



**AGENDA
PLANNING ADVISORY BOARD
REGULAR MEETING
SEPTEMBER 8, 2021
5:00 PM
CITY HALL COMMISSION CHAMBERS
204 ASH STREET
FERNANDINA BEACH, FL 32034**

- 1. CALL TO ORDER / ROLL CALL / DETERMINATION OF QUORUM**
- 2. PLEDGE OF ALLEGIANCE**
- 3. APPROVAL OF MEETING MINUTES**
 - 3.1 Approval of Minutes for the August 11, 2021 Workshop.
 - 3.2 Approval of Minutes for the August 11, 2021 Regular Meeting.
- 4. BOARD BUSINESS**
 - 4.1 Presentation of LDC Text Amendments for enhanced tree protection as recommended by the City Tree Committee
 - 4.2 Discussion on upcoming LDC Text Amendments and next steps.
- 5. STAFF REPORT**
- 6. PUBLIC COMMENT**
- 7. ADJOURNMENT**

NEXT PAB REGULAR MEETING IS SCHEDULED FOR

All members of the public are invited to be present and be heard. Persons with disabilities requiring accommodations in order to participate in this program or activity should contact the City Clerk at (904) 310-3115 or TTY/TDD 711 (for the hearing or speech impaired). All interested parties may appear at said meeting and be heard as to the advisability of any action, which may be considered with respect to such matter. For information regarding this matter, please contact the Planning Department (904) 310-3135.



**MINUTES
PLANNING ADVISORY BOARD
WORKSHOP
AUGUST 11, 2021**

- 1. CALL TO ORDER 4:00**
- 2. ROLL CALL/ DETERMINATION OF QUORUM**

MEMBERS PRESENT:

Genece Minshew (Chair)	Mark Bennett
Victoria Robas	Peter Stevenson
Barbara Gingher	John Boylan

MEMBERS ABSENT:

Jenny Schaffer (V-Chair)

OTHERS PRESENT:

Kelly Gibson, Planning & Conservation Director
Jacob Platt, Senior Planner
Tammi Bach, City Attorney
Taylor Hartmann, Recording Secretary
Angela Biagi, WGI (Zoom)
Andrew Crozier, WGI (Zoom)

- 3. BOARD BUSINESS**

- 3.1 Vision 2045 Work In Progress Update: WGI will present the initial findings of outreach conducted in June-July 2021 and request PAB and public feedback on the approach before moving forward with document preparation. Draft Vision 2045 Plan documents are anticipated for public commenting in late August.*

Andrew Crozier, WGI, presented a PowerPoint slideshow that summarized a number of outreach efforts including Juneteenth, online and mail-in surveys, document research, and stakeholder interviews. Resiliency, sustainability, and preservation were found to be the foundational blocks of the 2045 Vision.

Ms. Minshew questioned whether the final document would be enforceable or just a list of recommendations.

Mr. Crozier introduced 6 goals identified after reviewing all of the outreach feedback and the developed objectives and potential implementation strategies for each goal.

Members agreed that more conversation needs to be had on a number of topics.

Members will provide Ms. Gibson with individual feedback to send to the WGI consultants.

- 4. PUBLIC COMMENT**
No parties wished to speak.

- 5. ADJOURNMENT 5:00**

DRAFT



**MINUTES
PLANNING ADVISORY BOARD
REGULAR MEETING
AUGUST 11, 2021**

1. CALL TO ORDER 5:05

2. ROLL CALL / DETERMINATION OF QUORUM

MEMBERS PRESENT:

Genece Minshew (Chair)	Mark Bennett
Victoria Robas	Peter Stevenson
Barbara Gingher	John Boylan

MEMBERS ABSENT:

Jenny Schaffer (V-Chair)

OTHERS PRESENT:

Kelly Gibson, Planning & Conservation Director
Jacob Platt, Senior Planner
Tammi Bach, City Attorney
Taylor Hartmann, Recording Secretary

3. PLEDGE OF ALLEGIANCE

4. APPROVAL OF MEETING MINUTES

4.1 Approval of Minutes for the May 26, 2021 Special Meeting.

Member Stevenson noted that under item 4.1 in the first paragraph, the last sentence should read "...which will..."

ACTION TAKEN: A motion was made by Member Stevenson seconded by Member Robas to approve the minutes with the noted amendments.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

4.2 Approval of Minutes for the July 14, 2021 Regular Meeting.

ACTION TAKEN: A motion was made by Member Stevenson seconded by Member Gingher to approve the minutes as presented.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

4.3 Approval of Minutes for the April 28, 2021 Port Subcommittee Regular Meeting.

Member Robas suggested that under this, Item 4.3, Regular Meeting be changed to Workshop on the agenda.

ACTION TAKEN: A motion was made by Member Robas seconded by Member Stevenson to approve the minutes with the noted amendments.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

4.4 Approval of Minutes for the July 28, 2021 Port Subcommittee Regular Meeting

Member Robas suggested that under this, Item 4.4, Regular Meeting be changed to Meeting on the agenda.

Member Stevenson stated that the last comment on the last page of the minutes should say that there is a continued problem of waste being left by truckers parked on the street.

ACTION TAKEN: A motion was made by Member Robas seconded by Member Stevens to approve the minutes with the noted amendments.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

5. OLD BUSINESS

There were no Old Business items to discuss.

6. NEW BUSINESS

6.1 **PAB 2021-0004: GILLETTE & ASSOCIATES, INC., AGENT FOR WILLIAM MOCK, S. 15TH STREET REQUEST FOR VOLUNTARY ANNEXATION, SMALL SCALE FUTURE LAND USE MAP AMENDMENT AND ZONING MAP CHANGE FOR PARCELS: 00-00-31-1800-0267-081 & 00- 00-31-1800-0267-0082**

Mr. Platt introduced the case and staff recommended approval of an MU-1 zoning designation and mixed-use future land use map category.

Member Bennett inquire about setback requirements for the MU-1 zoning district.

Chair Minshew inquire as to why MU-1 is being recommended for these parcels. Mr. Platt explained that the applicant requested MU-1 and based on staffs' analysis, the LDC, and the adjacent properties' zoning and land uses this is an appropriate designation and consistent with the Comprehensive Plan.

Nick Gillette, 20 S. 4th Street, was present to answer any questions.

Public hearing was opened.

Frank Roberto, 2166 Lakeside Drive South, inquired whether any building plans had been submitted with the annexation application.

Cynthia Roberto, 2166 Lakeside Drive South, inquired about maximum building heights for residential and commercial buildings.

Public hearing was closed.

ACTION TAKEN: A motion was made by Member Bennett, seconded by Member Stevenson to recommend approval of PAB case 2021-0004 to the City Commission requesting that a voluntary annexation, assignment of the Mixed Use (MU) Future Land Use Map category and Mixed Use (MU-1) zoning district as described be approved; AND that PAB case 2021-0004 as presented is sufficiently compliant with the Comprehensive Plan and Land Development Code and applicable Florida Statutes to be approved at this time.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

6.2 **PAB 2021-0005: Comprehensive Plan Amendment - GOAL 5P Ocean Highway & Port Authority, Port of Fernandina Facilities Element CITY OF FRNANDINA BEACH, INCORPORATING**

“GOAL 9: PORT FACILITIES ELEMENT” INTO “GOAL 5: CONSERVATION & COASTAL MANAGEMENT” AS A SUB-ELEMENT, AS REQUIRED BY FLORIDA STATUTE 163.3178(2)(K).

Mr. Platt provided the Board with a brief history of the development of a statute compliant Comprehensive Plan Port element.

Member Robas identified section 5P.01.02 and felt it would be beneficial to set a specific date. Members agreed to use, “...as of August 11, 2021...”

Member Robas identified section 5p.02.01 and inquired about including the Community Redevelopment Area. Mr. Platt stated that staff discussed this and did not feel that it was pertinent to this element.

Member Robas identified section 5.03.02 and confirmed that the revised landscape buffer requirement will be included in the Land Development Code text amendments presented in December.

Member Stevenson stated that the title is the only place where Ocean Highway & Port Authority (OHPA) is mentioned and does not seem appropriate to keep it in the title. Members briefly discussed this and agreed to keep OHPA in the title.

Public hearing was opened and closed with no parties wishing to speak.

ACTION TAKEN: A motion was made by Member Robas, seconded by Member Bennett to accept the final draft of the Port Facilities Element with the noted amendments.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

- 6.3 **PAB 2021-0006: Comprehensive Plan Amendment - Private Property Rights Element CITY OF FERNANDINA BEACH, REPLACING “GOAL 9 WITH PRIVATE PROPERTY RIGHTS ELEMENT,” AS REQUIRED BY FLORIDA STATUTE 163.3177(6)(I).**

Mr. Platt provided a brief introduction of the new statute.

Ms. Bach provided the Board with an overview of what this new statute encompassed and stated that City business such as annexations and Future Land Use Map amendments could not move forward without the adoption of the property rights element into the City’s Comprehensive Plan.

Public hearing was opened and closed with no parties wishing to speak.

ACTION TAKEN: A motion was made by Member Bennett, seconded by Member Robas to accept Goal 9 as the Property Rights Element of the City’s Comprehensive Plan.

Vote upon passage of the motion was taken by voice vote, and being all ayes, carried.

7. BOARD BUSINESS

There were no Board Business items to discuss.

8. STAFF REPORT

9. PUBLIC COMMENT

Theresa Domagola, 2881 Turtle Shores Drive, spoke about concerns regarding potential development around Bailey Road and how that type of density would affect residents currently living there.

10. ADJOURNMENT 6:18

DRAFT

Taylor Hartmann, Recording Secretary

Genece Minshew, Chair

FINAL REPORT OF RECOMMENDATIONS FOR CITY CANOPY INCREASE



August 3, 2021

Prepared by:
The City Tree Committee (CTC) of Fernandina Beach

CTC Committee Members:

Lynda Bell, Keep Nassau Beautiful
Lisa Finkelstein, Fernandina Beach Main Street
John Hillman, The Range at Crane Island
David Jensen, WestRock, Urban Forestry
Margaret Kirkland, Amelia Tree Conservancy
Tammi Kosack, Resident
Matt Meskimen, MCG Homes

Daphne Forehand, Staff Liaison
Taylor Hartmann, Staff Liaison

TABLE OF CONTENTS

KEY FINDINGS	3
CREATION OF THE COMMITTEE	4
VISUALIZING A 5% INCREASE	5
CANOPY INCREASE ACTION PLAN	6
<i>Large Scale Plantings</i>	7
<i>Small Scale Plantings</i>	8
<i>Land Development Code Amendments</i>	9
<i>Community Outreach</i>	10
<i>Website Updates</i>	11
<i>Website Icons</i>	12
<i>Designation of Tree Holding Area</i>	13
RECENT EVENTS FOR CANOPY INCREASE	14-15
FUTURE LARGE SCALE PLANTINGS	16
FINANCING THE ACTION PLAN	17
METHODS OF MEASURING PROGRESS	18
FORMAL RECOMMENDATIONS	19
APPENDIX	20



KEY FINDINGS

As the City of Fernandina Beach continues to grow and develop, long term planning and management is critical to preserve, enhance, and restore our urban forest.

As the City of Fernandina Beach continues to grow and develop, long-term planning and management is critical to preserve, enhance, and restore our urban forest. The findings of this report include:

- Review of 5% canopy coverage goal established by City Commission, with the conclusion that this goal is unattainable
- Utilized 2019 canopy coverage data to determine baseline values for future actions
- Recommendations and solutions through LDC amendments to offset loss, increase canopy, and realize an attainable goal.

Research conducted by reviewing similar canopy coverage initiatives in various municipalities reveals that more time is needed to realize canopy growth. The established timeline and goal of 5% growth in 5 years do not provide ample time to plant or measure the growth of newly established trees. A revised goal and timeline would allow for measurable growth as the average age of tree maturity are upwards of 40-70 years. (Appendix A, B, C)

The recommendations included within this report are in alignment with the City's Comprehensive Plan. The establishment of a 10, 15, or 20-year goal would further align with the Comprehensive Plan and provide for measurable progress, which could be captured through aerial assessments performed every 2 years.

Community engagement and public education are critical components for maintaining, protecting, and revitalizing our urban canopy. One of the ways in which these components are addressed is through website updates. The website will include easy to access to tree protection requirements and resources for citizens to get involved in volunteer efforts.

For these findings and recommendations to reach success, adequate time, strategic planning, and an effort from everyone including City staff, residents, and the business community is required. The planting, care, and preservation of trees on public and private property are efforts that all can take part in to restore, protect and increase our tree canopy.

