and drop-down fields for more detailed data inputs) for analysis.
- Detailed financial estimates as outputs.
- Provides green infrastructure input parameters, but all input parameters are general (e.g., tree cover percentage as opposed to types and locations of individual trees).
- Site specifics are limited to the zip code containing the site plus the number of acres of site (and other general descriptive parameters).
- In general, seems designed for use by developers. May not be applicable to large sites like a highway right-of-way.
- Focused on runoff volume reduction estimates: it does not produce any peak flow results. "Volume reduction in this context implies infiltration, evapotranspiration and reuse, and does not include detention in ponds or vaults. All runoff volume captured in Best Management Practices (BMPs) is assumed to be kept on site."[25]
- Benefits output data provided as Annual $ Green Benefits and Life Cycle $ Green Benefits (net present value).

LANDIS PEDESTRIAN AND BICYCLE LEVEL OF SERVICE (PLOS/BLOS) METHOD

The Landis PLOS Method was used as a basis for the development of the 2010 version of the Highway Capacity Manual's (HCM's) multimodal level of service and includes two components that each calculate the level of service grades for pedestrians and bicycles. Just as with the HCM methods, the Landis method calculates PLOS and BLOS by assigning a letter grade—"A" through "F"—to a roadway segment based on a combination of input variables that describe its geometric and traffic characteristics. According to Huff and Liggett, "[t]his grade is meant to correspond to the perceived level of service that that roadway provides to pedestrians or bicyclists, respectively."[26]

PLOS Evaluation Highlights

- Inputs include buffer width and tree spacings. PLOS measured on a street link is sensitive to separation of walkways from traffic (buffer widths) but not sensitive to trees or landscaped buffers.

- Landis PLOS analysis is limited in the number of green streets characteristics it is capable of measuring, but it is more appropriate for these purposes than the Highway Capacity Manual (2010) method.

IV. CALCULATOR TESTS

Following the identification of the initial list of 22 matched-pair green and non-green case study sites and selection of the three most promising green streets infrastructure calculators, the MTI team tested the calculators. The three calculators selected by the team in consultation with Caltrans were as follows.

1. i-Tree Design.

2. CNT Green Values National Stormwater Management Calculator.

3. Landis Pedestrian Level of Service (PLOS).

CALCULATOR TEST CASE STUDY SITE SELECTIONS

The following matched-pair sites were selected for the calculator test in a quarterly project progress meeting with Caltrans on July 19, 2019:

1. **Site 1A:** San Pablo Avenue from Lincoln to Eureka in the city of El Cerrito (green).

2. **Site 1B:** 23rd Street from Garvin to McBryde in the City of Richmond (non-green).

3. **Site 7A:** CA 299 from Walnut to Willow in the City of Willow Creek (green).

4. **Site 7B:** CA 89 from Grand to Bidwell in the City of Greenville (non-green).

5. **Site 11A:** Lakeside Drive from Madison to West Grand in the City of Oakland (green).

6. **Site 11B:** Lakeside Drive from 14th Street to Madison in the City of Oakland (non-green).

SUMMARY OF CALCULATOR TEST FINDINGS

Despite best efforts to identify matched-pair green and non-green sites, the MTI team found that they can be substantially different in terms of their development context, street and traffic characteristics, and other features. As a result, the preliminary calculator test runs for the three green street and three non-green street sites found that, for the most part, there was little benefit from comparing green to non-green sites as a way to test the capabilities and shortcomings of each calculator. To address this problem, the research team employed additional tests using calculator runs based on hypothetical "before" conditions for the three green street sites, where all green street infrastructure elements from each green site were replaced with non-green features similar to what is found at each non-green paired site.

This summary focuses primarily on the results comparing "before" and "after" conditions for the three calculator test green sites listed above: sites 1A, 7A, and 11A.

i-Tree Design Calculator

While the benefits of trees estimated by the calculator were small (in dollar-value terms), the calculator provides what appear to be reasonable results that could be useful for Caltrans in evaluating the benefits of proposed street tree installations. In terms of limitations, the analytical results of this calculator are limited to trees. In other words, there is no explicit consideration of soils, biostrips, or other non-tree green infrastructure features.

The research team also identified several shortcomings of the calculators. Proper identification of tree species for data entry into i-Tree Design can be challenging. Therefore, the research team recommends that any Caltrans efforts to use the i-Tree Design calculator in the future should employ the services of an experienced arborist capable of making reliable field identifications.

CNT Green Values National Stormwater Management Calculator

Overall, the research team found that this calculator tends to be simplistic in its estimation methods and highly questionable in its results. Nevertheless, this calculator offers an estimation of benefits for several categories of benefits and green infrastructure types that other calculators evaluated in this study did not, including the value of biostrips, permeable pavements, amended soils, and others. These findings suggest that while Caltrans may find it useful to use the Green Values Calculator for estimating some on-street green infrastructure benefits (particularly in the absence of other available tools), it should NOT be used for estimating the value of street trees (see below). Furthermore, using this calculator takes more time and effort on the part of the analyst than other calculators the team reviewed or tested, since it requires the user to input data for the roof surface areas of adjacent buildings, parking lot areas, driveway surface areas, and other aspects of land use that are not within Caltrans' jurisdiction or direct regulatory influence.

Therefore, the research team strongly cautions Caltrans to consider the risks of using this calculator: it will require significant training and use protocols to ensure the proper specification of inputs for off-street land use characteristics so that the influences of these factors are held constant and do not interfere with the estimation of on-street factors. Ultimately, Caltrans and the MTI team decided that this calculator was too problematic to suit Caltrans' uses.

Landis Pedestrian Level of Service (PLOS) Method

While this calculator's estimated benefits from street trees (average tree spacings) and pedestrian buffer width (planter strips and biostrips) appear small, and while these two green streets infrastructure components represent only a small subset of possible green streets infrastructure types and potential benefits, the familiarity of most transportation officials with HCM-based methods (the Landis method is similar), the ease of acquiring the needed input data, and the ease of calculating results all lead the MTI team to recommend using this calculator.[27]

While the research team found the method useful (as reported above), caution is warranted since the method was developed in the late 1990s and has been supplanted in use since then by various HCM-based methods. Nevertheless, the method is largely consistent with previous and subsequent techniques, and it accounts for factors critical to estimating green streets' benefits such as the width of planter strips. Further research and development of HCM-based methods that include these and other potentially useful variables that capture green streets' benefits is desirable.

CALCULATOR TEST RECOMMENDATIONS

Based on these calculator test findings and subsequent discussions with Caltrans, the MTI team decided to move forward with the analysis of the hypothetical "before" and "after" conditions of the seven green street case study sites using the i-Tree Design and Landis PLOS calculators.

V. CASE STUDY SUMMARIES

It is important to note that there are several potentially important benefits from green streets infrastructure that the two calculators used in this study (i-Tree Design and Landis PLOS) are not designed to measure. Therefore, these case study findings should be considered as limited and suggestive rather than as definitive accounts of the total benefits at each site and what each green street infrastructure type yields.

In particular, the methods used here largely do not account for the benefits of street trees and other vegetation in reducing the urban heat island effect; the stormwater filtering, runoff, and retention benefits of biostrips and other planters; nor the benefits to bicyclists (which the Landis BLOS method does not measure).

Furthermore, the case studies do not evaluate the benefits or costs of specific tree species. Great care needs to be taken in the selection of trees, and researchers should consider a variety of factors that are not evaluated in this study.

The following (“green”) case study sites were analyzed using i-Tree Design and Landis PLOS.

1. Site 1A: San Pablo Avenue from Lincoln to Eureka in the city of El Cerrito.

2. Site 3A: Cherry Avenue from the CA 85 Overpass to Almaden Expressway in the city of San José.

3. Site 5A: Woodman Avenue from Saticoy Street to Lanark Street in the city of Los Angeles.

4. Site 7A: CA 299 from Walnut to Willow in the City of Willow Creek.

5. Site 8A: CA 299 from Court Street to Bremer Street in the City of Weaverville.

6. Site 9A: South Hope Street from West 12th Street to West 11th Street in the City of Los Angeles.

7. Site 11A: Lakeside Drive from Madison to West Grand in the City of Oakland.

To measure their benefits, two scenarios were developed and used for each site and each calculator: a hypothetical “before” scenario that captures the benefits present before the green features were installed on the street, and an “after” scenario that captures the benefits of the green street features after their installation.

These “before” and “after” scenarios were input into the two calculators selected for this project’s analysis. The data input into each calculator for this case study are summarized below.

I-TREE DESIGN CALCULATOR INPUTS

To measure the benefits from street trees, this study used the i-Tree Design tool, which requires inputs detailing the location of site, the number and type of trees, tree diameters (at "breast height"), a visual assessment of each tree's health, and whether they are fully exposed to sunlight. A 20-year forecast period was used to calculate the trees' benefits.

LANDIS PLOS CALCULATOR INPUTS

To understand how the green features have augmented the walkability of the case study sites, this study compares the pedestrian level of service for both scenarios. The following provides an overview of the inputs for the PLOS calculator.

1. "Through" lanes per direction—not including medians, turn lanes, or continuous-left-turn lanes.

2. Width of outside lane, to outside stripe (in feet): width of right-most travel lane, excluding striped paved shoulders, bike lanes, and marked parking stalls.

3. Paved shoulder, bike lane, or marked parking area: outside lane stripe to pavement edge (in feet); besides a paved shoulder or a bike lane, this width may also be used by marked (striped or hashed) parking stalls.

4. Bidirectional traffic volume (Average Daily Traffic).

5. Posted speed limit (miles per hour).

6. Percentage of heavy vehicles.

7. FHWA's pavement condition rating: for a longer-term view normalizing the location of a road within its re-pavement cycle (MTI team used "4" as an average).

8. Percentage of road segment with occupied on-street parking: excludes driveways. Either one side or an average of both sides may be considered at any given time.

9. Percentage of segment with sidewalks.

10. Sidewalk width (the width of planters or tree boxes is not included).

11. Sidewalk buffer or parkway width (the distance between the sidewalk and pavement which includes tree boxes' width).

12. Buffer or parkway average tree spacing.

SITE 1A: SAN PABLO AVENUE (CA 123) LINCOLN AVENUE TO EUREKA AVENUE, EL CERRITO, CA

Location and Characteristics

This segment is a 670-foot section of San Pablo Avenue located in the city of El Cerrito in Contra Costa County, California. As shown in Figure 1, the study segment runs from Lincoln Avenue to Eureka Avenue.

Figure 1. The Location of Site 1A: San Pablo Avenue from Lincoln Avenue to Eureka Avenue, El Cerrito, CA

As Figure 2 shows, this segment of the street serves both northbound and southbound traffic with two lanes of traffic for each direction of travel, separated by a raised, planted median. Although the segment is a part of California State Route 123, the speed limit of 30 miles per hour has been posted due to the presence of retail and commercial uses along the route. According to Caltrans, the volume of bidirectional Annual Average Daily Traffic was 39,200 vehicles in 2017.[28] Since the green features are constructed on the east side of the street, this study includes only the Average Daily Traffic volume of northbound traffic, which was estimated at 19,600 vehicles in 2017.

Figure 2. Recently Installed Elm Trees and Biostrips Along the East Side of San Pablo Avenue Between Lincoln Avenue to Eureka Avenue Looking North in El Cerrito, CA

There is no designated bike lane on this segment of road; however, 85 percent of the segment has on-street parking, and 95 percent of it has continuous sidewalks with biostrips as sidewalk buffers.

Green Infrastructure Description and Analysis Input Data

There are two types of green streets infrastructure on this site: biostrips and street trees. Since the biostrips (and the trees planted therein) are installed on the east (northbound) side of the street, data from the east side of the street were used in the estimation of benefits using the i-Tree Design[29] and the Landis method's Pedestrian Level of Service (PLOS)[30] calculators.