CREATION OF THE COMMITTEE

On January 28, 2019, the City Commission held a Goal Setting Workshop to discuss and clarify the City of Fernandina Beach goals. During this workshop, one of the City Commission's main discussion items included the expansion of the existing City tree canopy by 5% over the next 5 years. Upon their consensus on completing a canopy study, the Department of Planning and Conservation was assigned the task of information gathering to create a report offering a framework that emphasizes the health, protection, maintenance, and growth of our existing mature canopy, and most importantly lay out strategies for replacement and planting of new diverse tree species native to our area. Staff developed Land Development Code changes for adoption in early 2020 which significantly modified the City's tree protection mitigation ratios and set forth penalties for unpermitted tree removal. Presentation of the City's Tree Management Plan was provided by the City Arborist in August 2020. (Appendix A) At its annual goal-setting meeting in January 2021, the City Commission prioritized and emphasized its original goal to increase the tree canopy by 5% and directed staff to provide feedback on additional Land Development Code amendments. The direction was to return to the City Commission by August 2021; with the understanding that the requested action would take greater buy-in from the community at large, Staff initiated and established an internal committee for support. The Department of Planning and Conservation began the task of creating the City Tree Committee by recruiting professionals from fields including development, business, landscape design, and tree/environmental advocacy groups.

Throughout this 3-month period, members took part in discussions regarding the impact of tree conservation both as citizens and within their professional fields. Also highlighted during this period were 3 panel discussions. The first panel focused on Tree Professionals. They included tree removal companies, arborists, and tree nurseries. The second panel provided insight on GIS and our partnership with Nassau County's Property Appraiser expert staff. The third and last panel discussion emphasized the important impact of Design Professionals and allowed a well-rounded exchange of questions and feedback.

As a result, committee and panel discussions provided necessary fact-finding information laid out below, generating a consensus on the attainability of the proposed goal, the establishment of current strategies put in place to beef up the tree replacement outreach, and future plantings.



VISUALIZING A 5% INCREASE

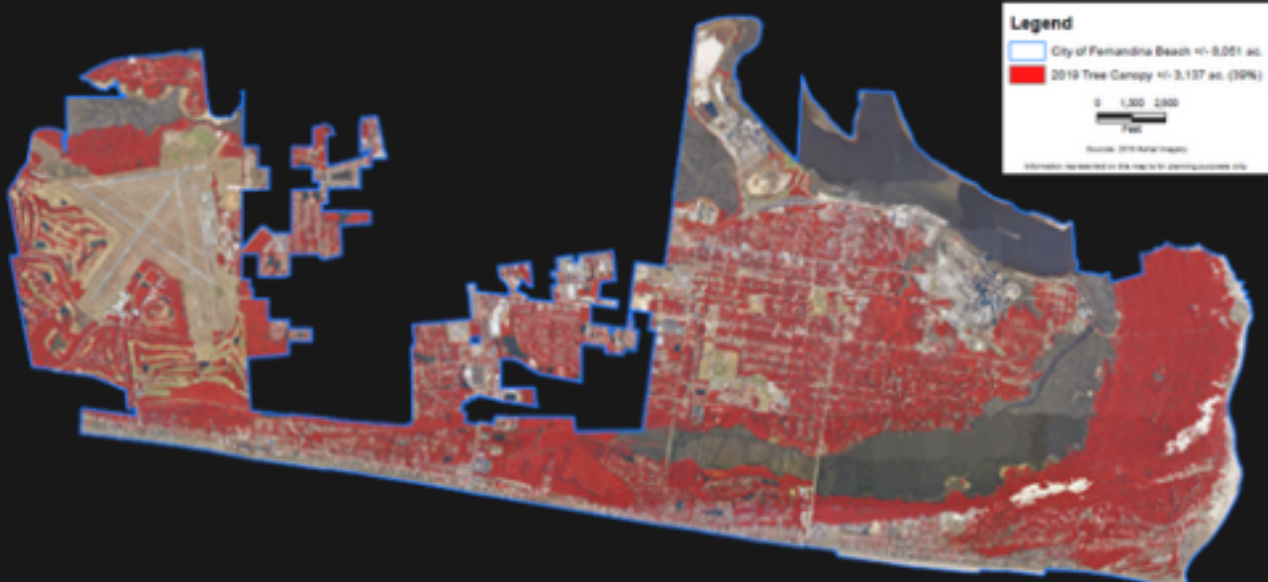
In order to create a framework of goals and actions, it was critical for the committee to identify and establish key baseline values, the first of which came from a 2019 canopy coverage analysis performed by Carter Environmental Services (CES). Using the most recent aerial imagery (2019), CES concluded that the City had an estimated canopy of 39%. However, one must also understand that this is an aging canopy that requires continual maintenance and tree replacement in order to account for natural loss. (Appendix B)

- **Total acreage of the COFB:** 8,051
- **2019 Canopy Coverage Analysis:** 39% (equivalent to 3,140 acres)
- **5% Increase (Appendix C):** Totals 157 acres
- **Trees Per Acre:** 33 (Based on 41' canopy spread, totaling 1,320 sq. ft.)
- **Mortality Rate of Newly Planted Trees (Appendix D): (0-5 Years After Planting):** 7% (equivalent to 363 trees or 11 acres)
- **Total Tree Removal between 2014-Present:** 12,906
- **Average Annual Tree Removal (Appendix E)** = 1,613 (development and hazard trees)

**5,181
TREES**
Meeting the canopy coverage goal of 5% by 2024 would require the City to successfully plant and maintain 5,181 trees in 2.4 years.

TIMELINE	ANNUAL TREES TO BE PLANTED	ANNUAL COST*	COST INCLUDING LABOR AT \$400
3 Years Established Goal	1,909	\$524,920	\$763,600
10 Years	518	\$142,477	\$207,200
15 Years	345	\$94,875	\$138,000
20 Years	260	\$71,500	\$104,000

* These numbers are based on the average price of a code-compliant tree at \$275 per tree. The average price per tree including installation, maintenance, and labor cost is \$400-\$475.





CANOPY INCREASE ACTION PLAN

After the first introductory meeting to present the goal of the City Commission and introduce the purpose behind creating the City Tree Committee, members were asked to view a map of the city boundary and select a quadrant to scout and identify locations for future tree plantings.

Areas identified included: North 3rd Street behind the port warehouse, Fernandina Beach Middle and High schools, the City golf course, Central Park, Ash Street rights-of-way, Hickory Street right-of-way, the airport, and the Nassau County Humane Society. (Appendix F, G)

The recommendation of the City Tree Committee is for the Department of Planning and Conservation to initiate and oversee the following actions.

Large Scale Plantings

Small Scale Plantings

LDC Code Based
Amendments

Community Outreach

Website Updates

Designation of Tree Holding
Area

LARGE SCALE PLANTINGS (> 10 TREES)

The committee recognizes the need to establish interdepartmental coordination between the departments of Parks & Recreation, Maintenance, and Planning & Conservation in order to facilitate employee training, implementation of outreach, tree plantings, volunteering efforts.



Seasonal Tree Giveaways

The Department of Planning and Conservation will now hold 3 tree giveaway events yearly in collaboration with community partners. To avoid the hurricane season and the extreme heat during the summer months, these will be done every fall, spring, and winter. Registration links will be made available approximately 1 month prior to each event on the City's newly revamped tree website.



Trees in Parks & Rights of Way

Locations of possible large-scale tree planting opportunities were suggested to the Committee. These locations will need to be reviewed to verify locations of utilities, future planned development, and maintenance issues. One location that has been reviewed and approved for a fall planting is along Hickory Street near the soccer fields. A total of 150 trees will be planted in the fall. (Appendix F)



Golf Course Trees

The Department of Planning & Conservation plans to work with the golf course management team to establish a yearly assessment of the current health of trees located on the City golf course as well as the planning for future plantings.



Existing Retention Pond Plantings

Community outreach to property owners will be implemented to determine potential planting areas. Tree selection will be based on water-tolerant species. Encouraging the clustering of trees will promote wildlife habitats and shaded areas for families to gather. (Appendix H)



Trees in Bosque Bello

Bosque Bello Cemetery has an aging canopy and will need continuous attention to monitor dying trees and a replacement strategy. Funds that were approved to create a master plan are available in the 2021 fiscal year budget. To date, however, no official plan has been put into place. Coordination with the Department of Parks & Recreation would be beneficial for specimen selection and proper maintenance once trees have been planted. Plantings not located along roadsides in the cemetery would need to have an archaeologist on site to cover the City in the event that historical artifacts are uncovered.



City School Planting

Initiate conversation with the Nassau County School Board Staff, to discuss future plantings on school grounds, this effort is for the next school year.

SMALL SCALE PLANTINGS (< 10 TREES)

These small scale plantings require community involvement and advocacy. All requests can be made through the City's tree website for immediate action.



Free Tree Replacement Program

For every tree removal permit approved, citizens are asked if they would like to receive a free tree. Staff will assist residents in determination of appropriate species and location.



Tree Dedication Program

Citizens or local businesses can request a tree for a special occasion or in memory of a loved one. Tree species and final location will be vetted by staff. Dedications will be recognized through staff issued certificates.



Natives for Invasives Replacement Program

Citizens can request a free native tree in exchange for removing an invasive species such as Brazilian pepper, Chinese tallow, and Chinaberry from their property or public rights-of-way.



Arbor Day

The City of Fernandina Beach is proud to hold the Tree City USA designation. In order to maintain this title, the City must recognize both Florida Arbor Day (third Friday of January) and National Arbor Day (last Friday of April). With that in mind, the Department of Planning & Conservation is committed to using these celebrations to promote planting events.

LAND DEVELOPMENT CODE AMENDMENTS

The following bullets briefly summarize the Committee's recommended Land Development Code amendments:

- Allow staff level deviations from dimensional standards for tree protection under certain criteria
- Expand “protected tree” definition to include newly planted trees
- Require trees surrounding stormwater detention and retention areas
- Increase tree removal fees by \$50
- Reduce impervious surface ratio to 45% for residential zoning districts
- Require permits for concrete slabs exceeding 50 square feet
- Double minimum landscape requirements for new residential development
- Provide for allowance to relocate trees on the same site
- Establish an enforcement mechanism for tree replacement and mitigation

Please see Appendix I for a comprehensive analysis.



COMMUNITY ACTION

Achieving a substantial canopy coverage increase requires community action. The recommendations and solutions brought forth through this Committee are unique in that it is not just a City plan, but rather a *community-wide collaboration* to rebuild the urban forest through partnership.

Local School Outreach

After discussions with local guidance counselors, it was agreed that an effort will be made by schools to promote a volunteer program for city-sponsored planting events. The students would help with digging and planting activities, all to be supervised by the City's Urban Forester. This would help students earn community service hours, instill pride, and stress the importance of trees in the community.

Heritage Tree Program

The City must make an initial investment, perhaps through a mailer, to make all residents aware of this program and the ease in which they can nominate a tree for this designation. The most recent tree inventory data, provided by the Nassau County Property Appraiser's Office indicates that there are well over 100 trees that would qualify as Heritage trees, but have yet to be nominated. It is important to note that this title provides an additional layer of protection should anyone ever look to remove the tree.

Social Media and Promotion

The City will utilize various media platforms to inform citizens, promote tree programs, and advertise upcoming planting related events. Platforms include: social media posts via Facebook, the creation of a Twitter tag #Rootfortrees, PEG Channel segments, articles in the New-Leader's City Scoop, and a banner at the top of the city website.

City Tree Unit

A small number of employees from the Parks & Recreation, Maintenance, and Utilities departments will receive training on how to properly establish a new tree planting, maintain green spaces without damaging trees, and regularly work with the City's Urban Forester to preserve the existing aging canopy. This unit of dedicated employees further promotes the need for interdepartmental coordination and collaboration.

Local Advocacy Groups

The City relies on these organizations to continue their efforts in promoting tree education, plantings, and provide volunteers to assist with the long-term care and assessment of mature trees.

Tree Workshop

The City's Urban Forester will provide biannual tree maintenance workshops. This event will be open to all individuals interested in learning about the importance of trees as well as proper planting, pruning, and long-term care techniques. Additionally, they will include an overview of the City's tree website with all of its features.

Creation & Distribution of Infographics

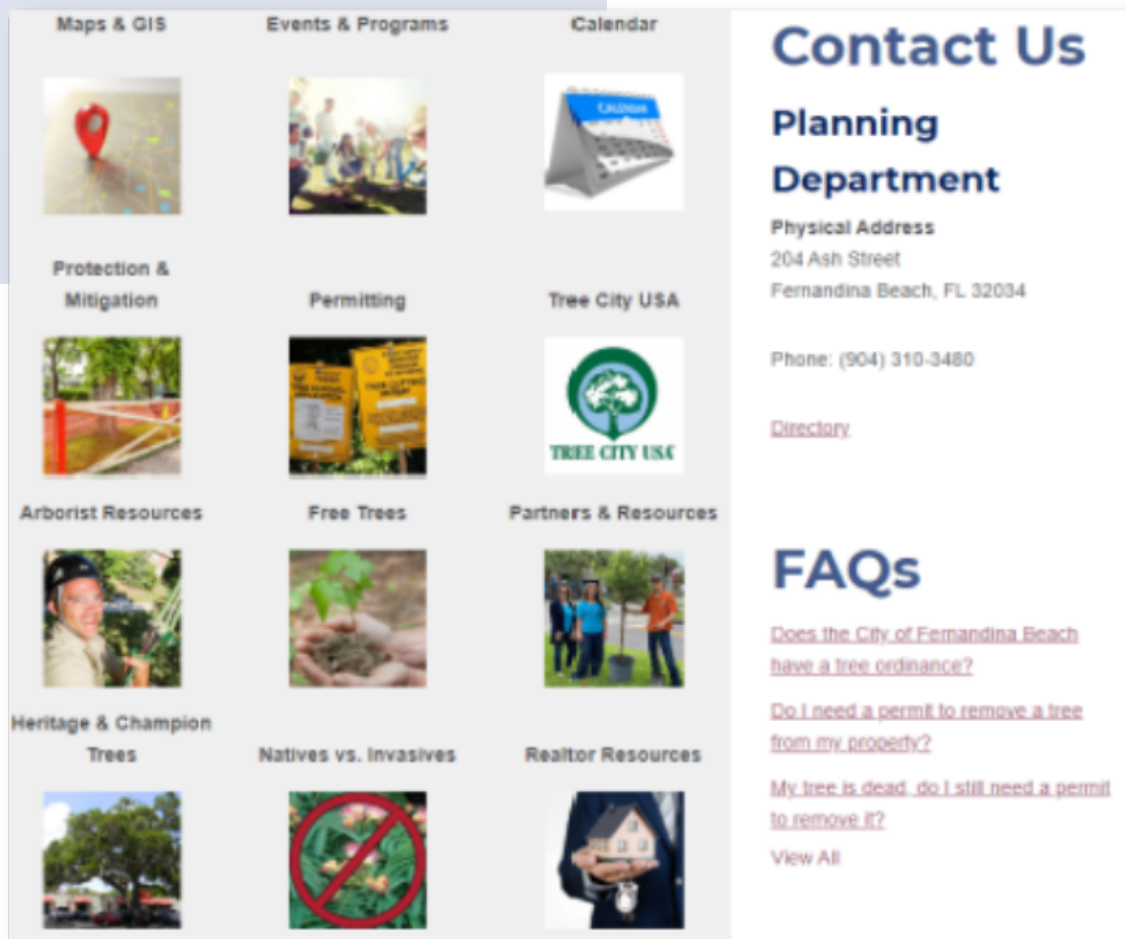
The City will increase the distribution of easy-to-read tree protection infographics and materials to real estate, design professionals, and advocacy groups

WEBSITE UPDATES

Public education and outreach are critical components needed to fuel our community's understanding and engagement in reaching our goal of increasing our tree canopy. Because the LDC provides an abundance of information, the material was divided into individual sections and their corresponding icons. In instances where topics overlap, such as permitting or tree protection and mitigation, a user can access related topics at the bottom of each page.

The creation of a user-friendly site where citizens and professionals alike could quickly and easily access all tree-related information is one of the ways we plan to reach the community.

In addition, the Committee endeavored to provide a visually appealing and interactive website that promotes tree education. The following is a brief synopsis of what each section contains.



WEBSITE ICONS

The following is a brief synopsis of what each section contains.

- Under Maps & GIS, citizens will find a collection of canopy coverage maps, tree inventory data, as well as a link bringing them directly to the newly created Tree Tracker App.
- The Events & Programs icon will provide access and information on all tree planting opportunities offered by the City.
- The Calendar icon will inform citizens of specific dates, times, and locations of all upcoming City sponsored tree plantings.
- Both Permitting and Tree Protection & Mitigation icons will provide critical information from the Land Development Code formatted into an easily readable quick reference guide.
- Tree City USA will provide the user with an overview of what this designation means and Fernandina Beach's history of achieving such a title.
- Under Arborist Resources, citizens will learn the difference between an arborist and an urban forester and locate an ISA Certified Arborist near them.
- The Free Trees icon will detail how residents can request a tree provided by the city, at no cost.
- Partners & Resources will include links to: the Nassau County Property Appraiser's website and various community partners.
- Heritage & Champion trees will be a place where citizens can go to learn what these two specific titles mean, explore the City's existing Heritage trees, learn how to nominate new Heritage trees, and more.
- The Natives vs Invasives icon will provide information and resources on both types of species as well as outlining how a resident can receive a free tree upon removal of an invasive species.
- Realtor Resources will be a tool for those who work with new and/or soon-to-be residents of the City. This page will be used to provide a snapshot of Fernandina Beach including its designation as a Tree City and general tree protection guidelines.

DESIGNATION OF SPACE FOR STAGING TREES AND SUPPLIES

To better support the goal of the City Commission and the recommendation of the City Tree Committee, an area is needed for the staging of trees. The area would require access to a water supply, fencing for security, and ease of access for delivery purposes. In addition, this location should provide adequate space for the storage of materials critical to the installation of trees such as: mulch, shovels, gator bags and hoses. Although funds have been allocated within the 2021-22 budget to cover any expenses tied into securing this type of area, interdepartmental discussions have already taken place for the possibility of utilizing existing gated/secured area owned by the City.



1

**Dedicated Space in
Maintenance Yard**
(Committee Recommended)



2

**Dedicated Space at lot
behind water tower**



3

**Dedicated space at other
City owned property
(Recreation Center, Airport
etc.)**

RECENT EVENTS & INITIATIVES FOR CANOPY COVERAGE INCREASE

Florida Arbor Day - January 15, 2021

In celebration of Florida's Arbor Day, on Friday, January 15, 2021, members of the City's Planning & Conservation staff, the Nassau County staff of the Florida Forest Service, the maintenance technician from the Fernandina Beach Housing Authority, and the Tree Surgeons held a small tree planting event on Hickory Street and S. 13th Street. The Florida Forest Service donated 10 shade trees and Liberty Landscape donated two large oak trees and a magnolia tree. A previous event was held at the same location on December 21, 2020, where 12 fruit trees were planted. (Appendix J)



Tree Giveaway with Keep Nassau Beautiful April 17, 2021

Residential Planting

On April 17, 2021, during the City of Fernandina Beach yearly recycling event and in partnership with Keep Nassau Beautiful, we were able to donate 250 trees of various species to over 100 local residents. (Appendix J)

Volunteers Grove Initiative by Amelia Tree Conservancy – Central Park April 2021

Atlantic Avenue / S. 13th Street

On April 22, 2021, The City of Fernandina Beach, in partnership with the Amelia Tree Conservancy, celebrated Earth Day by dedicating an area in Central Park called Volunteers Grove. This area was dedicated to honor Amelia Island's countless volunteers. During this event 5 native shade trees and 54 shrubs were planted. (Appendix J)



RECENT EVENTS & INITIATIVES FOR CANOPY COVERAGE INCREASE



Amelia Park Homeowner's Association Initiative, Common Areas – April 22, 2021

North Park Drive

On April 26, 2021, the Amelia Park Homeowner's Association planted 39 Live Oaks throughout the community's common areas. The trees were planted on Lake Park Drive, North Park Drive, Park Avenue, Park Lane, and School Street. (Appendix J)

National Arbor Day - April 30, 2021

North 3rd Street

In celebration of Arbor Day, on Friday, April 30, 2021, members of the City's Planning & Conservation staff held a small tree planting event on N. 3rd Street and planted 2 Live Oaks and 2 Weeping Yaupon Holly trees. Volunteers have stepped in to help with maintenance which includes watering the trees for the establishment period. (Appendix J)



FUTURE LARGE SCALE PLANTINGS

BEGINNING FALL 2021

Hickory Street Corridor

An estimated total of 150 trees will be planted in the rights-of-way along Hickory Street, between Parkview Place West and South 15th Street. (Appendix F)



Hickory & South 13th Street

As part of an ongoing initiative, the Department of Planning & Conservation proposes to plant additional shade trees at this location. (Appendix F)



Main Beach Parking Lot

At the June 24, 2021, TRC meeting, City Staff recommended removing all asphalt parking islands to be replaced with curbs and salt-tolerant landscaped beds including Cabbage Palm trees. This proposed project received unanimous agreement from members. (Appendix F)



FINANCING THE ACTION PLAN

Funds from the Tree Trust Fund are generated by income from building permit tree removal fees. For the 2020-21 fiscal year, the approved fee schedule shows that Tree Removal fees are \$500 for up to the first 3 trees and \$100 for each additional tree. Additionally, with regards to tree mitigation, the City provides a Fee In Lieu option at a cost of \$400 per tree.

While every year approximately half of its proceeds are kept in a reserve account, the remaining revenues are distributed into various expense accounts such as Salary related accounts, Program, Professional Services, and Operating Supplies accounts. In the upcoming fiscal year 2021-22, funds have also been allocated to the Equipment account for the purchase of an auger and spade which will allow relocations of selected trees.

The following table offers the current financial data as of July 2021. (Appendix K, L)

BUDGET 2020-2021

ACCOUNT	2021 BUDGET	EXPENSES TO DATE	FUNDS AVAILABLE
PROGRAM	\$50,648.00	\$30,221.54	\$20,427.46
SALARY	\$27,542.00	\$ 7,147.31	\$20,394.69
PROF SERV	\$53,500.00	\$350.00	\$53,150.00
OP SUPPLIES	\$11,500.00	\$ 6,957.89	\$ 4,542.11
TOTAL	\$143,191.00	\$44,676.74	\$98,514.26
2021 REVENUE	\$132,140.00		
2021 RESERVE	\$199,737.00		

ESTIMATED BUDGET 2021-2022*

ACCOUNT	2022 BUDGET
PROGRAM	\$132,200
SALARY	\$ 27,211
PROF SERV	\$ 53,500
OP SUPPLIES	\$ 63,750
EQUIPMENT (AUGER + SPADE)	\$ 15,000
TOTAL	\$291,661
2022 REVENUE	\$130,000
2022 RESERVE	\$123,435

* The projected 2021-22 fiscal year budget is in harmony with a restructured goal of a 5% canopy coverage increase in 15 years.



METHODS OF MEASURING PROGRESS

METHOD	FREQUENCY	PROS	CONS
AERIAL IMAGERY* ALSO ASSESS FOR NEIGHBORHOODS IN NEED	EVERY 2 YEARS	LARGE AREA OF COVERAGE, PARTNERSHIP WITH NASSAU COUNTY PROPERTY APPRAISER'S OFFICE. - EQUITABLE DISTRIBUTION OF CANOPY ACROSS CITY	ACCURACY IS DEPENDENT ON TIME OF YEAR AND PROPERLY IDENTIFYING SHADOWS - PLANTING REFUSALS**
CONTRACTED TREE INVENTORY	10 YEARS	HIGHLY ACCURATE	COSTLY, ONLY CAPTURES A SINGLE TIMEFRAME, MUST BE UPDATED WEEKLY TO ASSESS LANDSCAPE CHANGES
TREE REMOVAL PERMIT ASSESSMENT	TWICE A YEAR	IDENTIFY CANOPY LOSS EARLY ON	ARBORIST HAZARD ASSESSMENTS DO NOT REQUIRE PERMITS OR CITY NOTIFICATION
HANDHELD GPS FOR TARGETED TREE SURVEYING	AT EVERY FUTURE PLANTING	ACCURACY, LESS EXPENSIVE, IMMEDIATE RESULTS	LACKS A COMPREHENSIVE INVENTORY

*Aerial imagery and canopy analysis provided by Nassau County Property Appraiser's office

**Identify why citizens might refuse a street tree and work to address those concerns

FORMAL RECOMMENDATIONS

BASED ON ALL OPTIONS PRESENTED

Recommendation 1:

Maintain the 5% canopy coverage goal but extend the timeframe to a period of 15 years. This would allow the combined efforts of community outreach, increased initiatives, and code-based changes to be captured on a much larger scale and afford all new plantings the time necessary to approach maturity.

Recommendation 2.

With regards to the care and continual maintenance of future plantings, the CTC recognizes the importance of coordinated efforts between the Planning & Conservation, Maintenance, Parks & Recreation, and Utilities departments. Therefore, it is the recommendation of the CTC that an interdepartmental Tree Unit be created, and that focus be put on training any/all employees involved on how to properly plant, mulch, prune, and mow around newly planted trees.

Recommendation 3.

Designate a space in the Maintenance yard for staging trees and storage of materials necessary to the proper installation and establishment of newly planted trees.

Recommendation 4.

Direct the Department of Planning and Conservation to adopt all 11 code-based changes.

APPENDIX

Materials Referenced for analysis by CTC.