The data input into each calculator for this case study are summarized below.

i-Tree Design Calculator

Using Google Maps and Google Earth, 49 trees were identified and included as inputs to this calculator for the "after" scenario. As Table 2 indicates, the trees are mainly from two categories: White Ash and Elm.

Table 2. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One Elm tree, 10-cm diameter.
After Green Features Implementation	Total of 49 trees including: • 12 White Ash trees ranging from 9–17 cm in diameter. • 37 Elm trees ranging 2–17 cm in diameter.

Figure 2 shows a sample of the trees on the site. The hypothetical "before" scenario includes just one tree as required by the i-Tree Design calculator.

Figure 3. Recently Planted Elm Trees on the East (Right) Side of San Pablo Avenue in El Cerrito, CA

PLOS Calculator

In order to determine the pedestrian benefits of the green features—with biostrips (see Figure 4) and street trees providing sidewalk buffers to improve travel conditions for pedestrians—the only parameters that are different between the “before” and “after” scenarios are sidewalk buffer width and average tree spacing, as shown in Table 3.

Figure 4. New Biostrips with Street Trees Provide a Pedestrian “Buffer” from Street Traffic on the East Side of San Pablo Avenue (Looking South) in El Cerrito, CA

Table 3. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 2 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 8 ft Bidirectional ADT traffic volume: 19,600 (veh/day) Posted speed limit: 30 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 85% % of segment with sidewalks: 95% Sidewalk width: 5 ft Sidewalk buffer/parkway width: 0 ft
After Green Features Implementation	Lanes per direction: 2 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 8 ft Northbound Estimated ADT traffic volume: 19,600 (veh/day) Posted speed limit: 30 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 85% % of segment with sidewalks: 95% Sidewalk width: 5 ft Sidewalk buffer/parkway width: 8 ft Buffer/parkway mean tree spacing: 26 ft

As mentioned above, only the attributes of east side of the street have been measured and included in the process. To estimate the average daily traffic (ADT) for the east side of the street (northbound direction), the total ADT for this street segment has been divided in half.

Benefits Analysis Findings

Estimated benefits from the construction of green infrastructure at Site 1A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

There are two main outputs obtained from this calculator as used in this study: air quality and CO2 sequestration benefits, provided in dollar benefits and pounds of carbon sequestered as seen in Figure 5 and Figure 6

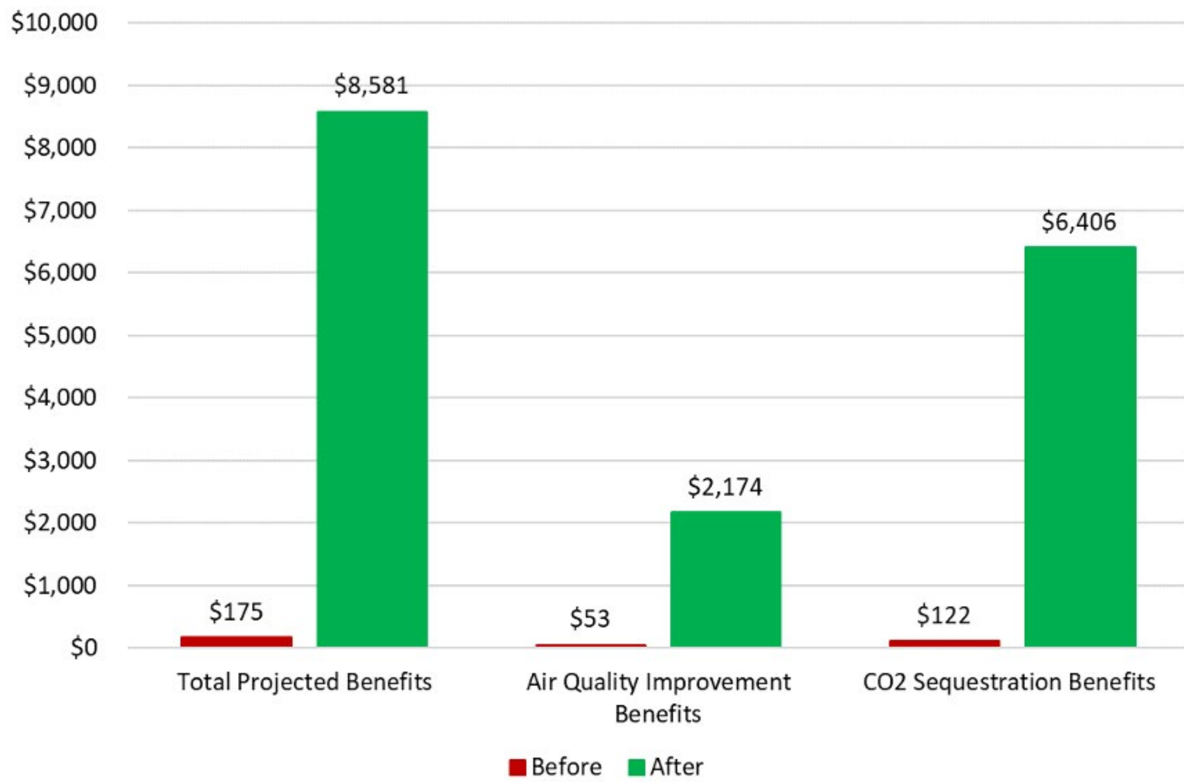

Figure 5. The 20-Year Monetary Value of Trees at Site 1A Estimated Using the i-Tree Design Calculator

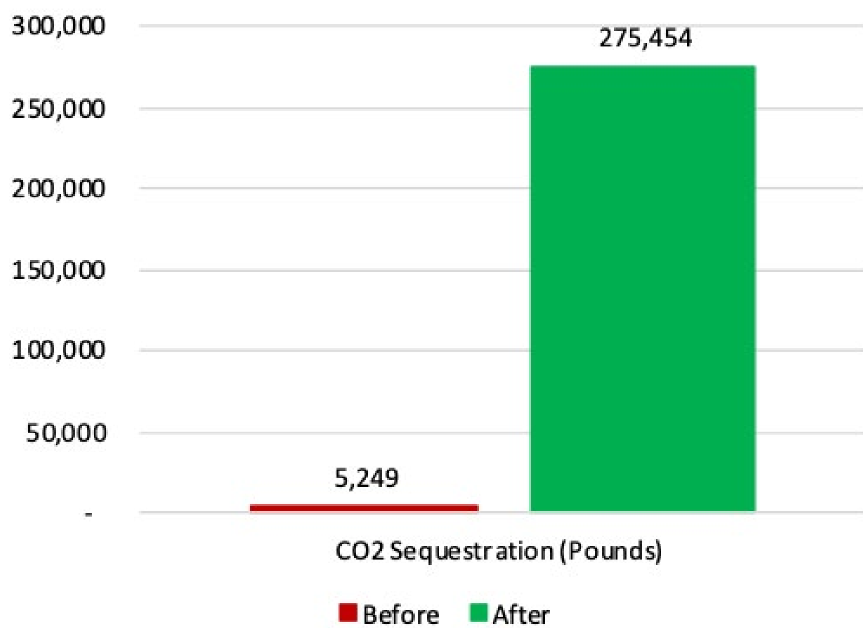

Figure 6. The 20-Year CO2 Sequestration Benefits of Trees at Site 1A Estimated Using the i-Tree Design Calculator

Figure 5 and Figure 6 show the added value of having trees on this street by comparing the “before” and “after” scenarios. In both cases, the greatest benefit from the street trees comes in the form of CO2 sequestration. Air quality improvement is provided by absorbing and intercepting pollutants such as ozone, sulfur dioxide, nitrogen dioxide, and particulate matter, as well as reducing energy production needs and lowering air temperature.

PLOS Calculator

As Table 4 indicates, adding street trees on this segment has improved the pedestrian level of service dramatically. Since the PLOS calculator is highly sensitive to whether there is a sidewalk buffer, the presence of biostrips or tree planters as a buffer has improved travel conditions for pedestrians on the street from letter grade “C” to “B.”

Table 4. Results from Pedestrian Level of Service Calculator

Scenario	Output
Before Green Features Implementation	PLOS: 2.59 C (2.51–3.50) Moderately High
After Green Features Implementation	PLOS: 2.05 B (1.51–2.50) Very High

Case Study 1A Conclusions

As mentioned above, planting trees on the street provides significant benefits in terms of the pedestrian travel conditions and environmental variables. Sequestering CO2 and reducing air pollutants (through absorption) such as ozone, sulfur dioxide, and nitrogen dioxide are the most direct impacts on air quality caused by the green features on the site. Also, the “after” scenario’s provision of a buffer for the sidewalk, as well as its enhancement of the pedestrian environment, has improved the walkability grade from a level of service rating of “C” to a “B.”

SITE 3A: CHERRY AVENUE, FROM CA 85 OVERPASS TO ALMADEN EXPRESSWAY, SAN JOSÉ, CA

Location and Characteristics

This segment is a stretch of Cherry Avenue located in the city of San José in Santa Clara County, California. As shown in Figure 7, the study segment runs from the State Route 85 Overpass to Almaden Expressway.

Figure 7. The Location of Site 3A: Cherry Avenue, from California State Route 85 Overpass to Almaden Expressway, San José, CA

This segment is surrounded by large surface parking lots and “strip-mall” retail buildings. Cherry Avenue has two lanes per direction divided by left-turn lanes and raised median islands along this segment. It carries an estimated 10,000 vehicles per day based on traffic counts reported by City of San José for segments located roughly a mile away.[31]

There is a five-foot-wide class II bike lane on this segment, and 95 percent of the street has continuous sidewalks. There are no permitted on-street parking spaces on this part of Cherry Avenue.

Green Infrastructure Description and Analysis Input Data

On-street trees, planter strips, and biostrips are the newly constructed (“after”) green features on this segment on both sides of the street (see Figure 8). Since the biostrips and trees are constructed on both sides of the street, the data from both directions were used in the estimation of benefits using i-Tree Design and PLOS calculators.

Figure 8. Looking South on Cherry Avenue in San Jose, CA

The data input into the i-Tree Design and PLOS calculators for this case study are summarized below.

i-Tree Design Calculator

As Table 5 indicates, the newly planted trees are from Carolina Laurel Cherry category.

Table 5. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One tree from Carolina Laurel Cherry family, 3-cm diameter.
After Green Features Implementation	• Total of 75 trees from Carolina Laurel Cherry family. • Diameters ranging from 2 to 3 cm.

PLOS Calculator

Providing sidewalk buffers to improve travel conditions for pedestrians is one of the benefits of the on-street trees with planter strips. In order to determine the benefits provided by the site's street trees, sidewalk buffer (biostrip) width and average tree spacing are the only parameters which differ in the "before" and "after" scenarios, as shown in Table 6.

Table 6. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 2 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 9 ft Bidirectional ADT traffic volume: 10,000 (veh/day) Posted speed limit: 40 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 0% % of segment with sidewalks: 95% Sidewalk width: 8 ft Sidewalk buffer/parkway width: 0 ft
After Green Features Implementation	Lanes per direction: 2 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 9 ft Bidirectional ADT traffic volume: 10,000 (veh/day) Posted speed limit: 40 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 0% % of segment with sidewalks: 95% Sidewalk width: 8 ft Sidewalk buffer/parkway width: 6 ft Buffer/parkway mean tree spacing: 40 ft

Benefits Analysis Findings

Estimated benefits from the construction of green infrastructure at Site 3A from the i-Tree Design and PLOS calculators are presented below.

i-Tree Design Calculator

The two main outputs obtained from this calculator, air quality and CO2 sequestration benefits, are provided in both dollar benefits and pounds of carbon sequestered as seen in Figure 9 and Figure 10.