A. Fernandina Beach Tree Management Plan 2019-2024

B. City of Fernandina Beach Tree Canopy Analysis 2009-2019 (Carter)

C. What Does 5% Look Like

D. Tree Mortality Rates

E. Tree Removal Report 2014-2021 (Development & Hazards)

F. Future Planting Locations List

G. City Maps with Quadrants for Potential Plantings

H. Guidance for Planting Trees in Stormwater Management Ponds

I. Chart of Proposed LDC Amendments

J. Tree Planting Spreadsheet 2018-2021

K. Tree Fee Schedule 2020-2021

L. Budget Year Reports 2020-2021 YTD

2019-
2024

Fernandina Beach Tree Management Plan



City of Fernandina Beach

2019-2024

TABLE OF CONTENTS

KEY HIGHLIGHTS FROM YOUR ARBORIST	2
TREE INVENTORY SUMMARY (City-owned trees)	2
INTRODUCTION	3
TREE INVENTORY SUMMARY (City-owned trees)	3
Canopy Coverage Analysis (All trees within City Limits).....	3
TREE PLANTING.....	5
ACTION PLAN FOR 5% CANOPY INCREASE:.....	6
APPENDICIES.....	8
SOURCES	9

KEY HIGHLIGHTS FROM YOUR ARBORIST

TREE INVENTORY SUMMARY (City-owned trees)

In 2009 and 2017, a tree inventory was conducted on over 14,000 City-owned trees. It appears that a small number of forested areas/wetlands were skipped due to inventory costs exceeding the budgeted allocation. This inventory can be found on the Nassau County Property Appraiser's website: (www.nassauflpa.com). The 2009 Selvig inventory report and companion 2010 Master's thesis are available on the City's website: (www.fbfl.us).

CANOPY COVERAGE ANALYSIS (All trees within City Limits)

Did our canopy SHRINK or GROW based on all the assessments? Our current canopy coverage is likely around 39% as 2 reports show. However, there IS a significant difference between the estimates using 2008 and 2009 aerials. Should another historical analysis be done to satisfy our curiosity, or should we simply accept our current 39% and move on?

- **37% Canopy Coverage using 2008 aerials:** This assessment was conducted in 2009 as part of the *Selvig Tree Appraisal*. View pg. 37
- **39% Canopy Coverage using 2018 aerials:** This assessment was conducted by the Nassau County Property Appraiser's office throughout the entire county. By request, they isolated data for the City limits. Did our canopy GROW?
- **44% Canopy Coverage using 2009 aerials AND 39% using 2019 aerials:** Provided in 2020 by *Carter Environmental Services*.

Observation 1 - On the 2019/2009 assessments, comparing the large natural areas where no development occurred. We observed gaps in the interior in 2019, but not in 2009. Could differences be from image quality/shadowing, winter vs. summer, hurricane Matthew (2016), Irma (2017) ... or was there actual canopy loss? Your City Arborist expected to find MORE FOLIAGE in the interior due to normal growth and re-sprouting, even with the 2016-2017 hurricane seasons. The 2009 aerials appear to have over-predicted the canopy percentage across the board.

Observation 2 - All trees retained and planted in new developments will continue to grow and increase the canopy coverage. It is interesting to see this ingrowth already happening in older developments as the Carter report highlights so well! This data is outstanding, even with possible biases. It helps us reflect on past actions and informs our decisions for the future!

GOAL ANALYSIS

In 2019, the Commission set a goal to increase canopy by 5% by 2024. In 2020, the Commission implemented a significant revision to its tree protection ordinance by modifying mitigation ratios from 20/25% to 50% for all development. It is expected that the resulting changes will affect the number of fees paid for mitigation inches, thereby inspiring design choices that preserve more trees onsite.

Finding SPACES to plant requires buy-in from all departments with suitable areas. This remains the City's principal challenge when considering new plantings, especially on a large scale. The City needs to reconsider its planting philosophy for trees in public rights-of-way and modify the Greenway Management Plan to allow for tree plantings. Other ideas for planting can be found in the report.

INTRODUCTION

Forests generally develop over time through a complex interaction of climate, soils, and organisms; an ecosystem that is relatively stable and self-sustaining. Natural or man-made disturbances like wildfire, windstorms, timber harvesting, or planting might occur over large areas from time to time, but the natural process continues for the most part. In an urban environment, the natural landscape may be modified in a smaller area, but in a more drastic and permanent way. As infill occurs, the natural environment becomes fragmented and displaced by fill dirt, concrete, structures, and a hodge-podge of native and non-native vegetation. With long term planning and management, the urban forest can be better preserved, replaced, and shaped with intentionality to compliment society and the environment.

This management plan outlines the goals and methods the City will use to preserve and enhance our urban forest in a sustainable way while accommodating social and economic needs.

TREE INVENTORY SUMMARY (City-owned trees)

The first step in creating a tree plan is to assess the present condition. In 2009 and 2017, a tree inventory was conducted for Fernandina Beach, examining over 14,000 City-owned trees. A small number of forested areas and wetlands were omitted due to time and expense outweighing the usefulness of the data. The tree inventory can be found on the Nassau County Property Appraiser's GIS map (www.nassauflpa.com), utilizing the "Map Layers" tab, under "Planning and Growth Management". By analyzing the data, City staff can make better management decisions.

The 2009 Selvig Tree Inventory and Canopy Analysis report as well as the 2010 Latimer Master's thesis based on the above report are available on the City's website: (www.fbfl.us).

Inventory Results:

Approximately 65% of the trees were located along city streets with the remaining 35% in public spaces. Additionally, nearly 70% of the trees were reported to be in good condition. The data further revealed that 28% of our public trees are live oaks, 19% are sabal palms, and 12% are laurel oaks. The 2009 and 2010 reports recommended increasing diversity through future tree plantings. Even so, we want to use reliable tree species that can tolerate the harsh environmental conditions found in Fernandina Beach. *The Ecology of Maritime Forests of the Southern Atlantic Coast* is an excellent document on local tree species

Canopy Coverage Analysis (All trees within City Limits)

Of course, the City's tree inventory is limited to City-owned trees. To broaden the scope and knowledge of the entire tree canopy within the City limits, aerial photography can be utilized. Although this does not capture tree-specific data, it does provide a more comprehensive snapshot of the canopy to observe and influence changes over time.

Disclaimer: It is important to note that **image analysis results are simply ESTIMATES**. Aerial photos contain many inherent differences (image clarity, pixel color, shadowing, seasons/years, etc.) An estimated 37% Canopy Coverage using 2008 aerials.

This assessment was conducted in 2009 as part of the Selvig Tree Appraisal.

An estimated 39% Canopy Coverage using 2018 aerials.

This assessment was conducted by the Nassau County Property Appraiser's office throughout the entire county. By request, their staff isolated the data for the city limits of Fernandina Beach and verbally reported an estimate of 39% canopy coverage. Did the canopy GROW slightly?

An estimated 44% Canopy Coverage using 2009 AND

An estimated 39% Canopy Coverage using 2019 (See appendix documents).

Before learning about the county's 2018 assessment, City staff contracted with Carter Environmental Services in St. Augustine to conduct an analysis using the current City boundary using aerials from 2009 and 2019. Take into consideration that some properties within the current City limits were not under City ownership in 2009, however they were still included.

Based on the 2018 and 2019 aerials, our canopy coverage is currently around 39%. However, there IS a significant difference between the 2008 and 2009 results.

The assessment based on the 2008 aerials suggests the canopy GREW 2 percentage points (a 5.3% difference). $(3,137_{\text{now}} / 2,979_{\text{then}} \times 100) - 100 = 5.3\%$

The assessment based on the 2009 aerials suggests the canopy DECREASED by 5.3 percentage points (a 12.3% difference). $(3,137_{\text{now}} / 3,577_{\text{then}} \times 100) - 100 = 12.3\%$

	Acres	Percent
FB Total	8,051	100.0
Canopy 2008	2,979	37.0
Canopy 2019	3,137	39.0
Difference	158	2.0
% Difference	5.3	

	Acres	Percent
FB Total	8,051	100.0
Canopy 2009	3,577	44.4
Canopy 2019	3,137	39.0
Difference	-440	-5.5
% Difference	-12.3	

This discrepancy between the 2008 and 2009 aerials may be something we have to accept unless additional analysis work is conducted based on different aerials. However, we could simply accept the current 39% estimate and move on. To begin with, we will compare the large natural areas (where no development occurred) in the 2019/2009 aerials. In 2019 we see gaps in the interior that are largely absent in the 2009 assessment. Why? Could this be differences in image quality, seasons (winter vs. summer), storm damage from Hurricane Matthew (2016), and Irma (2017), or actual canopy loss? Your City arborist expected to find a DENSER canopy in undisturbed areas due to normal growth and re-sprouting, even with minimal storm damage. Could the 2009 aerials have OVER-predicted the canopy percentage in natural areas and throughout the entire city? Yes, perhaps. Can the annual growth rate of every tree (39% canopy coverage) in the city be able to replace some of the simultaneous developments? Yes, easily!

In addition, all the trees retained and planted in new developments will continue to grow and increase the canopy coverage. It is interesting to see this already occurring within older developments as the Carter report has highlights so excellently. Even if there are possible errors, we can use this data to reflect on past behaviors and consider better ways to supplement our canopy.

As part of the assessment, Cater Environmental Services will deliver a speech at the upcoming meeting of the City Committee as the schedule permits. Again, this report is available on our City website: (www.fbfl.us).

TREE VALUATION

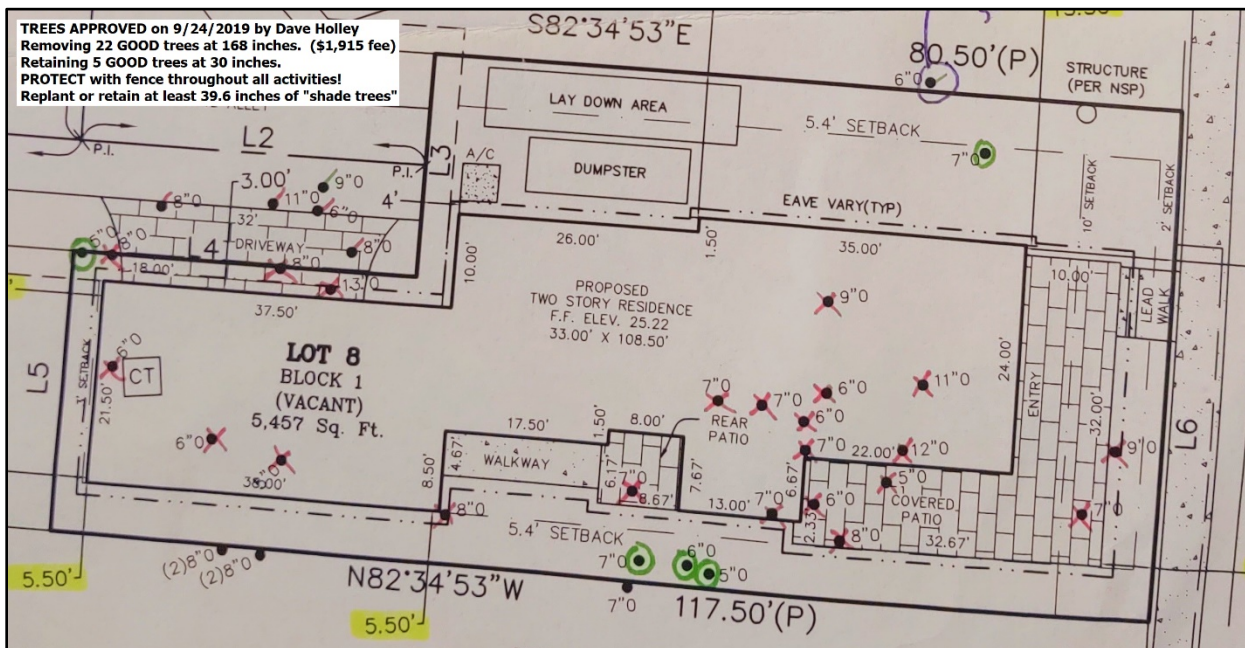
Trees provide a variety of services to people, wildlife, and the environment such as:

- Capturing stormwater (on the canopy, within fallen leaves, and from root absorption).
- Moderating the temperature (making things cooler in the summer and warmer in winter).
- Reducing wind speeds and improving air quality.
- Adding value to residences and businesses
- Maximizing local patronage and tourism for businesses and many more.

Selvig Tree Appraisal used i-Tree software in 2009 to quantify the value of the annual environmental and aesthetic benefits of the 7,000 trees contained in the inventory, and the value totaled \$56,637,455. Some years later, the 2017 inventory provided an additional 7,091 trees for a total estimated value of \$114,000,000.

TREE PLANTING

In 2019, the City Commission established a goal to increase the canopy coverage by 5% before the end of 2024. Also, in May of 2020, the City Commission revised the tree protection ordinance, making tree preservation requirements stricter for new developments. Previously, at least 20% of the inches approved for removal had to be mitigated (retained or replanted onsite) for residential properties and 25% for commercial lots. **The new standard is to mitigate 50%** of the inches slated for removal, but it will not be possible on many small lots.



To mitigate 20%, this plan shows 30 inches being retained. Replanting 9.6 inches is feasible. To mitigate 50%, this site would need to replant 69 inches or about 27 shade trees. Not advised!

This means the tree fund will inevitably collect substantially more mitigation dollars at \$400 per tree. In theory, if all tree funds can be converted into actual trees, this will preserve over 15% more canopy.

Finding SPACES to plant will require buy-in from all departments with suitable areas. However, at some point, the city will run out of amenable spaces for new trees.

ACTION PLAN FOR 5% CANOPY INCREASE:

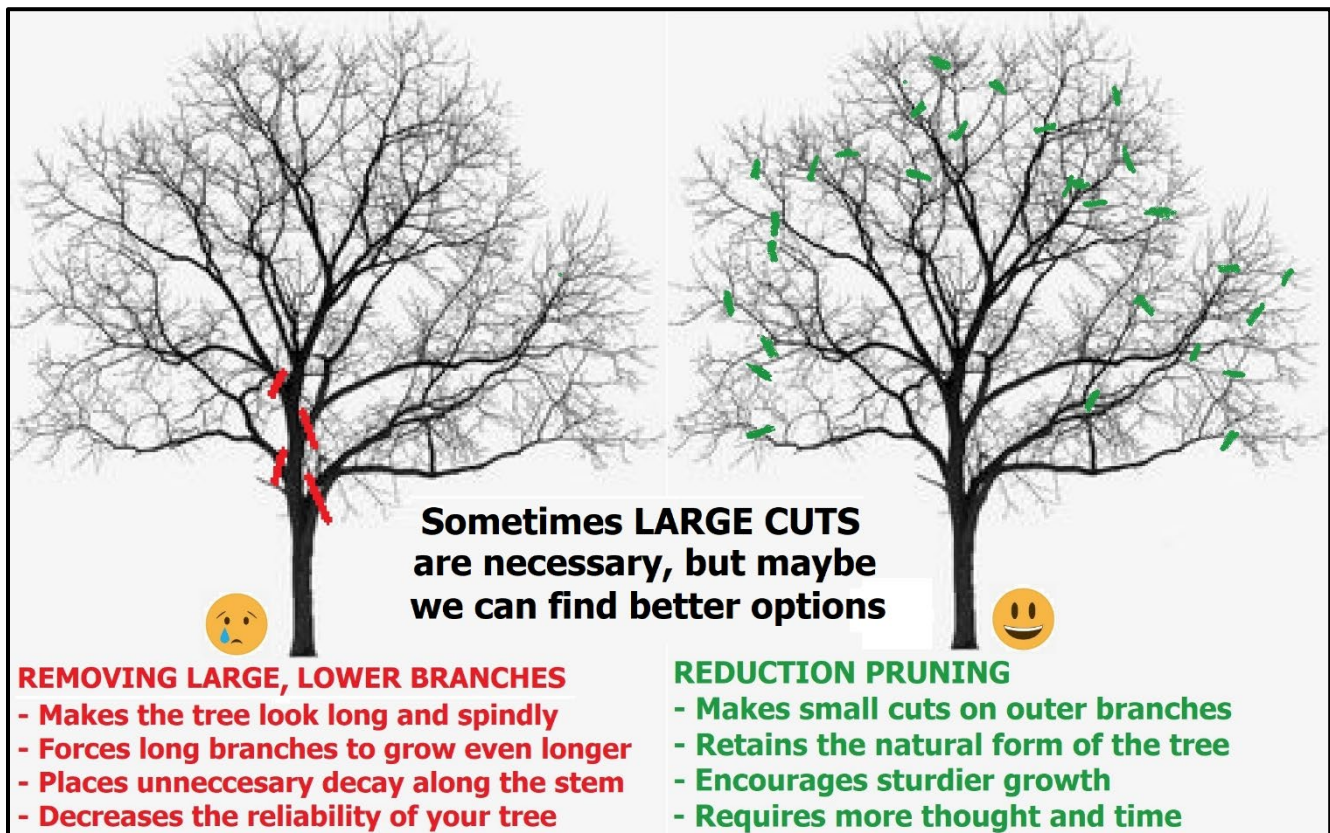
- Arbor Day Plantings – We celebrate FLORIDA Arbor Day in January and NATIONAL in April. In 2020, we celebrated by planting 32 trees at MLK Park and 1 tree at City Hall.
- Emma Love Planting – In February of 2020, we planted 20 trees with students and teachers at Emma Love Hardee. Schools can be excellent places to plant trees!
- Non-profit partnerships – Keep Nassau Beautiful planted 5 trees in City Parks in 2020, and the Junior Woman's Club planted 1 tree.
- Filling in street tree vacancies identified on the GIS tree inventory. Mapping new areas.
- Fernandina Loves Trees – We are encouraging each city resident to plant 1 tree at home.
- Trees for Permits Program – Every time a tree removal is approved, I ask people to let me know if they would be interested in obtaining a free tree if/when they become available. Many people do not respond, although a few have expressed interest.
- Natives for Invasive Replacement Program – Brazilian pepper, Chinese tallow, and Chinaberry are a few non-native plants. If residents agree to remove them, the City will provide replacement trees as an incentive. The first one is currently in the works.
- Adopt a Street Tree – Jacksonville has a program where people can request free trees in their right-of-way if City staff approves. The homeowner would handle the watering.
- Education and tree giveaway at schools – Besides planting trees at schools, we can give away bare root tree seedlings to students to take home and plant.
- Trick or Tree Halloween Giveaway – Bare root tree seedlings can be obtained cheaply. While kids collect candy on Centre Street, a small tree can be given away in a damp, sealed baggie. Even if some trees do not make it into the ground, others will.
- Trees in Parks (Central Park, Lighthouse, Egan's Creek Park, Atlantic Rec Center, Peck Center, MLK Center)– Parks are easy to plant since they are usually free of utilities. However, open spaces must be retained for events and regular use.
- Trees in Bosque Bello– Trees can also be planted on the edges in Bosque Bello cemetery and infilled as declining trees are removed. Understandably, many spaces will be unavailable for planting due to burial plots.
- Trees in Greenway – Similar to parks, the greenway is an easy place to plant, but not as easy to keep watered. Perhaps the best way to improve the canopy here would be to protect natural sprouts from mowing until they are large enough to be considered real trees.
- Trees in Golf Course – Similar to the greenway, the spaces between the greens grow naturally. Trees in maintained areas are mostly mature, and sometimes we lose a few. Although new plantings may not be as beneficial to residents, there's certainly ample space.
- Tree partnerships with Nassau County planting/maintenance or to encourage more tree planting in county rights-of-way and at boat ramps. County roadways often have large, barren road shoulders. If the city agreed to plant and establish trees on county property, a few biological deserts could be converted into an oasis. Potential planting areas may include Jasmine Street, Citrona Drive, Will Hardee Road, Susan Drive, Simmons Road, North and South 14th Street, Amelia Island Parkway, and Crane Island Drive.

RECENT TREE PLANTING EVENTS (68 trees in 2020 and 142 since 2018)

DATE	# Trees	Event Details
5/1/2018	3	Live oaks for Central Park for National Arbor Day
11/16/2018	4	Live oaks in ROW across from City Hall on Ash Street, placed by business
1/18/2019	25	Florida Arbor Day railroad buffer at S 3 rd and Elm (cedar & wax myrtle)
4/26/2019	4	National Arbor Day at Peck - 4 live oaks
8/2/2019	1	Class Reunion at Peck Center - 1 live oak
12/9/2019	6	Live oaks at Central Park, going above and beyond to offset new solar field
12/17/2019	1	Palm transplanted from Waterfront to Central Park
12/18/2019	1	Keep Nassau Beautiful - 1 live oak at Central Park
1/17/2020	32	Florida Arbor Day - 32 trees at MLK Park
2/21/2020	20	Emma Love tree planting with students (oak, poplar, magnolia, redbud)
2/21/2020	3	Citizen allowed 3 pine seedlings to be planted on private property
4/24/2020	1	Junior Women's Club - 1 Bottlebrush in 2 nd Street ROW across from City Hall
4/30/2020	2	Keep Nassau Beautiful - 2 magnolias at park beside City Hall Park
4/30/2020	2	Keep Nassau Beautiful - 2 live oaks at Egans Park

TREE MAINTENANCE

Routine tree maintenance is conducted on City trees for safety, clearance, and long-term reliability. Removing dead wood, reducing/removing certain branches, or total tree removal will be considered on a case by case basis. The City Arborist is available to assist any department with tree care.



APPENDICIES

Available on City Website at www.fbfl.us/trees

Diversity of Tree Canopy (Aggregated 2009 and 2017 Inventories)

2009, 2019 Canopy Coverage analysis

Relative Age Distribution of Tree Species

Public Trees Condition assessment

2009 Tree Management Plan

2018 Tree Inventory Update

i-tree reports (current condition of canopy) and value

Latimer, Fremont, Urban Forest Planning: A revised process using technology and concept development to develop structure and function, March 2010

SOURCES

Edwards, A. R. (2005). *The Sustainability Revolution*. Gabriola Island: New Society Publishers.

Geiger, J., & King, D. H. (2004). *The Large Tree Argument: The Case for Large Stature Trees vs. Small Stature Trees*. Retrieved October 3, 2009, from Center for Urban Forest Research:
http://www.fs.fed.us/psw/programs/cufr/research/studies_detail.php?ProjID=136

Harris, W., & Dines, N. T. (1998). *Time Saver Standards for Landscape Architects*. New York: McGraw Hill Publishing Company.

Lyle, J. T. (1985). *Design for Human Ecosystems*. New York: Van Nostrand Reinhold.

Matheny, N. P., & Clark, J. R. (1993). *Evaluation of Hazard Trees in Urban Areas*. Champaign: International Society of Arboriculture.

Matheny, N. P., & Clark, J. R. (2008). *Municipal Specialist Certification Study Guide*. Champaign: International Society of Arboriculture.

Nelson, G. (2003). *Florida's Best Native Landscape Plants*. Gainesville: University Press of Florida.
Recommended On-Line Resources:

International Society of Arboriculture: The professional accrediting agency for arboriculture. The site contains general information, links to research and construction details
website: www.isa-arbor.com

Center for Urban Forest Research: A branch of the U.S. Forest service. They conduct a wide variety of research on the performance of trees.
website: <http://www.fs.fed.us/psw/programs/cufr/>

University of Florida: Landscape Plants: Contains a wide variety of resources regarding plant care, selection, design, maintenance standards, storm management and species profiles.
website: <http://hort.ifas.ufl.edu/woody/>

Monrovia Nurseries: An excellent resource for selecting plant material
website: <http://www.monrovia.com/>

i-tree: A database program that helps analyze tree inventories for both value and composition
website: www.itreetools.org



42 Masters Drive
St. Augustine, FL 32084
Tel: 904.540.1786
www.carterenv.com

City of Fernandina Beach Tree Canopy Analysis 2009 – 2019

Introduction

As the City of Fernandina Beach has grown, maintaining sustainable urban forests has become a priority. In 2009, the City contracted a Tree Management Plan to assess the cultural, economic and environmental aspects of its urban forests. Canopy cover within the City was assessed as part of this plan. This was done by manipulating aerial imagery in Adobe Photoshop to isolate tree features. The report found total tree canopy coverage to be 37%. It was recommended when future aerals became available canopy cover estimation could be done to track changes over time.

This analysis continues the work of the 2009 assessment, using Geographic Information Systems (GIS) and statistical algorithms to estimate tree canopy coverage from 2009 to 2019. A GIS-based feature extraction model was created to assess canopy change from 2009 – 2019. Essentially an exercise in computer image recognition, the model classified features by their unique spectral signatures within aerial imagery. True color aerial imagery consists of three bands - red, green and blue (RGB), each color band containing a value between 0 and 255. Examples of unique features such as water, pavement, trees, etc. were manually delineated and inputted into a model creating unique definitions for each classification. A classification algorithm then correlates aerial imagery with the sample definitions to extract specific features. The model estimated a total of 3,577 acres of canopy coverage in 2009 and 3,137 acres in 2019 – a 12% loss. The text below describes the technical methodology, results and discusses the intricacies and limitations of this analysis.

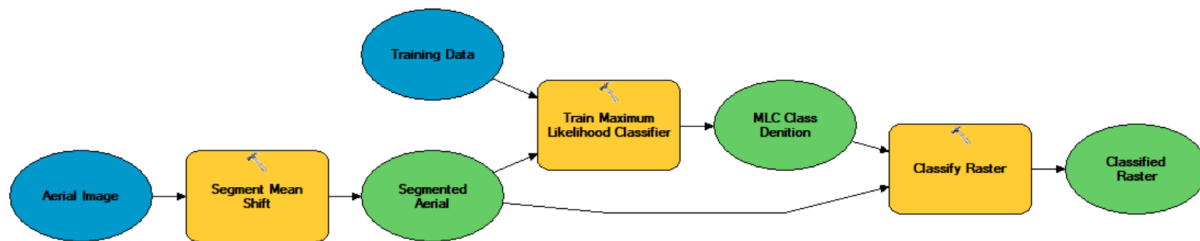
Methodology

Segmentation and classification tools within ESRI's ArcGIS were used to extract features, grouping those with similar spectral signatures into defined classes. Below describes each step of the model:

- **Segmentation of Aerial Imagery:** Segmentation provides a simplified version of the original aerial. It generalizes and groups similar spectral signatures causing less noise in the overall analysis. Image

segmentation was performed via the Segment Mean Shift tool. This method uses a moving window that iteratively calculates the average pixel value to determine which pixels should be included in each group. The result is a grouping of image pixels characterized by an average color value.