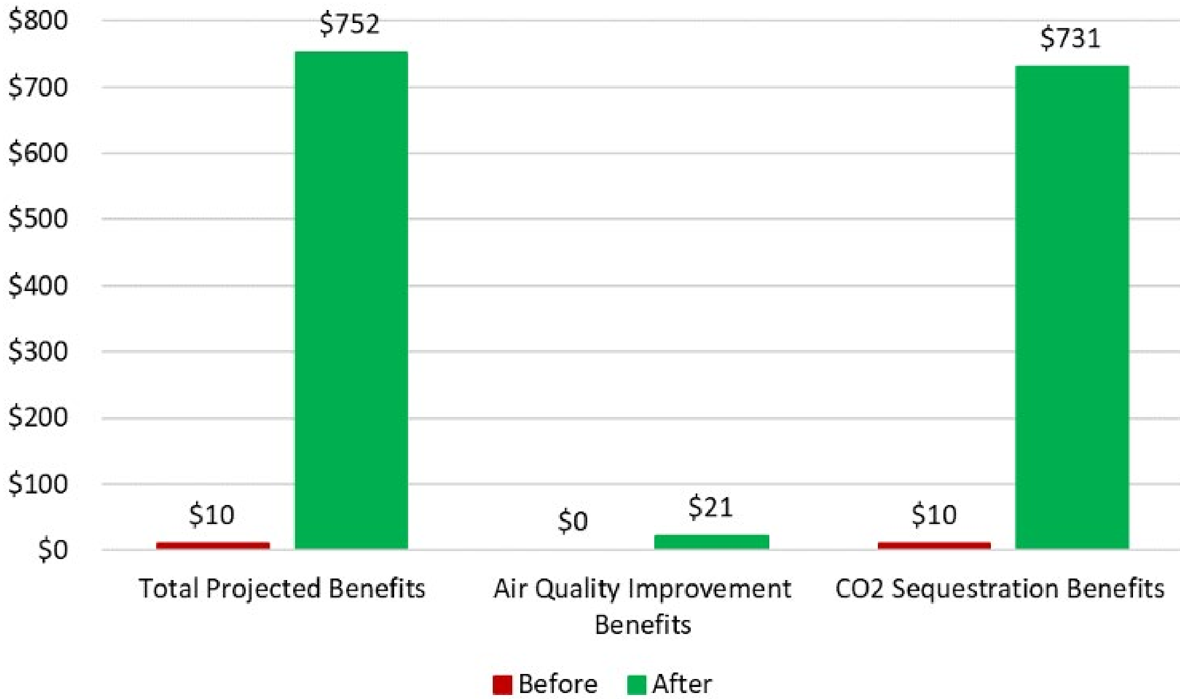

Figure 9. The 20-Year Monetary Value of Trees at Site 3A Estimated Using the i-Tree Design Calculator

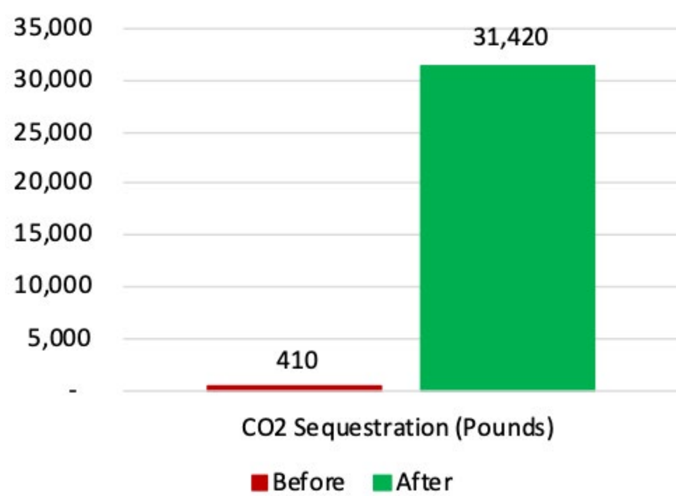

Figure 10. The 20-Year CO2 Sequestration Benefits of Trees at Site 3A Estimated Using the i-Tree Design Calculator

Figure 9 and Figure 10 show the added value of having trees on the street by comparing the “before” and “after” scenarios. The greatest benefit for both cases is CO2 sequestration. Since the air quality improvement depends on the type of trees, the reported benefits from absorbing air pollutant is lower the other benefits.

PLOS Calculator

As Table 7 indicates, adding street trees and biostrips (serving as pedestrian buffers) on this segment has considerably improved the pedestrian level of service. The PLOS letter grade has improved from “C” to “B,” and the PLOS score (from which the letter grade is derived) has improved by 16 percent.

Table 7. Results from Pedestrian Level of Service Calculator

Scenario	Output
Before Green Feature Implementation	PLOS: 2.58 C (2.51–3.50) Moderately High
After Green Feature Implementation	PLOS: 2.18 B (1.51–2.50) Very High

Case Study 3A Conclusions

According to the analysis results from the PLOS calculator, having planter strips with street trees as a sidewalk buffer provides the most important benefit for the pedestrians on the street. The PLOS letter grade improved from a “C” to a “B”, while the PLOS score improved by 20 percent. “Before” and “after” comparisons of i-Tree Design calculator outputs indicate that the type of tree is very important in determining the air quality benefits.

SITE 5A: WOODMAN AVENUE FROM SATICOY STREET TO LANARK STREET, LOS ANGELES, CA

Location and Characteristics

This segment is a stretch of Woodman Avenue located in the city of Los Angeles in Los Angeles County, California. As shown in Figure 11, the study segment runs from Saticoy Street to Lanark Street.

Figure 11. The Location of Site 5A: Woodman Avenue from Saticoy Street to Lanark Street, Los Angeles, CA

As Figure 12 shows, the unique feature of this segment is the presence of a frontage road serving local traffic on the west side of the street, which is separated from through traffic on the arterial portion of Woodman by a raised, planted median. This case study analysis does not include the frontage road or the west side of the arterial street.

The arterial portion of this segment serves both northbound and southbound traffic with three lanes of traffic for each direction of travel, separated by a yellow-painted double line in the middle. Activities along this segment are mostly commercial and residential. The posted speed limit is 35 miles per hour. Since this study excludes the frontage road, and green features of interest (street trees) are located on the east side of street, the average daily traffic (ADT) volume for the east (northbound) side of street is 14,718.[32]

Figure 12. Looking South on Woodman Avenue, the frontage road on the west side (right side of picture) of the street is separated from the east side (arterial) by elevated and planted median with a meandering pedestrian path on Woodman Avenue between Saticoy Street to Lanark Street

There is no designated bike lane on this segment of road; however, 90 percent of the segment has on-street parking, and all of it has continuous sidewalks. There are segmented tree planters on some parts of this segment.

Green Infrastructure Description and Analysis Input Data

There are two types of green street infrastructure on this site: biostrips and street trees. Since the biostrips are installed in the median between the frontage road and the arterial, and the trees in planter strips are on the east side, only data from the east side of the (arterial) street were used in the estimation of benefits using the i-Tree Design[33] and Landis Method's Pedestrian Level of Service (PLOS)[34] calculators.

i-Tree Design Calculator

As Table 8 indicates, the trees on this segment are mainly from the following species: Fern Pine, Planetree, Victorian Box, Pinyon Pine, and Brisbane Box.

Table 8. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One tree from Fern Pine family, 10-cm diameter.
After Green Features Implementation	Total of 55 trees including: • Fern Pine, Planetree, Victorian Box, Pinyon Pine, Brisbane Box. • Diameters ranging between 2–25 cm.

Figure 13 shows a sample of the trees on the site. The hypothetical "before" scenario includes just one Fern Pine tree.

Figure 13. Trees on the East Side of Woodman Avenue Looking South

PLOS Calculator

Providing sidewalk buffers to improve travel conditions for pedestrians (see Figure 14) is one of the benefits of the green features on this site.

Figure 14. Street Trees with Planters Provide a Pedestrian “Buffer” from Traffic on the East Side of Woodman Avenue

In order to determine the pedestrian benefits provided by street trees, sidewalk buffer width and average tree spacings are the only parameters that differ between the “before” and “after” scenarios, as shown in Table 9. Some portions of this segment have continuous tree planter strips, while some segments have only tree boxes. While tree planter strips are continuously constructed along most segments of this street, other segments have tree planter boxes. Therefore, the segments with planter strips are differentiated from the ones that have tree boxes only.

Table 9. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 2 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 6 ft Northbound ADT traffic volume: 14,718 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 90% % of segment with sidewalks: 100% Sidewalk width: 10 ft Sidewalk buffer/parkway width: 0 ft
After Green Features Implementation (without planter strips)	lanes per direction: 2 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 6 ft Northbound ADT traffic volume: 14,718 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 90% % of segment with sidewalks: 100% Sidewalk width: 10 ft Sidewalk buffer/parkway width: 0 ft Buffer/parkway mean tree spacing: 40 ft
After Green Features Implementation (with planter strips)	Lanes per direction: 2 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 6 ft Northbound ADT traffic volume: 14,718 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 90% % of segment with sidewalks: 100% Sidewalk width: 5 ft Sidewalk buffer/parkway width: 5 ft Buffer/parkway mean tree spacing: 40 ft

As mentioned before, only the attributes of the east side of the street were measured and included in the process.

Findings of Benefits Analysis

Estimated benefits from the installation of green infrastructure at Site 5A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

The two main outputs obtained from this calculator, air quality and CO2 sequestration benefits, are provided in both dollar benefits and pounds of carbon sequestered as seen in Figure 15 and Fig-ure 16.

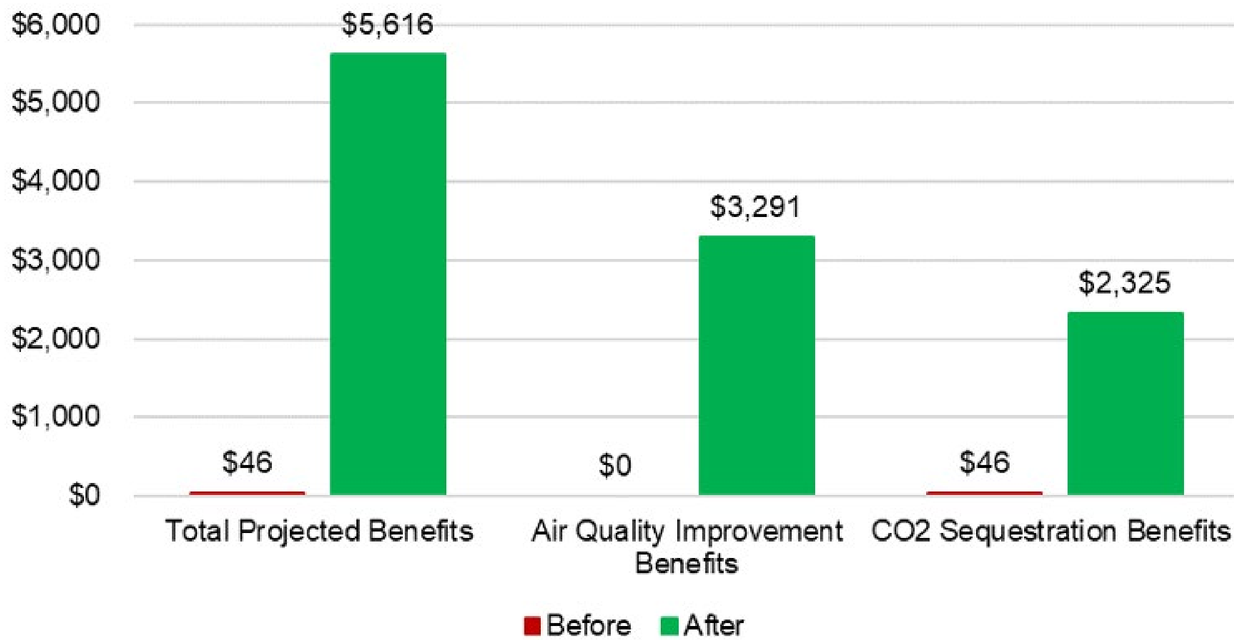

Figure 15. The 20-Year Monetary Value of Trees at Site 5A Estimated Using the i-Tree Design Calculator