- **Training Sample Data:** Sample data tells the model what a specific class should look like. These samples were manually delineated across the study area identifying tree canopy, built areas, open water, fields, bare earth and estuarine. Sample values should be normally distributed, and an ample number of features are needed to produce statistically significant results. The sample data was then inputted into a training algorithm – in this case, a Maximum Likelihood Classifier (MLC). Values of pixels within each class were statistically correlated via the training process and a definition was created as the tool output.
- **Classification:** The Classify Raster tool then performed an image classification on the segmented aerial image using the created MLC classifier definition file.



Workflow of the Tree Canopy Analysis Model

- **Manual QA/QC:** The final step was to manually review the model results and clean up any significant erroneously classified areas.

Results

The model estimated 3,577 acres of canopy coverage in 2009 and 3,137 acres in 2019 – a 12% loss. Based upon the 8,051-acre Fernandina Beach City Limits, tree canopy constituted 44% of the study area in 2009, and 39% in 2019. Percentage canopy cover was calculated in reference to the 8,051-acre study area. Graphic results can be seen on the maps supplied with this report, Figure 1: 2009 Model Results, Figure 2: 2019 Model Results and Figure 3: Tree Canopy Change Analysis.

Discussion

Creation of this sort of image classification model is part art and part science. Many different training algorithm types were explored to find the best results. Within each of the methodologies tried, a number of

different input parameter scenarios were tested. Through this process the “Maximum Likelihood Classifier” algorithm was ultimately chosen.

Model results are only an estimation and should not be treated as an absolute measurement of canopy coverage. It is a reasonable estimation but also a useful tool for analyzing trends. None of these models are perfect and often identify other objects resembling tree canopy, such as marsh, shrubs, shadows, or certain color cars or roofs. Inconsistencies in aerial imagery such as exposure, time of day and season can also make a big difference. Separately delineating deciduous areas ended up making a huge improvement in results. Shadows, especially over grass or other green-colored surfaces often mimicked the spectral signatures of tree canopy.

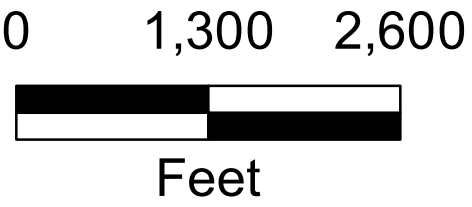
Discerning the difference between shrubs and trees can also be difficult. Additional helpful data to discern differences between shrubs and trees could be via elevation models. Corrected (ground surface) and uncorrected (raw data) LiDAR elevation data can be used to determine the height of objects above ground, for example trees or buildings. The intersection of the already identified color signatures combined with this elevation data could be useful to further fine-tune model results.

Figures 1 and 2 depict manually reviewed and edited model results. In addition, a change analysis was done for Figure 3, which shows areas of significant canopy reduction. The raw output was edited to isolate these areas of larger canopy loss. Outside of these larger areas someone would see a confusing speckled landscape of loss and gain fragments. These were edited out as it looks like noise. Minor variations in the source aerials causes a lot of tiny fragments when comparing differences in years. Results could represent minor tree growth and loss here and there, but could also cause to confuse, showing false artifacts of minor fragmented differences in the 2009 vs. 2019 aerials.

Image recognition technology has infiltrated many disciplines from technology to the natural world. As imagery becomes higher resolution and additional remote sensing data such as detailed elevation becomes available, the accuracy will only improve, providing an increasingly useful tool for urban forest management and beyond.

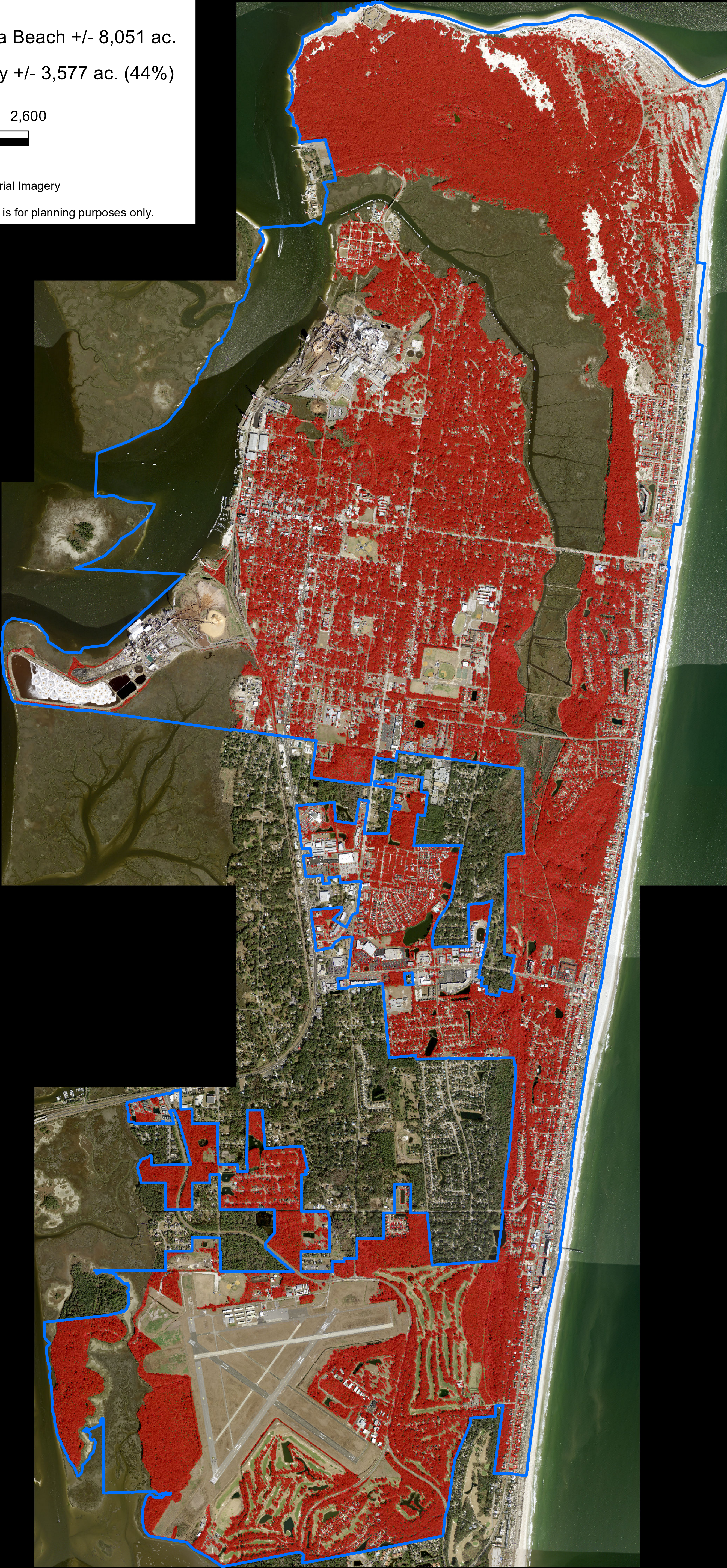
Legend

- City of Fernandina Beach +/- 8,051 ac.
- 2009 Tree Canopy +/- 3,577 ac. (44%)



Sources: 2009 Aerial Imagery

Information represented on this map is for planning purposes only.



CARTER ENVIRONMENTAL SERVICES, INC.



42 Masters Drive
St. Augustine, FL 32084
904-540-1786

www.carterenv.com

2009 Tree Canopy Model Results
Tree Canopy Assessment
City of Fernandina Beach, Florida

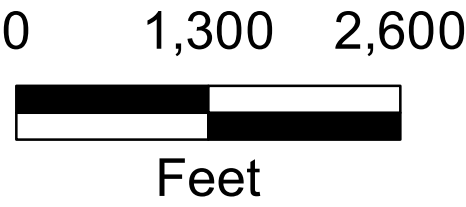
Project: 5.19382

Date: Apr 14 2020

Figure: 1

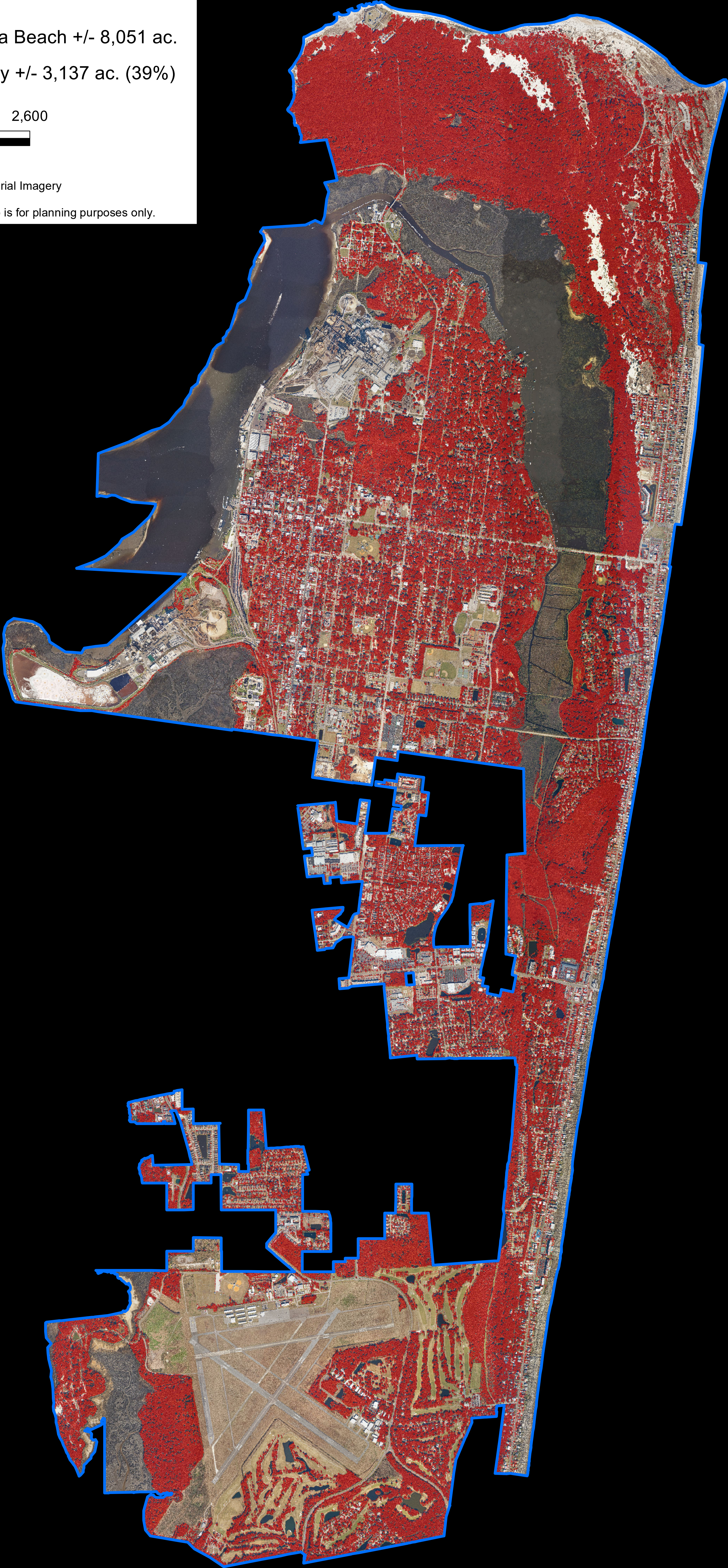
Legend

- City of Fernandina Beach +/- 8,051 ac.
- 2019 Tree Canopy +/- 3,137 ac. (39%)



Sources: 2019 Aerial Imagery

Information represented on this map is for planning purposes only.



CARTER ENVIRONMENTAL
SERVICES, INC.



42 Masters Drive
St. Augustine, FL 32084
904-540-1786

www.carterenv.com

2019 Tree Canopy Model Results

Tree Canopy Assessment

City of Fernandina Beach, Florida

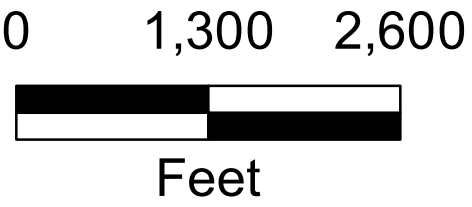
Project: 5.19382

Date: Apr 14 2020

Figure: 2

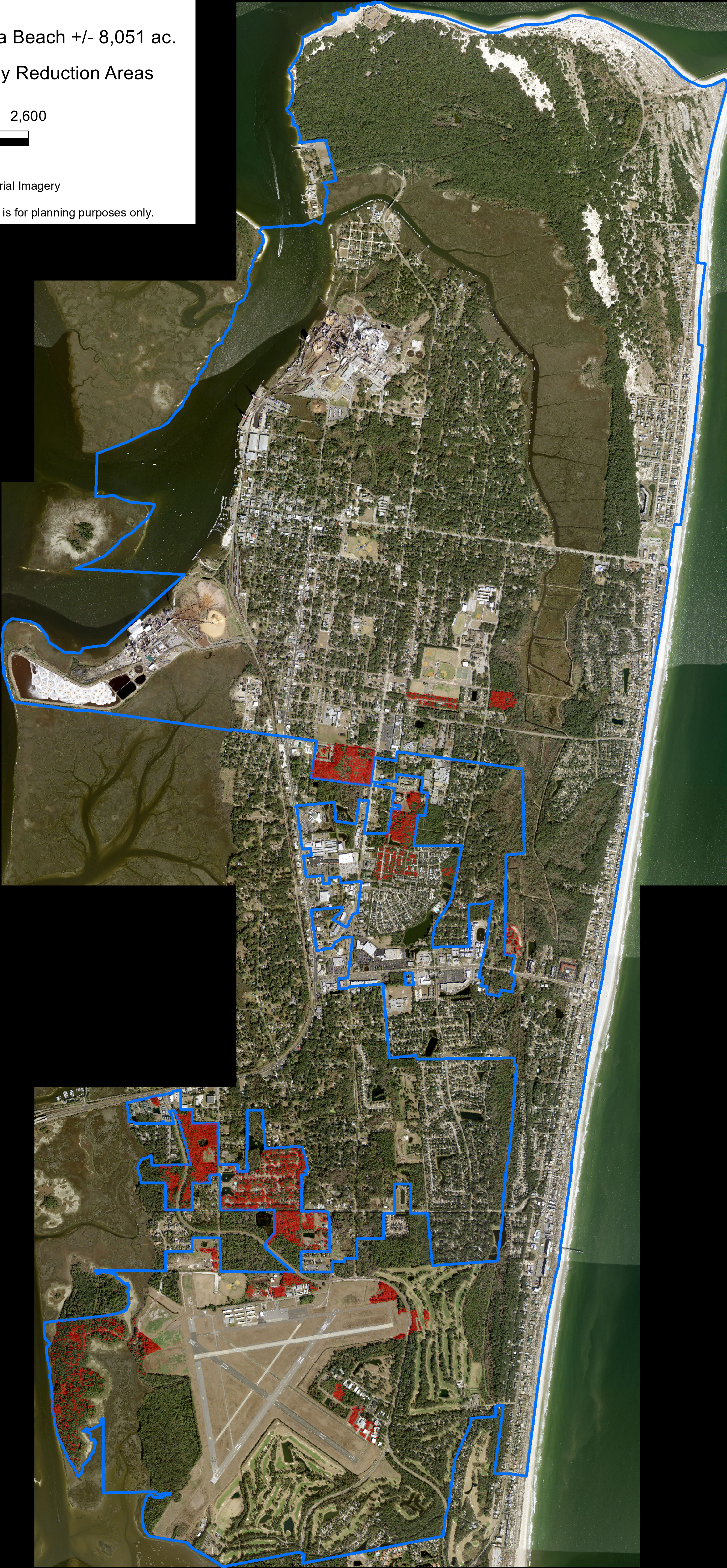
Legend

- City of Fernandina Beach +/- 8,051 ac.
- Significant Canopy Reduction Areas



Sources: 2019 Aerial Imagery

Information represented on this map is for planning purposes only.



CARTER ENVIRONMENTAL
SERVICES, INC.



42 Masters Drive
St. Augustine, FL 32084
904-540-1786

www.carterenv.com

Tree Canopy Significant Reductions 2009 - 2019

Tree Canopy Assessment

City of Fernandina Beach, Florida

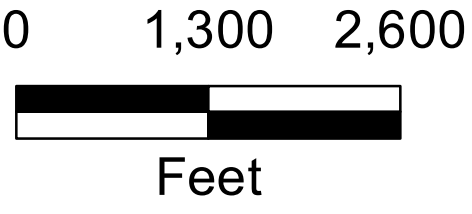
Project: 5.19382

Date: Apr 14 2020

Figure: 3

Legend

- City of Fernandina Beach +/- 8,051 ac.
- Canopy Removed
- Canopy Added



Sources: 2019 Aerial Imagery

Information represented on this map is for planning purposes only.



CARTER ENVIRONMENTAL
SERVICES, INC.



42 Masters Drive
St. Augustine, FL 32084
904-540-1786

www.carterenv.com

Canopy Change Analysis 2009 - 2019
Tree Canopy Assessment
City of Fernandina Beach, Florida

Project: 5.19382

Date: Apr 14 2020

Figure: 4

What Does 5% Look Like?

- City of Fernandina Beach = 8,051 Acres
- 39% Canopy coverage in 2019 = 3,140 Acres
- 3,140 acres of current coverage increased by 5% = 157 acres of canopy coverage.
- 1 acre = 43,560 sq ft
- Avg mature tree canopy spread of the 4 identified trees = 41' diameter (using the lowest estimation)
- Total sq ft coverage of each tree: $A=3.14r^2$
- $3.14 \times 20.5^2 = 1320$ sq ft per tree = 33 trees per acre = 5,181 trees for 157 acres
- Average tree mortality rate 0-5 years after planting: 6.6-7% (7% = 363 trees = 11 acres) (does not account for hurricanes – too unpredictable)

Common Native FL Trees

Southern Magnolia Age of Maturity: 50 years Height @ maturity: 60-80' Spread @ maturity: 30-40' Growth rate per year: 12-24" Distance from other trees when planted: 15-20' Sources: maggraa.pdf (ufl.edu) & Magnolia grandiflora L (usda.gov) (age of maturity)	Live Oak Age of Maturity: 70 years Height @ maturity: 60-80' Spread @ maturity: 60-120' Growth rate per year: 13-24" Distance from other trees when planted: 40' Sources: quevira.pdf (ufl.edu) & Southern Live Oak National Wildlife Federation (nwf.org) (age of maturity)
Red Maple Age of Maturity: 70-80 years Height @ maturity: 60-75' Spread @ maturity: 25-35' Growth rate per year: 13-24+" Distance from other trees when planted: 20-30' Source: aceruba.pdf (ufl.edu) & Acer rubrum L (usda.gov) (age of maturity)	American Elm Age of Maturity: 15-40 years Height @ maturity: 70-90' Spread @ maturity: 50-70' Growth rate per year: 24" + Distance from other trees when planted: 15' Sources: ulmamea.pdf (ufl.edu) & Ulmus americana L (usda.gov) (age of maturity)



Urban Tree Mortality: A Literature Review

**By Deborah R. Hilbert, Lara A. Roman, Andrew K. Koeser,
Jess Vogt, and Natalie S. van Doorn**

Abstract. Tree survival is a performance metric for urban forestry initiatives, and an understanding of the factors that influence mortality can help managers target resources and enhance survival. Furthermore, urban tree planting investments depend on tree survival to maximize ecosystem services. In this literature review, we categorized factors commonly associated with urban tree mortality and summarized mortality rates published in 56 studies, focusing on studies of trees along streets, in yards, and in landscaped parks. Study designs included quantitative field monitoring of uneven-aged tree populations and tracking planting cohorts of even-aged trees, as well as qualitative analyses. Annual mortality rates ranged from 0.6 to 68.5% for cohort studies and 0 to 30% for repeated inventories of uneven-aged trees. The 1st, 2nd, and 3rd quartiles of annual mortality were 2.8 to 3.8%, 4.4 to 6.5%, and 7.1 to 9.3% for planting cohorts, and 1.6%, 2.3 to 2.6%, and 3.0 to 3.3% for repeated inventories of uneven-aged trees (ranges reflect studies that reported a range for the time period or mortality rate). For cohort studies, annual mortality tended to be highest during the first five years after planting. The most commonly cited biophysical factors associated with mortality were taxa (15 articles), tree size/age (13 articles), and site characteristics (12 articles). The most commonly cited human-related factors were stewardship, maintenance, and vandalism (15 articles). More long-term studies are needed to investigate how site characteristics influence mortality, including rarely examined soil and microclimate characteristics. Future research should also examine institutional structures related to mortality outcomes, as well as parcel-level sociodemographic factors and resident behaviors.

Key Words. Ecological Monitoring; Street Tree; Tree Death; Tree Demography; Tree Population; Tree Survival; Urban Park; Yard Tree.

INTRODUCTION

In urban forestry, substantial resources are invested in the planting and maintenance of trees. For instance, 81% of municipalities in the United States allocate public dollars to tree planting and care, which amounts to an estimated \$37.50 annually per public tree (street trees, park trees, and trees in other public places; Hauer and Peterson 2016). In total, 45% of municipal tree budgets are spent on planting and care-related activities, and another 23% is spent on removal (Hauer and Peterson 2016). These efforts aim to enhance the functional lifespan of trees, maximizing the many environmental, economic, and societal benefits provided by urban woody vegetation (Pataki et al. 2011; Roy et al. 2012). The success of these planting and maintenance efforts can be measured by tree survival (Roman et al. 2013; Roman et al. 2016), as survival is essential to achieve the intended ecosystem services associated with tree maturity (Ko et al. 2015b; Widney et al. 2016). Continuing research on factors that increase or decrease survival provides insights into the basic demographic processes of urban forest

population dynamics. Indeed, the population dynamics and growing conditions of planted trees in landscaped and heavily built-up urban areas are quite dissimilar from trees in natural forests (i.e., trees in rural, wildland settings) (Urban 2008; Roman et al. 2016). Translating urban tree mortality research into practice can ultimately strengthen management of individual trees and planting projects as well as the urban forest system as a whole.

Research on tree mortality from natural forests suggests that trees often die as a result of many different additive and interacting factors. As trees age, the impact of chronic and acute stressors accumulates, which ultimately leads to tree death (Franklin et al. 1987). This interpretation of the mortality process, supported by patterns in long-term growth (Das et al. 2007), was described by Manion (1981) as the “disease decline spiral” and later modified by Franklin et al. (1987) as the “mortality spiral.” In Manion’s (1981) classic book, “urban environment” was listed as a predisposing factor, yet the “urban environment” encompasses a wide range of biophysical and

socioeconomic conditions and causal mechanisms. Furthermore, in the urban context, the word “mortality” connotes both death and pre-death removal of trees (Roman et al. 2016); whereas removal is not part of natural (and unlogged) forest systems. In other words, purposeful removals by humans can be a key element of urban tree mortality. Indeed, for many urban tree mortality field monitoring studies, mortality has been defined as a combination of trees observed standing dead plus those observed removed (e.g., Nowak et al. 2004; Lima et al. 2013; Roman et al. 2014a; Ko et al. 2015a; Escobedo et al. 2016; Boukili et al. 2017). Moreover, the site conditions found in urban areas can often be more challenging than those found in natural forest areas, such as compacted soils and low nutrient availability (Urban 2008; Scharenbroch et al. 2017). At the same time, urban trees in maintained and landscaped areas (i.e., not urban trees in closed-canopy wooded park settings or afforested areas) can be given advantages, such as reduced competition for light, as well as supplemental irrigation and fertilizer. Indeed, such tree maintenance is fundamental to arboricultural best practices (Ferrini et al. 2017). Considering the many stresses and advantages for trees growing in the “urban environment” of Manion’s (1981) book, a comprehensive literature review of the factors affecting urban tree mortality is warranted to re-conceptualize the mortality process in the urban context.

Given the complicated nature of the social-ecological systems in which urban trees exist (Pickett et al. 1997; Mincey et al. 2013; Vogt et al. 2015a), factors influencing mortality can be described as being human-related, biophysical, or a combination of the two. Biophysical predictive factors of urban tree mortality include species or other taxonomic groups, functional groups (e.g., hardwoods vs. softwoods), drought tolerance, tree size, and time since planting (e.g., Nowak et al. 2004; Koeser et al. 2014; Roman et al. 2014a; Roman et al. 2014b). Human-related factors include land use, construction and development, and stewardship or maintenance activities (e.g., Hauer 1994; Nowak et al. 2004; Boyce 2010; Lawrence et al. 2012; Koeser et al. 2014; Roman et al. 2014b). Human-related and biophysical factors can be deeply coupled. For instance, species and site selection choices by tree professionals and residents relate to later susceptibility to drought, but irrigation may enable trees to survive in regions with varying precipitation patterns (Roman

et al. 2014b; Koeser et al. 2014; Mincey and Vogt 2014; Vogt et al. 2015a; Martin et al. 2016).