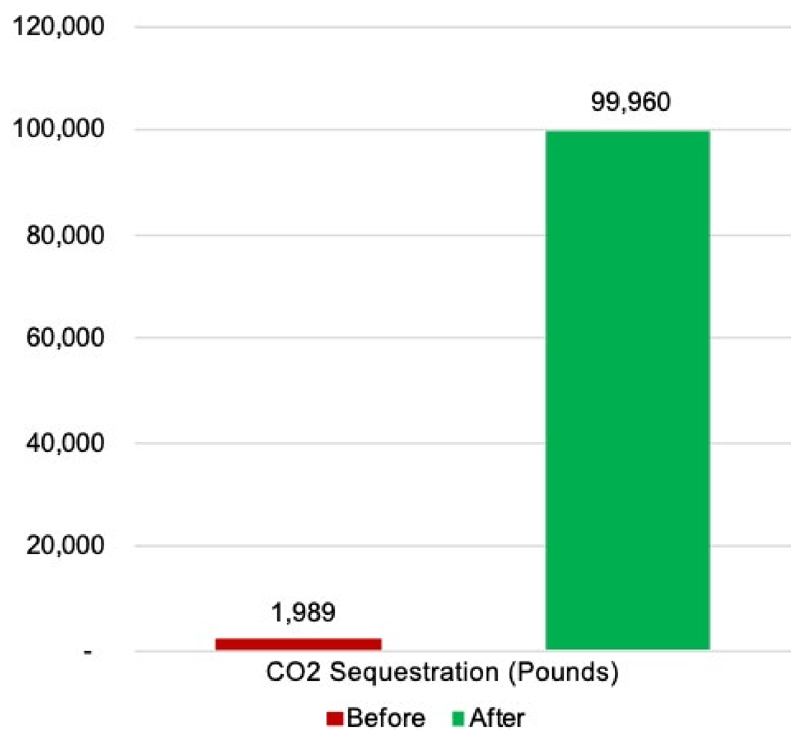

Figure 16. The 20-Year CO2 Sequestration Benefits of Trees at Site 5A Estimated Using the i-Tree Design Calculator

Figure 15 and Figure 16 show the added value of having trees on this street by comparing the “before” and “after” scenarios. For both cases, the greatest benefit from the street trees comes in the form of CO2 sequestration. Air quality improvement is provided by trees’ absorbing and intercepting pollutants such as ozone, sulfur dioxide, nitrogen dioxide, and particulate matter. Since the air quality factor is sensitive to the type of tree, the reported benefit from absorbing air pollutants in the “before” scenario (which has one Fern Pine) is zero.

PLOS Calculator

As Table 10 indicates, adding the street trees and their planter strips on this segment has improved the pedestrian level of service significantly. Since the PLOS calculator is highly sensitive to whether there is a sidewalk buffer, the presence of planters as a buffer has improved travel conditions for pedestrians on the street.

As mentioned before, since there are some segments where trees are planted without continuous planter strips, the “after” scenario is divided to include both of these sections as shown in Table 10.

Table 10. Results from Pedestrian LOS Calculator

Scenario	Output
Before Green Feature Implementation	PLOS: 2.28 B (1.51–2.50) Very High
After Green Feature Implementation (without planter strips)	PLOS: 2.28 B (1.51–2.50) Very High
After Green Feature Implementation (with planter strips)	PLOS: 2.01 B (1.51–2.50) Very High

Case Study 5A Conclusions

Having street trees with continuous planter strips as a sidewalk buffer provides the most important benefit for pedestrians on this street. Although the PLOS letter grade remained the same for all “before” and “after” scenarios, the PLOS score (from which the letter grade is derived) improved by 10 percent after the continuous planter strips were installed. “Before” and “after” comparisons of i-Tree Design calculator outputs indicate that the type of tree is very important in determining the air quality benefits.

SITE 7A: CALIFORNIA STATE ROUTE 299, FROM WALNUT WAY TO WILLOW ROAD, WILLOW CREEK, CA

Location and Characteristics

This segment is a stretch of SR 299 located in the city of Willow Creek in Humboldt County, California. As shown in Figure 17, the study segment runs from Walnut Way to Willow Road.

Figure 17. The Location of Site 7A: California State Route 299, from Walnut Way to Willow Road, Willow Creek, CA

Activities along this segment are mostly retail and commercial. Although this is a California state highway, there is just one lane of traffic per direction and one segmented left-turn lane. The bidirectional Average Daily Traffic (ADT) count for both directions is 5,000 vehicles.[35] Since the street trees are planted on the both sides of the street, this study includes the bidirectional traffic.

There is a four-foot-wide designated bike lane, plus a three-foot-wide paved shoulder, which together are considered by the calculator in measuring the width of the pedestrian buffer (see Figure 18). Approximately 95 percent of this segment has continuous sidewalks. There are continuous tree planter strips along the street which provide a buffer from traffic for the pedestrians on the sidewalk.

Figure 18. Looking West Along State Route 299 in Willow Creek, CA

Green Infrastructure Description and Analysis Input Data

Street trees are the only green feature on this segment, and they are planted on both sides of the street. Therefore, the estimation of benefits using the i-Tree Design calculator[36] and the Landis method's Pedestrian Level of Service (PLOS) calculator[37] was conducted based on the data from both sides.

The data input into each calculator for this case study are summarized below.

i-Tree Design Calculator

As Table 11 indicates, the street trees on this segment are London Planetree.

Table 11. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One London Planetree with 10-cm diameter.
After Green Features Implementation	56 London Planetrees with diameters of 6–25 cm. All are in excellent condition.

PLOS Calculator

In order to determine the benefits provided by street trees, sidewalk buffer width and average tree spacing are the only parameters which are different between the "before" and "after" scenarios, as shown in Table 12.

Table 12. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 1 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 7 ft Bidirectional ADT traffic volume: 5,000 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 5% FHWA's pavement condition rating: 4 % of segment with occupied parking: 70% % of segment with sidewalks: 95% Sidewalk width: 7 ft Sidewalk buffer/parkway width: 0 Buffer/parkway mean tree spacing: 0
After Green Features Implementation	Lanes per direction: 1 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 7 ft Bidirectional ADT traffic volume: 5,000 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 5% FHWA's pavement condition rating: 4 % of segment with occupied parking: 70% % of segment with sidewalks: 95% Sidewalk width: 7 ft Sidewalk buffer/parkway width: 7 ft Buffer/parkway mean tree spacing: 25 ft

Findings of Benefits Analysis

Estimated benefits from the installation of green infrastructure at Site 7A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

There are two main outputs obtained from this calculator: air quality and CO2 sequestration benefits. Results are provided in both dollar benefits and pounds of carbon sequestered as seen in Figure 18 and Figure 19.

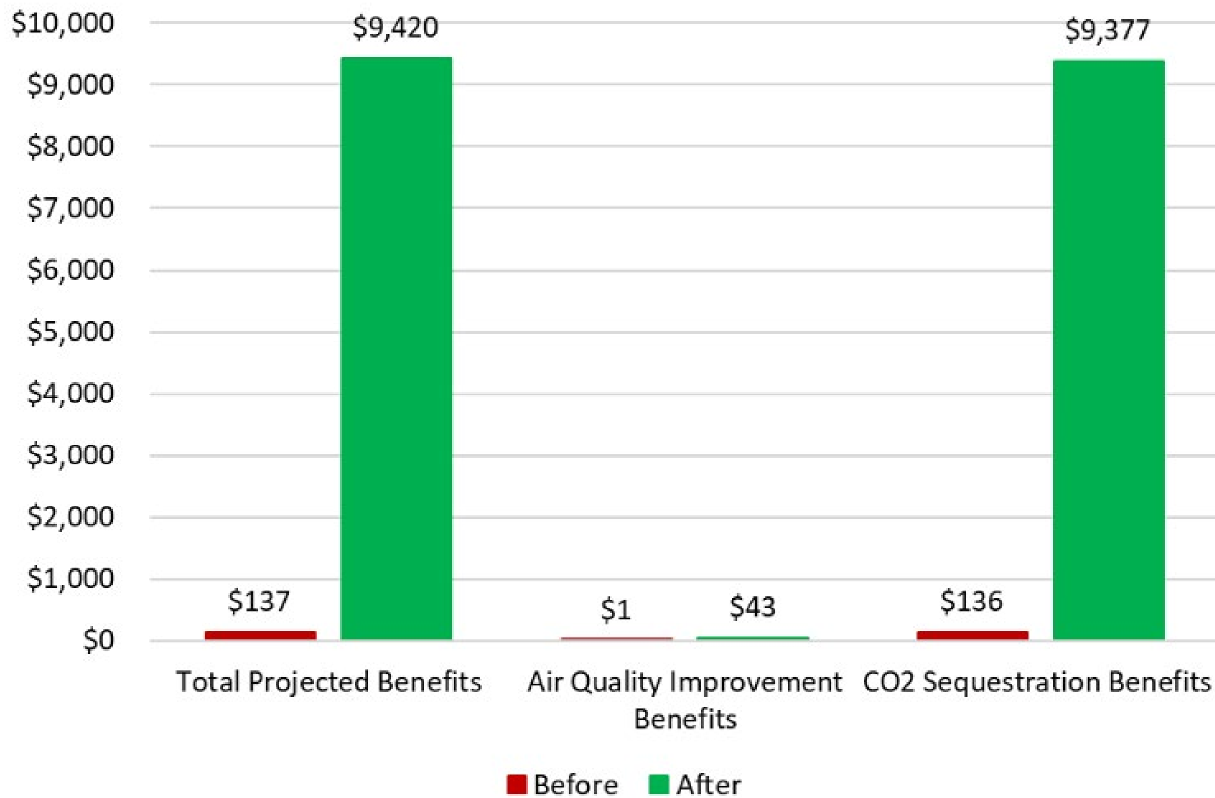

Figure 19. The 20-Year Monetary Value of Trees at Site 7A Estimated Using the i-Tree Design Calculator

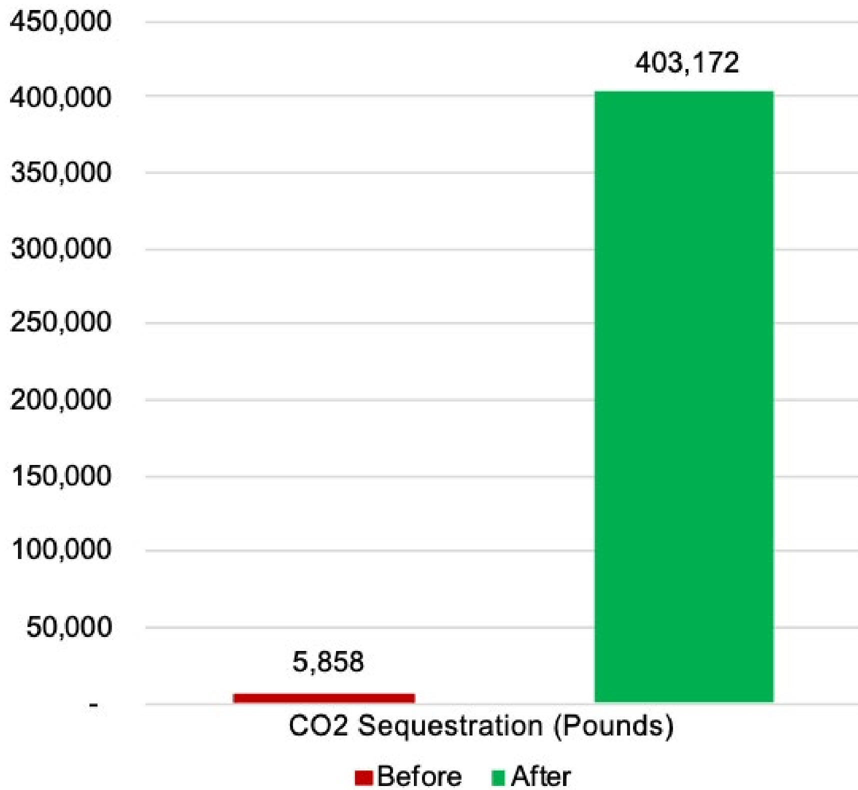

Figure 20. The 20-Year CO2 Sequestration Benefits of Trees at Site 7A Estimated Using the i-Tree Design Calculator

Figure 18 and Figure 19 show the added value of having trees on this street by comparing the “before” and “after” scenarios. For both cases, the greatest benefit from the street trees comes in the form of CO2 sequestration.

PLOS Calculator

As Table 13 indicates, having trees on this segment has improved the pedestrian level of service significantly. Although the letter grade assigned to the level of service has not changed in the “after” scenario, the PLOS score (from which the letter grade is derived) improved 40 percent.

Table 13. Results from Pedestrian Level of Service Calculator

Scenario	Output
Before Green Feature Implementation	PLOS: 2.49 B (1.51–2.50) Very High
After Green Feature Implementation	PLOS: 1.66 B (1.51–2.50) Very High

Case Study 7A Conclusions

Analysis using the i-Tree Design and Landis PLOS calculators suggests that the sidewalk buffer created by the presence of trees with planter strips is the most important benefit of implementing green features for pedestrians on this street. Although the PLOS letter grade remained the same ("B" in both the "before" and "after" scenarios), the PLOS score (from which the letter grade is derived) improved by 40 percent (2.49 in the "before" and 1.66 in the "after" scenario). Also, the results of the i-Tree Design calculator indicate that the planting of 56 London Planetrees significantly increased the amount of carbon sequestration.

SITE 8A: CALIFORNIA STATE ROUTE 299, FROM COURT STREET TO BREMER STREET, WEAVERVILLE, CA

Location and Characteristics

This segment is a 0.35-mile stretch of SR 299 located in the city of Weaverville in Trinity County, California. As shown in Figure 20, the study segment runs from Court Street to Bremer Street.

Figure 21. California State Route 299, from Court Street to Bremer Street, Weaverville, CA

Retail and small office uses are the dominant activities along this segment. Although the street is technically a state highway (California State Route 299), there is just one lane of traffic per direction with a shared left-turn lane and a maximum speed of 30 miles per hour (see Figure 22). According to Caltrans, the bidirectional Average Daily Traffic was 10,700 vehicles in 2017.[38]

There are five-foot-wide class II bike lanes on this segment, and 90 percent of the segment has on-street parking. Although six-foot-wide sidewalks are provided along both sides of this segment, there are no planter strips providing a sidewalk buffer, and the street trees are planted in small tree boxes.

Green Infrastructure Description and Analysis Input Data

Street trees (without biostrips or planter strips) are the only type of green infrastructure provided on this segment. The data input into each calculator for this case study are summarized below.

Figure 22. Looking East Along State Route 299 in Weaverville, CA

i-Tree Design Calculator

As Table 14 indicates, the street trees on this segment are from the Sweetgum family with diameters varying from 6 to 29 centimeters.

Table 14. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One tree from Sweetgum family, 10-cm diameter.
After Green Features Implementation	Total of 23 Sweetgum trees in excellent condition with diameters ranging from 6 to 29 cm.

PLOS Calculator

The Landis PLOS calculator considers providing a sidewalk buffer as the greatest benefit from street trees. Since there are no planter strips on this segment to provide a buffer, the sidewalk buffer width is zero in this case study. Therefore, as shown in Table 15, the only variable that is different in the "after" scenario is average tree spacing.

Table 15. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 1 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 5 ft Bidirectional ADT traffic volume: 10,700 (veh/day) Posted speed limit: 30 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 90% % of segment with sidewalks: 100% Sidewalk width: 6 ft Sidewalk buffer/parkway width: 0 ft Buffer/parkway mean tree spacing: 0 ft
After Green Features Implementation	Lanes per direction: 1 Outside lane width: 10 ft Paved shoulder/bike lane/marked parking width: 5 ft Bidirectional ADT traffic volume: 10,700 (veh/day) Posted speed limit: 30 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 90% % of segment with sidewalks: 100% Sidewalk width: 6 ft Sidewalk buffer/parkway width: 0 ft Buffer/parkway mean tree spacing: 30 ft

Findings of Benefits Analysis

Estimated benefits from the construction of green infrastructure at site 8A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

There are two outputs provided from this calculator considered in this study: air quality and CO2 sequestration benefits. Findings are provided in both dollar benefits and pounds of carbon sequestered as seen in Figure 21 and Figure 22.

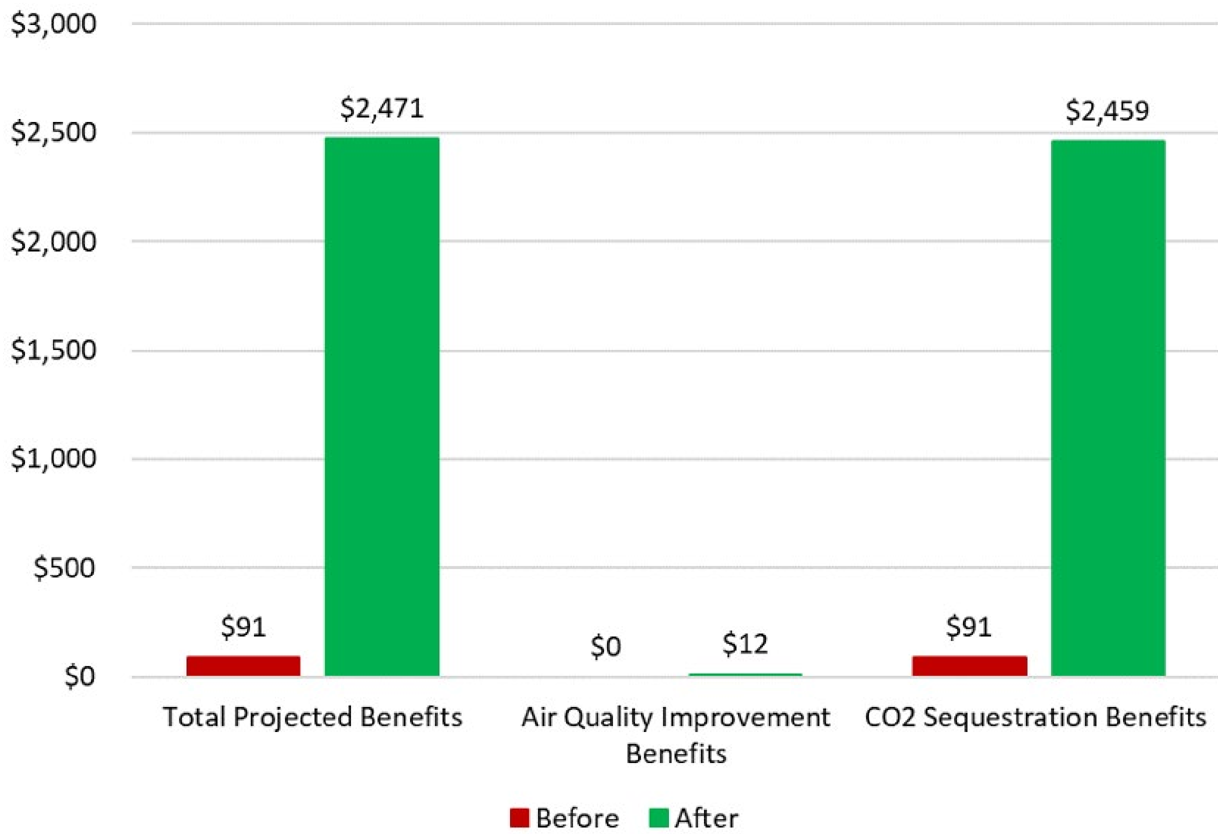

Figure 23. The 20-Year Monetary Value of Trees at Site 8A Estimated Using the i-Tree Design Calculator

Figure 21 suggests that the monetary benefits of the trees on this site primarily come from CO2 sequestration.

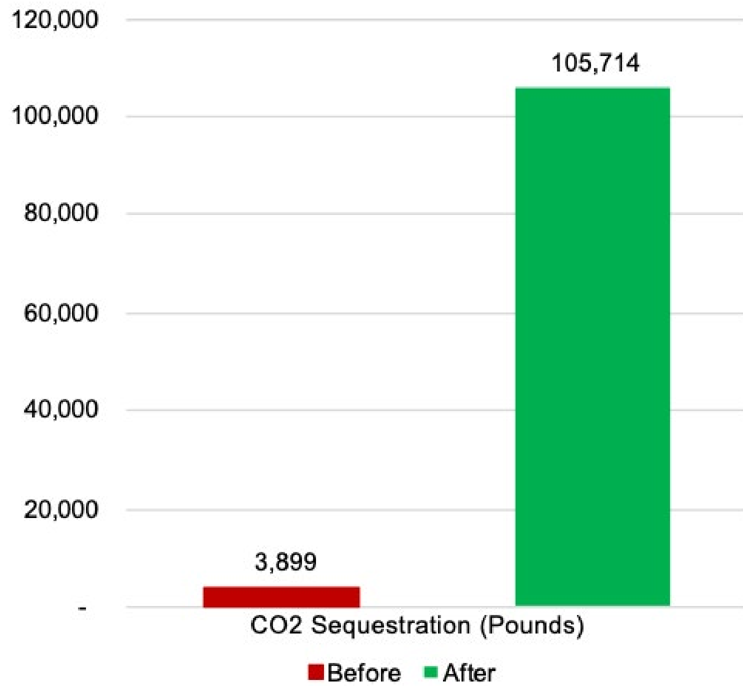

Figure 24. The 20-Year CO_2 Sequestration Benefits of Trees at Site 8A Estimated Using the i-Tree Design Calculator

Analysis of Figure 21 and Figure 22 together shows the value added by trees on this street.

PLOS Calculator

As Figure 18 indicates, there is no measurable improvement in Pedestrian Level of Service from adding the street trees. Since the "after" scenario does not have planter strips acting as a sidewalk buffer, and since the PLOS calculator is highly sensitive to whether there is a sidewalk buffer, there is no PLOS difference between two scenarios.

Table 16. Results from Pedestrian Level of Service Calculator

Scenario	Output
Before Green Feature Implementation	PLOS: 2.66 C (2.51–3.50) Moderately High
After Green Feature Implementation	PLOS: 2.66 C (2.51–3.50) Moderately High

Case Study 8A Conclusions

The result of this case study shows that it is important to have trees on the street for CO_2 sequestration, but in order to yield a measurable benefit for pedestrians using the Landis PLOS calculator, planter strips are also needed.

SITE 9A: SOUTH HOPE STREET, FROM WEST 12TH STREET TO WEST 11TH STREET, LOS ANGELES, CA

Location and Characteristics

This segment is a 700-foot stretch of South Hope Street in the City of Los Angeles in Los Angeles County, California. As shown in Figure 23, the study segment runs from West 12th street to West 11th Street.

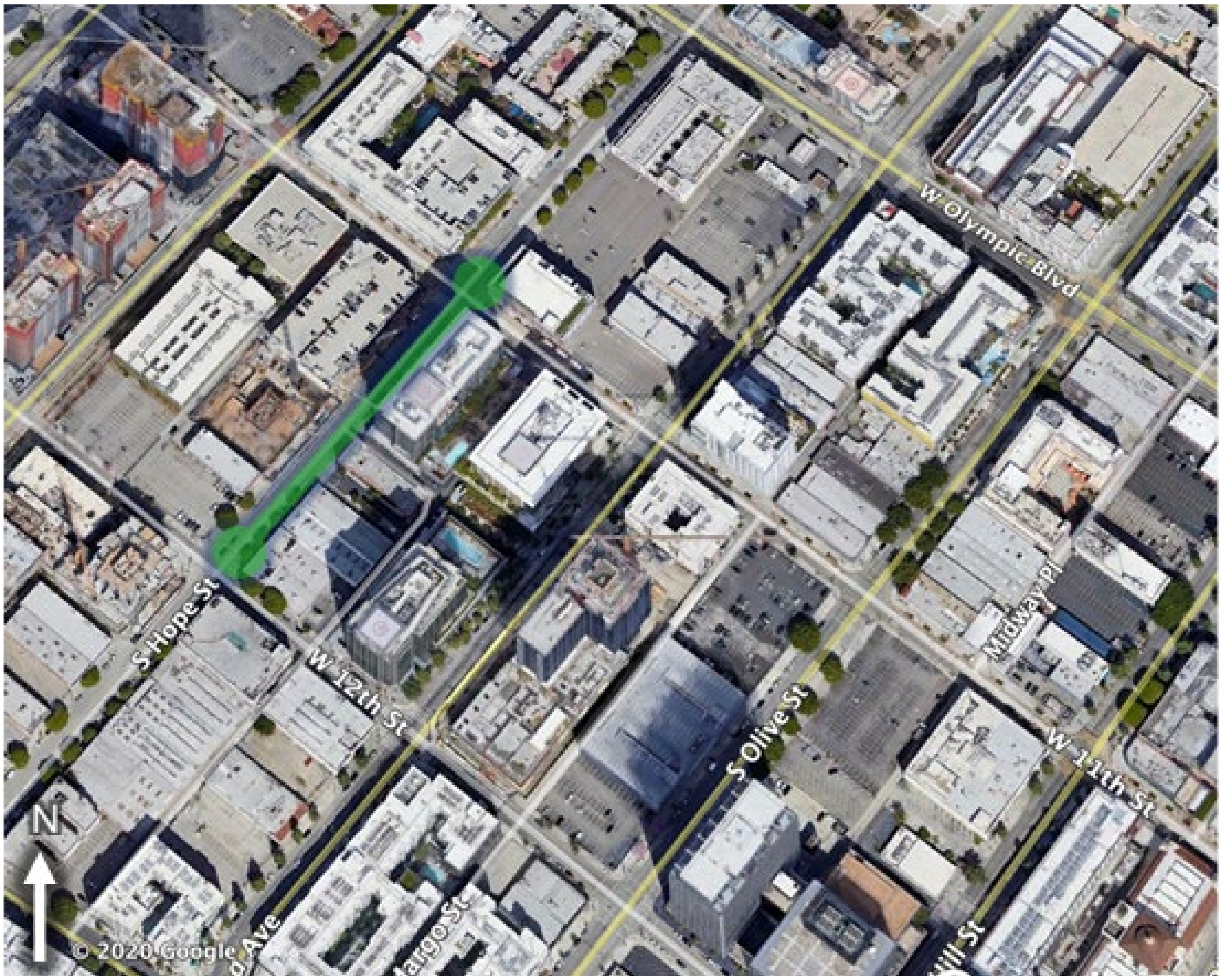

Figure 25. The Location of Site 9A: South Hope Street from West 12th Street to West 11th Street, Los Angeles, CA

Activities along this segment of street are mainly retail and office uses with residential units on upper levels. There is one lane of traffic for northbound and two lanes for southbound traffic. The Average Daily Traffic count is 7,600 vehicles per direction of travel.[39] Since the green infrastructure components (street trees) are planted on the east side of the street, this study does not use the bidirectional traffic data and focuses solely on the northbound traffic data.

There is no designated bike lane on this segment of road, and the entire segment has continuous sidewalks. The green feature on this side of street is street trees, planted in planter boxes on the southern half of this segment (i.e., with no continuous planter strips or biostrips), and on the northern half of this segment, the street trees are planted in biostrips (instead of planter boxes).

Green Infrastructure Description and Analysis Input Data

Since the street trees and biostrips are implemented on the east side of the street (which serves northbound traffic), the estimation of benefits using the i-Tree Design[40] and the Landis method's Pedestrian Level of Service (PLOS)[41] calculators was conducted based on the data from the east side of street.

The data input into each calculator for this case study are summarized below.

i-Tree Design Calculator

As Table 17 indicates, the street trees on this segment are from two species: Planetree and Brisbane Box trees.

Table 17. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One Brisbane Box tree with 10-cm diameter and in excellent condition.
After Green Features Implementation	• 8 Brisbane Box trees with diameters ranging from 17–46 cm. • One Planetree with 20-cm diameter. All in excellent condition.

PLOS Calculator

Since the trees on the southern end of this segment are planted without planter strips or biostrips serving as a pedestrian buffer (see Figure 24), there are two "after" scenarios for the PLOS calculator.

Figure 26. Street Trees in Planter Boxes Instead of Continuous Planter Strips on the East Side of South Hope Street, Los Angeles

As shown in Table 18, this scenario considers the biostrips' width as a buffer for the sidewalk (see Figure 25), and the other "after" scenario includes the trees with no planter strips.

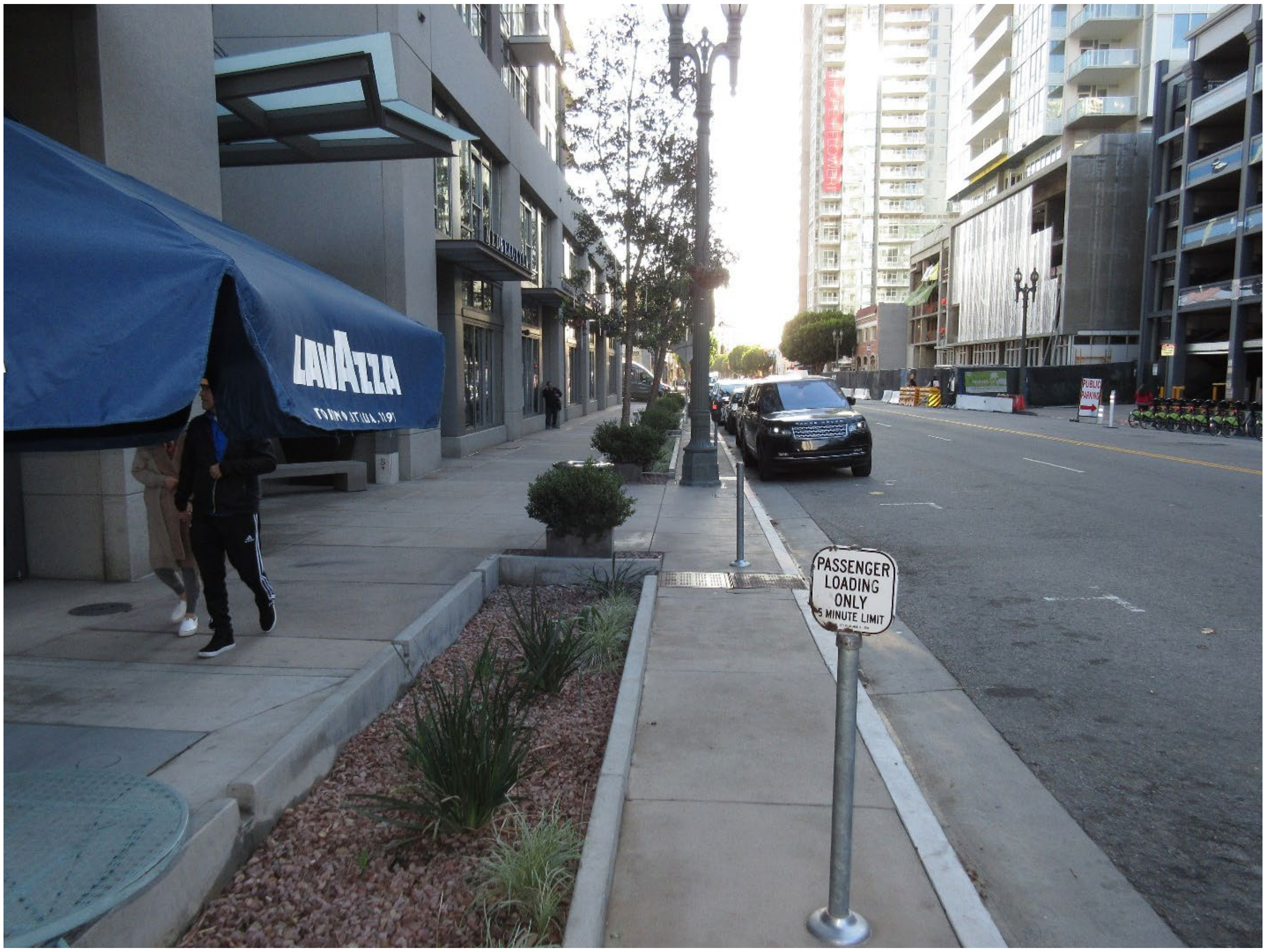

Figure 27. New Biostrips Along the East Side of South Hope Street in Los Angeles

Table 18. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 1 Outside lane width: 8 ft Paved shoulder/bike lane/marked parking width: 4 ft Westbound ADT traffic volume: 3,886 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 70% % of segment with sidewalks: 100% Sidewalk width: 7 ft Sidewalk buffer/parkway width: 0 ft
After Green Features Implementation without Biostrips	Lanes per direction: 1 Outside lane width: 8 ft Paved shoulder/bike lane/marked parking width: 4 ft Bidirectional ADT traffic volume: 3,886 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 70% % of segment with sidewalks: 100% Sidewalk width: 7 ft Sidewalk buffer/parkway width: 0 ft Buffer/parkway mean tree spacing: 50 ft
After Green Features Implementation with Biostrips	Lanes per direction: 1 Outside lane width: 8 ft Paved shoulder/bike lane/marked parking width: 4 ft Bidirectional ADT traffic volume: 3,886 (veh/day) Posted speed limit: 35 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 70% % of segment with sidewalks: 100% Sidewalk width: 7 ft Sidewalk buffer/parkway width: 5 ft Buffer/parkway mean tree spacing: 50 ft

As mentioned previously, only the attributes of the east side of the street have been measured and included in the process.

Findings of Benefits Analysis

Estimated benefits from the installation of green infrastructure at Site 9A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

There are two main outputs obtained from this calculator as considered for this study: air quality and CO2 sequestration benefits. These are provided in both dollar benefits and pounds of carbon sequestered in Figure 26 and Figure 27. Specifically, these figures show the added value of having trees on this street by comparing the “before” and “after” scenarios. For both cases, the greatest benefit comes from CO2 sequestration.

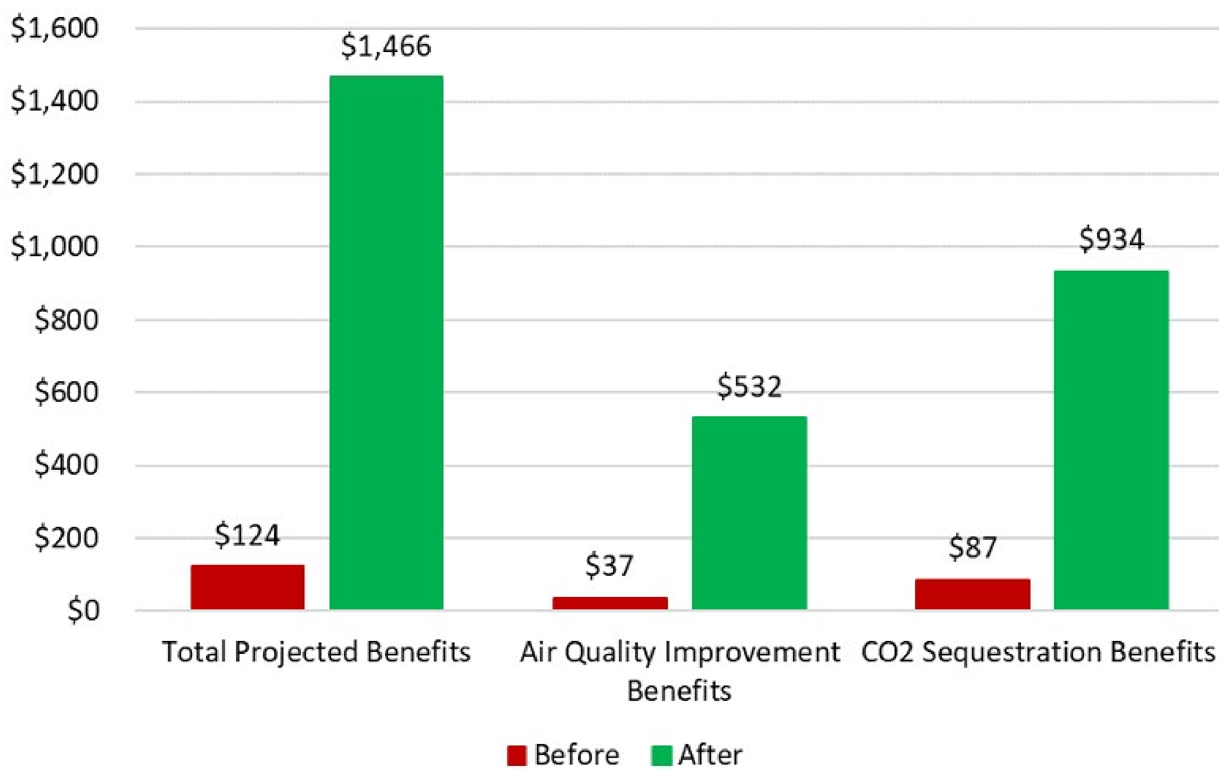

Figure 28. The 20-Year Monetary Value of Trees at Site 9A Estimated Using the i-Tree Design Calculator

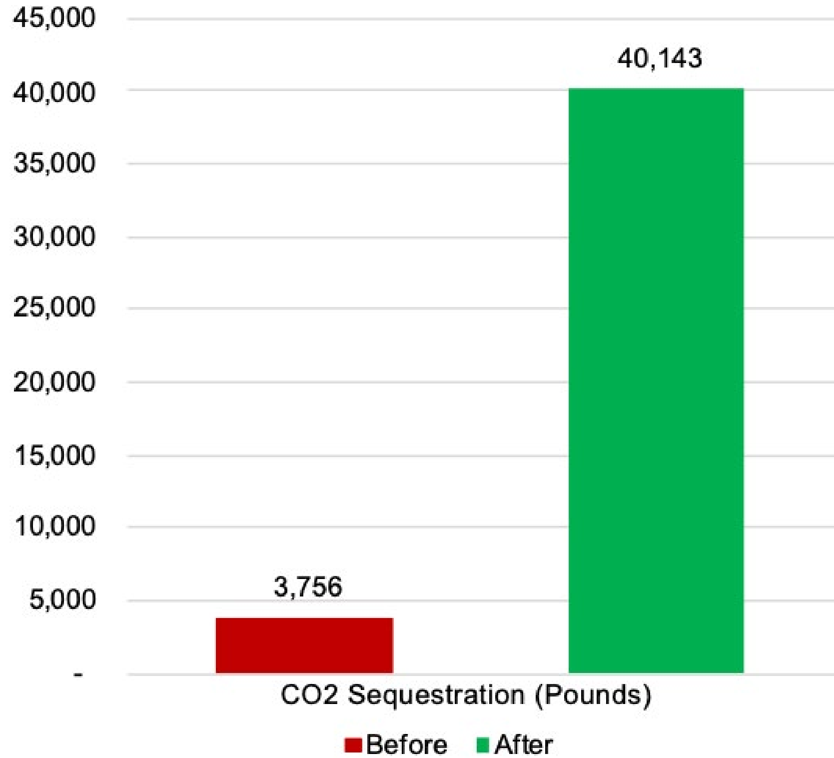

Figure 29. The 20-Year CO2 Sequestration Benefits of Trees at Site 9A Estimated Using the i-Tree Design Calculator

PLOS Calculator

As Table 19 indicates, adding the street trees without planter strips on this segment has not changed the pedestrian level of service. However, adding biostrips on the northern end of this segment has improved the LOS walkability score significantly, even though it has not improved the LOS letter grade.

Table 19. Results from Pedestrian LOS Calculator

Scenario	Output
Before Green Feature Implementation	PLOS:2.11 B (1.51–2.50) Very High
After Green Features Implementation (without biostrips)	PLOS:2.11 B (1.51–2.50) Very High
After Green Features Implementation (with biostrips)	PLOS: 1.82 B (1.51–2.50) Very High

Case Study 9A Conclusions

Although the number of trees in this location is relatively low, the benefits provided by the trees during the projected timeline are significant. Carbon sequestration and air quality enhancement are two major benefits of having trees on this street. Since having buffers for sidewalks is the most critical factor in the calculation of PLOS using the Landis method, the level of service score has not changed for the southern segment when there are no biostrips. In order to yield a measurable benefit for pedestrians using the Landis PLOS calculator, a continuous buffer is also needed. Therefore, the LOS score for walkability has improved by 15 percent for the northern segment, where the biostrips serve as a buffer for the sidewalk.

SITE 11A: LAKESIDE DRIVE FROM MADISON AVENUE TO WEST GRAND AVENUE, OAKLAND, CA

Location and Characteristics

This case study is located in city of Oakland, in Alameda County, California. The segment runs for 0.4 miles on Lakeside Drive from Madison Avenue to West Grand Avenue (see Figure 28).

Figure 30. The Location of Lakeside Drive from Madison Avenue to West Grand Avenue, Oakland, CA

This segment of street has high-rise residential and office buildings. The street has been recently redesigned in order to improve travel conditions for pedestrians. The unique characteristic of this segment is its immediate proximity to the lake along the entire route, as the name (Lakeside Drive) suggests. There are two travel lanes per direction, but this study includes only the east side of the street, since the green features including trees and biostrips are installed on this side. According to Oakland traffic counts, the bidirectional volume of Average Daily Traffic is 7,936 vehicles.[42]

There is a six-foot-wide (on average) bidirectional bike path on the east side of this segment, with travel conditions improved for pedestrians by planter strips (see Figure 29). Approximately 98 percent of the segment has continuous sidewalks. There are segmented tree planter strips (biostrips) along the street, which provide a buffer for the pedestrians on the sidewalk.

Figure 31. Looking North along Lakeside Drive in Oakland, the pedestrian path on the far right is separated from street traffic on the far left by biostrips, street trees, and a class IV bikeway in the middle.

Green Infrastructure Description and Analysis Input Data

Street trees and biostrips are the green features on this segment installed on the east side of the street (which serves northbound traffic). Therefore, only data from the east side of the street were used in the estimation of benefits using the i-Tree Design[43] and Pedestrian Level of Service (PLOS)[44] calculators.

The data input into each calculator for this case study are summarized below.

i-Tree Design Calculator

As Table 20 indicates, the street trees on the east side of this road segment are mainly from three species: London Planetrees, Oriental Planetrees and Maples.

Table 20. Input Data for i-Tree Design Calculator to Measure the Trees' Benefits

Scenario	Input
Before Green Features Implementation	One London Planetree Box tree with 10-cm diameter and in excellent condition.
After Green Features Implementation	• Three Maple trees with diameters ranging from 4–7 cm. • 17 London Planetrees with diameters of 3–7 cm. • 14 Oriental Planetrees.

PLOS Calculator

Note that some segments of the street have planter strips/biostrips between the sidewalk and traffic lanes (compare Figure 29 to Figure 30).

Figure 32. Looking South on Lakeside Drive in Oakland, in the foreground, the sidewalk is adjacent to the bikeway, and both are separated from traffic lanes by a planter strip with trees on the right. In the distant background, a segment with a biostrip between the sidewalk and bikeway can also be seen.

Therefore, there are two “after” scenarios for this street. As seen in Table 21, the first scenario describes segments where a biostrip buffer is installed between the sidewalk and the bikeway (a sidewalk-adjacent buffer), and another scenario includes a planter strip buffer (with recently planted street trees) between the bikeway and traffic lanes.

Table 21. Input Data for PLOS Calculator to Measure Pedestrian Levels of Service

Scenario	Input
Before Green Features Implementation	Lanes per direction: 2 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 10 ft Northbound ADT traffic volume: 4,000 (veh/day) Posted speed limit: 25 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 75% % of segment with sidewalks: 98% Sidewalk width: 8 ft Sidewalk buffer/parkway width: 0 ft Buffer/parkway mean tree spacing: 0 ft
After Green Features Implementation (with street-adjacent planter strips and NO sidewalk-adjacent biostrips)	Lanes per direction: 2 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 10 ft Northbound ADT traffic volume: 4,000 (veh/day) Posted speed limit: 25 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 75% % of segment with sidewalks: 98% Sidewalk width: 8 ft Sidewalk buffer/parkway width: 5 ft Buffer/parkway mean tree spacing: 65 ft
After Green Features Implementation (with street-adjacent planter strips and sidewalk-adjacent biostrips)	Lanes per direction: 2 Outside lane width: 12 ft Paved shoulder/bike lane/marked parking width: 10 ft Northbound ADT traffic volume: 4,000 (veh/day) Posted speed limit: 25 mph Heavy vehicle percentage: 2% FHWA's pavement condition rating: 4 % of segment with occupied parking: 75% % of segment with sidewalks: 98% Sidewalk width: 8 ft Sidewalk buffer/parkway width: 8 ft Buffer/parkway mean tree spacing: 65 ft

The second "after" scenario segment does not have any sidewalk-adjacent buffer, but the planter strip with trees between the street and the class IV bikeway remains. As mentioned previously, only the attributes of the east side of the street have been measured and included in this analysis.

Findings of Benefits Analysis

Estimated benefits from the construction of green infrastructure at Site 11A are presented below from each calculator: i-Tree Design and PLOS.

i-Tree Design Calculator

There are two main outputs obtained from this calculator as used in this study: air quality and CO2 sequestration benefits. Results are provided in both dollar benefits and pounds of carbon sequestered as seen in Figure 31 and Figure 32.

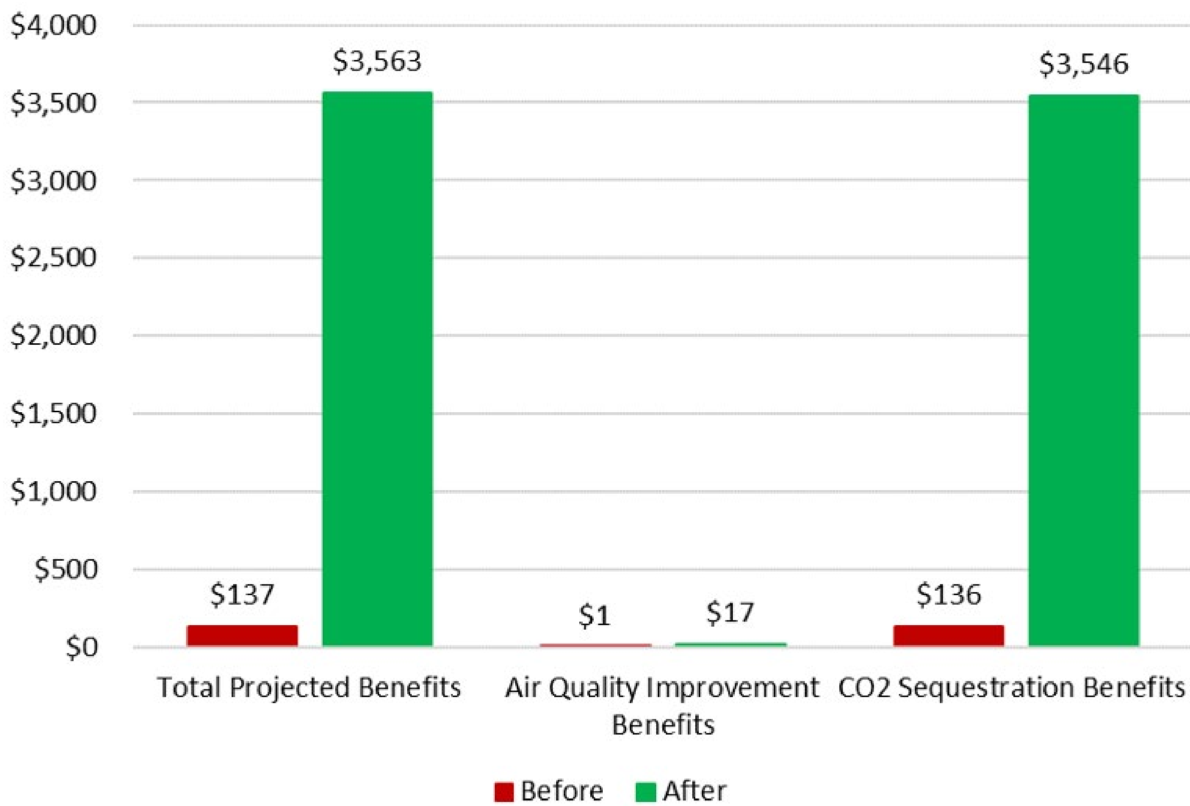

Figure 33. The 20-Year Monetary Value of Trees at Site 11A Estimated Using the i-Tree Design Calculator

Figure 32 suggests that the benefits of the trees on this site mainly come from CO2 sequestration, while the air quality benefit remains at the same low level when comparing before and after scenarios.

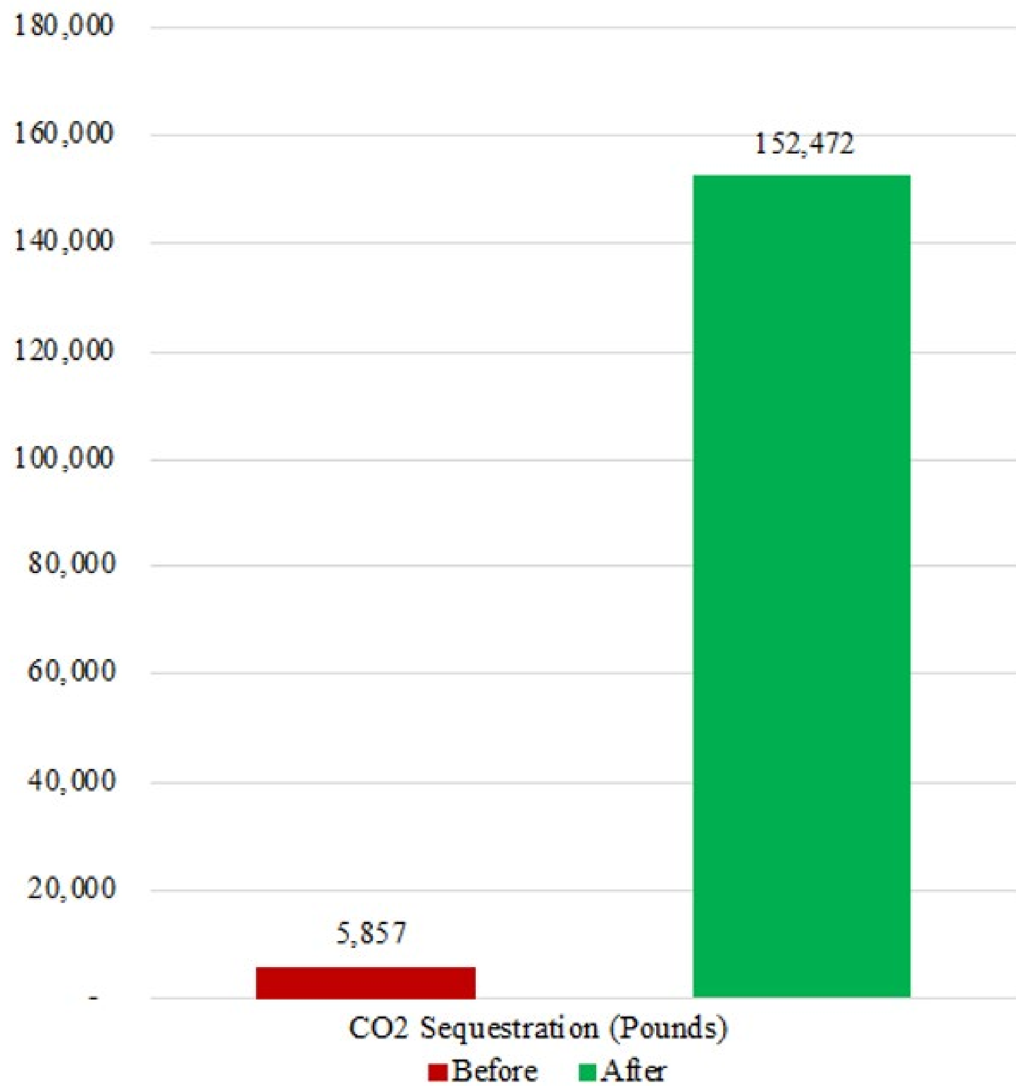

Figure 34. The 20-Year CO_2 Sequestration Benefits of Trees at Site 11A Estimated Using the i-Tree Design Calculator

PLOS Calculator

While the pedestrian level of service letter grade for all three scenarios is the same—it was already at the highest level in the "before" scenario—the LOS score (from which the letter grade is derived) improved by almost 20 percent after adding the trees with planter strips and the sidewalk-adjacent biostrips (see Table 22).

Table 22. Results from Pedestrian LOS Calculator

Scenario	Output
Before Green Features Implementation	PLOS: 1.42 A (below 1.50) Extremely High
After Green Features Implementation (with street-adjacent planter strips and NO sidewalk-adjacent biostrips)	PLOS: 1.22 A (below 1.50) Extremely High
After Green Features Implementation (with street-adjacent planter strips and sidewalk-adjacent biostrips)	PLOS: 1.11 A (below 1.50) Extremely High

Case Study 11A Conclusions

Like the other case studies, this case study analysis yields results suggesting that adding buffers between the sidewalk and street can substantially enhance the walkability of the street, while the effect of the street trees themselves (as measured by average tree spacings) is not significant. The greatest benefit of the trees comes from CO2 sequestration, which is increased 26 times after having green features on the street. Although air quality is 17 times greater than before implementing the green features, its total benefit is relatively low.

VI. DISCUSSION AND CONCLUSIONS

As mentioned earlier, it is important to note that there are several potentially important benefits from green streets infrastructure that the two calculators used in this study (i-Tree Design and Landis PLOS) are not designed to measure. Therefore, these case study findings should be considered as limited and suggestive rather than as definitive accounts of the total benefits at each site and the benefits each green street infrastructure type yields.

In particular, the methods used here largely do not account for the benefits of street trees and other vegetation in reducing the urban heat island effect; the stormwater filtering, runoff, and retention benefits of biostrips and other planters; or the benefits to bicyclists (which the Landis BLOS method does not measure). That being said, a number of conclusions (discussed below) can be identified by comparing the calculators' results from the seven case studies evaluated in this study.

Furthermore, the case studies do not evaluate the benefits or costs of specific trees. Great care needs to be taken in the selection of trees considering a variety of factors that are not evaluated in this study.

MONETARY BENEFITS OF STREET TREES

The monetary value of planting trees over a 20-year period is small but significant, according to analysis performed with the i-Tree Design calculator. The calculator measures these benefits in terms of stormwater runoff and retention, air quality improvements, and CO2 sequestration. This report does not address the findings from stormwater runoff and retention and focuses on i-Tree Design's air quality and CO2 sequestration estimates. The total estimated benefits from street trees (over a 20-year forecast period) on the seven case study sites trees range from a low of $752 for 75 trees at site 3A (Cherry Avenue in San Jose) to a high of $9,420 for 56 trees at site 7A (CA 299 in Willow Creek).

On a per tree basis, the lowest benefits come from site 3A (Cherry Avenue in San Jose) with $10 per tree, and the highest come from site 1A (San Pablo Avenue in El Cerrito) at $175 per tree. Since the trees on both of these sites have been planted recently, it is reasonable to conclude that the species of the trees at site 1A are more effective at providing monetary benefits (at least in terms of CO2 and Air Quality benefits) over the 20-year period than those at site 3A.

CO2 sequestration makes up the bulk of monetary value from trees for all sites in this study analyzed using i-Tree Design, except for site 5A (Woodman Avenue in Los Angeles). At site 5A, the benefits from air quality improvements are higher than CO2 sequestration. Since the trees at this site are larger and more mature, it is reasonable to conclude that the age of trees makes a real difference in the benefits provided, with larger, more mature trees providing air quality benefits, while younger, fast-growing trees quickly add vegetative mass that absorbs and retains CO2.

PLOS BENEFITS OF PEDESTRIAN BUFFERS

While the Landis PLOS method accounts for the benefits of short street tree spacings (i.e., a high number of trees) and of having a continuous biostrip or planter strip serving as a pedestrian buffer, the method does not appear sensitive to tree spacings, while it is very sensitive to buffers. For example, site 5A (Woodman Avenue in Los Angeles) has two “after” segments; both have 40-foot average tree spacings, but only one has a five-foot-wide planter strip sidewalk buffer. The segment without a buffer shows no change in PLOS score, while the segment with a buffer (but the same average tree spacing) shows an improvement in the PLOS score.

The importance of having a biostrip or planter strip buffer between the sidewalk and street traffic is also reflected in the PLOS findings for the other six cases in this study. For example, the installation of a buffer on sites 1A (San Pablo Avenue in El Cerrito) and 3A (Cherry Avenue in San José) yielded a full letter grade improvement on these streets; in both cases, the letter grade improved from a “C” to a “B.” Also notable is that while the LOS letter grade remained a “B” in the “before” and “after” scenarios for site 7A (CA 299 in Willow Creek), the installation of the buffer improved the LOS score from 2.49 to 1.66, effectively bringing the letter grade from a “B-” to a “B+.” This study’s findings suggest that a planter/biostrip serving as a pedestrian buffer can enhance the benefits of street trees to pedestrian stress levels and level of service.

POTENTIAL FOR FURTHER RESEARCH AND WIDER USE

The analysis tools used here, i-Tree Design and the Landis Pedestrian Level of Service method, have potential for wider use, both within and beyond Caltrans. For its ease of use, sensitivity to a range of tree and environmental characteristics, and scalability—it can be used to analyze one tree or many trees—i-Tree Design can potentially serve as a common frame of reference and analysis for a variety of potential users within Caltrans and other state departments, as well as local and federal government agencies. While the measurable benefits of a handful of street trees may seem small, this study suggests that adding together the trees analyzed using i-Tree Design by local and state agencies has the potential to provide a compelling picture of the carbon sequestration benefits of trees on public and private lands across California. With modest effort, it appears possible to use i-Tree Design (or some other application from the i-Tree Suite) as a common tool for both state and local agencies within California, and in doing so, to foster additional interagency cooperation and collaboration with respect to green streets.

A similar argument can be made for the Landis PLOS method. Since HCM-based methods (such as the Landis method) are already a common standard for the transportation industry, teaching and advocating for Caltrans and other transportation professionals to use these methods to capture the pedestrian benefits of green streets infrastructure (as done here with pedestrian buffers and street trees) would likely require little effort, with significant gains in the appreciation for green streets benefits.

ENDNOTES

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11. B.W. Landis and others, “Modeling the Roadside Walking Environment: A Pedestrian Level of Service,” (paper presented 79th Transportation Research Board Annual Meeting, Washington, D.C., January 2000).

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14. California Department of Transportation (Caltrans), “Complete Streets Program,” https://dot.ca.gov/programs/transportation-planning/office-of-smart-mobility-climate-change/smart-mobility-active-transportation/complete-streets (accessed July 7, 2020).

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27. Specifically, the calculator tests found no measurable benefits from average tree spacings, as well as small but potentially significant benefits from biostrips and planter strips adding pedestrian buffer space between sidewalk and traffic lanes.

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PEER REVIEW

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