Urban tree mortality can also be classified by life stages, such as establishment-related losses (Richards 1979). The establishment period—the first few years after tree planting (Sherman et al. 2016; Levinson et al. 2017; Harris and Day 2017; Leers et al. 2018)—is generally viewed as the life stage with the highest mortality for urban trees and has thus been the focus of many mortality studies (e.g., Nowak et al. 1990; Struve et al. 1995; Koeser et al. 2014; Roman et al. 2014b; Roman et al. 2015; Widney et al. 2016). The establishment stage for planted urban trees parallels with classic concepts in forest ecology, where younger and smaller trees have the highest mortality (Franklin et al. 1987; Lines et al. 2010). Trees in natural forests generally have a U-shaped or Type III mortality curve (e.g., Coomes and Allen 2007; Lorimer et al. 2001; Metcalf et al. 2009; Lines et al. 2010). The U-shaped mortality curve has high mortality rates for small trees, low for mid-sized and mature trees, and rising mortality rates for very large trees, whereas the Type III curve similarly has high mortality rates for small trees, and low mortality rates for all other sizes (Harcombe 1987). For either mortality curve shape, forest ecology studies generally report annual mortality rates of 1 to 3%, or even less, for mature overstory or canopy trees (e.g., Harcombe and Marks 1983; Condit et al. 1995; Lorimer et al. 2001). Following in this reasoning, Lugo and Scatena (1996) grouped causal factors for mortality in natural forests in the tropics based on intensity levels, with background annual tree mortality less than 5% and catastrophic greater than 5%. In the urban context, catastrophic factors include disease outbreaks (Poland and McCullough 2006), major storms (Staudhammer et al. 2011), and even war (Laçan and McBride 2009; Stilgenbauer and McBride 2010). Background causes are more gradual and could include a tree’s slow decline due to construction-related stress or other adverse site conditions (Koeser et al. 2013). Yet it is possible that the background rate of mortality is higher in urban environments compared to natural forests. For instance, a previous meta-analysis of street tree survival found typical annual mortality to be 3.5 to 5.1% (Roman and Scatena 2011), while Nowak et al. (2004) observed 6.6% annual mortality across all land uses in Baltimore, MD (including both planted trees in landscaped areas and naturally regenerating trees in natural

areas). Evaluating what rates of mortality are fairly typical for urban trees, and what rates are catastrophic, can help managers interpret program performance and researchers design realistic projection models (Roman 2014; Roman et al. 2016).

Tree mortality is also a fundamental component of managing urban forest population cycles: planting, growth, pruning, removal, and replacement. In heavily managed portions of the urban forest, such as street-scapes, yards, and landscaped parks, human interventions drive tree population cycles (Roman et al. 2016; Roman et al. 2018). Several models have incorporated mortality rates into projections to assist urban forest managers with decision-making about planting and removal actions. For instance, Miller and Marano (1984) and Bartsch et al. (1985) used tree inventory data combined with user-defined planting, growth, mortality, and removal rates to present street tree population simulations. These models were designed to help meet management objectives related to costs and desired benefits, but they are part of software programs no longer available to managers. More recently, researchers have proposed several projection models to assist with planning for tree removals, replacements, and pesticide treatment regimens due to *Agrilus planipennis* (emerald ash borer, EAB), which threatens widely planted *Fraxinus* spp. (Hauer 2012; VanNatta et al. 2012; Sadof et al. 2017). Another projection example is the i-Tree Forecast model (currently part of i-Tree Eco), which uses urban forest inventory data, default or user adjusted mortality rates, and species/location specific growth models to estimate forest structure and ecosystem services produced under alternative planting scenarios (Nowak et al. 2013). Similarly, projected ecosystem services for million tree planting campaigns in New York City, NY and Los Angeles, CA have assumed mortality scenarios (Morani et al. 2011; McPherson et al. 2008). Each of these projections is essentially a demographic population model: a simulation of population size and structure over time due to adding and subtracting individuals (Roman et al. 2016). Yet as Morani et al. (2011) pointed out in their projection model for tree planting in New York City, “the main limit for the population projector” was the lack of empirical mortality rate information. Furthermore, past research has shown that assumed survival rates in ecosystem services models can be higher than actual rates (Roman et al. 2014b; McPherson 2014; Ko et al. 2015a; Ko et al.

2015b). The potential value of urban forest population projection models is their capacity to reasonably predict urban forest changes (and associated benefits) under varying scenarios. Urban forest population models can enable managers to weigh the trade-offs regarding when, where, and how much to plant, and illustrate how maintenance and removal decisions relate to decadal-scale population cycles.

Urban foresters, ecologists, and arborists need accurate mortality information from empirical field data to understand the process of urban tree death, improve best management practices, and enhance projection models. Particularly in the context of maximizing return-on-investments of public dollars, survival rates are an important yet missing piece of cost-benefit considerations for municipalities (McPherson and Simpson 2002; McPherson and Kendall 2014; Ko et al. 2015b; Widney et al. 2016). Knowing the survival rates for public and private trees planted by municipalities, nonprofits, homeowners, and other parties is crucial to not only justifying expenditures on tree planting, but also to estimating the benefits these trees will provide to city residents into the future (Widney et al. 2016). In this review, we gathered existing literature on urban tree mortality to: (1) summarize reported mortality and survival rates to determine what levels of mortality could be considered typical in urban forests; and (2) identify and categorize biophysical and human factors associated with urban tree mortality.

METHODS

Literature Search

We conducted a literature search to find studies reporting urban tree mortality field data. We carried out systematic keyword and article title searches of urban forestry, urban ecology, and arboriculture journals using Web of Science, ScienceDirect, JSTOR, Google Scholar, the US Forest Service’s TreeSearch, and the Urban Forestry database at the University of Minnesota library. We searched for prospective articles in non-English languages by searching in Google Scholar, where non-English publications are better represented (Jascó 2005), as well as using the “all languages” options in the search engines listed above. In addition to the keyword searches, we conducted an exhaustive search (i.e., we scanned the titles and abstracts of all publications) of all volumes of *Journal of Arboriculture/Arboriculture & Urban Forestry*

(1976 to present; the publication of the International Society of Arboriculture was re-named to the latter in 2006), *Arboricultural Journal* (1965 to present), *Cities and the Environment* (2008 to present), and *Urban Forestry & Urban Greening* (2002 to present), since these are the journals most likely to have studies of interest. The date range for searching was “all time” for keyword searches, or the earliest publications for the comprehensive journal searches. This included material available online through December 2017.

We carried out keyword and title searches using the following terms: tree mortality, tree survival, tree survivability, tree survivorship, tree death, tree removal, tree population projection, tree population model, tree establishment, and tree failure. These terms were joined by the search term “AND” with the words urban, city, street, and yard. After identifying initial articles, more potential articles were found using “backward chaining” (searching the literature cited in the starting manuscript, then moving backward through a chain of references) and “forward chaining” (finding articles which cite the starting manuscript, following the chain of references forward). Both “chaining” techniques can be successful for comprehensive literature searches (Booth 2008). Forward chaining was conducted using Google Scholar, as this search engine searches a broad range of literature and is more likely to locate “gray literature” such as theses, extension articles, and conference proceedings (Haddaway 2015). The inclusion of “gray literature” was evaluated by researchers on a case-by-case basis. Theses which were later published in journals were excluded.

Studies were considered eligible for inclusion in our literature review if they: (1) examined tree mortality in landscaped or heavily built-up urban areas, such as trees in sidewalks, parking lots, yards, and manicured parks; and (2) were observational studies in real-world urban conditions. We excluded arboricultural planting experiments, such as tests of cultivar performance (e.g., Gerhold 2007), studies that focused completely on remnant or afforested forest fragments (e.g., Dislich and Pivello 2002), and studies which stated mortality assumptions in projection models (e.g., McPherson 2008). We included some plot-based studies that examined tree mortality across an entire city, and therefore included wooded park lands, but we focused our discussion on the other land uses.

Examining Mortality Information

We targeted urban forestry studies that presented data on mortality or survival rates and the influential factors associated with mortality. These factors could have been examined either quantitatively or qualitatively. Field-based monitoring studies generally fell into two study design categories: repeated inventories of uneven-aged tree populations and planting cohort studies of even-aged trees. If a study examined a population of trees of various size and age classes by comparing data from a current inventory with data from a prior inventory (either conducted by the same researchers or pulled from existing records), then we considered it to be a repeated inventory of uneven-aged trees. This category included monitoring i-Tree Eco style plots and repeated street tree inventories. If a study examined the survival and mortality of a group of trees planted around the same time, then we considered it to be a planting cohort study of relatively even-aged trees. In the context of planted urban trees, “age” means time since planting. Furthermore, some planting cohort studies examined groups of trees that were planted over a small range of years, which we considered to be a multi-year cohort. When we analyzed cohort studies, we considered the establishment phase to be the first five years since planting and the post-establishment phase to be over five years since planting. Some urban tree mortality studies did not fall into either category and therefore could not be analyzed for mortality rates *per se*. However, since they still pertained to real-world mortality and provided information on factors like human behavior and natural disasters, we included them in our review, the results, and discussion. These studies included surveys of residents and urban tree managers, one-time inventories following storm events, assessments of removal records, and a dendrochronology study.

For all planting cohort study data we calculated, annual mortality, q_{annual} , and cumulative survivorship, l_t , were defined as

$$q_{\text{annual}} = 1 - l_t^{1/t}$$

where t is the number of years since planting and l_t is the proportion of the original population remaining alive at time t (Roman and Scatena 2011; Roman et al. 2016). That original population is represented by baseline data, either the first inventory (for repeated inventory studies) or planting records (for planting cohort studies). For repeated inventory studies of

uneven-aged trees, annual mortality was calculated using provided periodic survival rate p_t (i.e., the proportion surviving over the time interval t) and the equation

$$p_{\text{annual}} = p_t^{1/t}$$

(Roman et al. 2016). For both cohort studies and repeated inventory studies of uneven-aged trees,

$$q_{\text{annual}} = 1 - p_{\text{annual}}$$

(Roman et al. 2016) was used. We assumed a constant rate of mortality when calculating annual mortality rates over a specified time period from a given study (Roman and Scatena 2011). We also summarized how the studies we reviewed defined and calculated mortality.

To summarize the typical mortality rates provided in the literature, we calculated the quartiles, since these summary statistics are less influenced by outliers than the mean. We did not use weighted quartiles by sample size because we did not want to attribute more weight to studies of larger tree populations based solely on that metric. If studies gave a range of mortality rates or study period lengths (i.e., time since last inventory for repeated inventories of uneven-aged trees, or time since planting for multi-year planting cohort studies), the minimum and maximum values were used in calculations, and we reported the corresponding lower and higher quartile values. For such studies that reported ranges, lower values represent the lowest possible interpretation of annual mortality, and higher values represent the highest possible interpretation of annual mortality. We did not use the mid-point because we could not be certain that the mid-point was representative of the underlying range of data. If a study provided mortality rates for one or more sub-groupings, we retained these sub-group values to use in summary tables and quartile calculations if (1) this was the only information reported; or (2) the sub-groupings were based on time since planting or tree size. For planting cohort studies, we used the quartile summary statistics for establishment and post-establishment mortality rates to create survivorship curves for fairly typical annual mortality (50th percentile), worse-than-normal (75th percentile), and better-than-normal (25th percentile). For two planting cohort studies that provided annual mortality information for different age classes (Lu et al. 2010; Roman et al. 2016), we created mortality curves by

graphing annual mortality against time since planting. Likewise, for repeat inventories of uneven-aged trees, when annual mortality information was provided for varying size classes (Nowak 1986; Nowak et al. 2004; Roman et al. 2014a), we created mortality curves by graphing annual mortality rates against size class (using diameter at breast height, dbh).

Factors associated with mortality outcomes from quantitative and qualitative studies were categorized as either human-related or biophysical and into sub-categories within these two major categories, recognizing the potential for interactive and coupled effects and the multi-scalar patterns in which they operate. We then grouped these factors as predisposing, inciting, or contributing, following the disease-decline model from Manion (1981). Predisposing factors represent the human and biophysical context at the time of planting. These conditions can then create vulnerabilities to inciting factors, which are short-term stressors that impact tree vigor. The inciting factors, in turn, create vulnerabilities to contributing factors, which are the direct mechanisms leading to tree mortality.

In addition to short summary tables in which we presented mortality rate quartiles and factors associated with mortality, we created three comprehensive tables: one outlining mortality rates in cohort studies, one outlining mortality rates in repeat inventory studies, and a final table summarizing studies that provided statistical analysis of factors associated with mortality. In order for a study to be included in the quartile calculations for annual mortality rates, it had to report annual mortality rates (or sufficient information to calculate annual rates) and a time interval. Studies that did not provide mortality information, time intervals, or whose methodologies were vastly different than the majority of papers, were excluded from these tables but were still considered in other summary results and discussion of the literature reviewed.

RESULTS AND DISCUSSION

Characteristics of the Literature

Fifty-six studies were analyzed. Fifty-two of the studies were published in peer-reviewed journals, three were internal reports or extension articles, and one was a master's thesis. Eighteen studies were published in the *Journal of Arboriculture/Arboriculture*

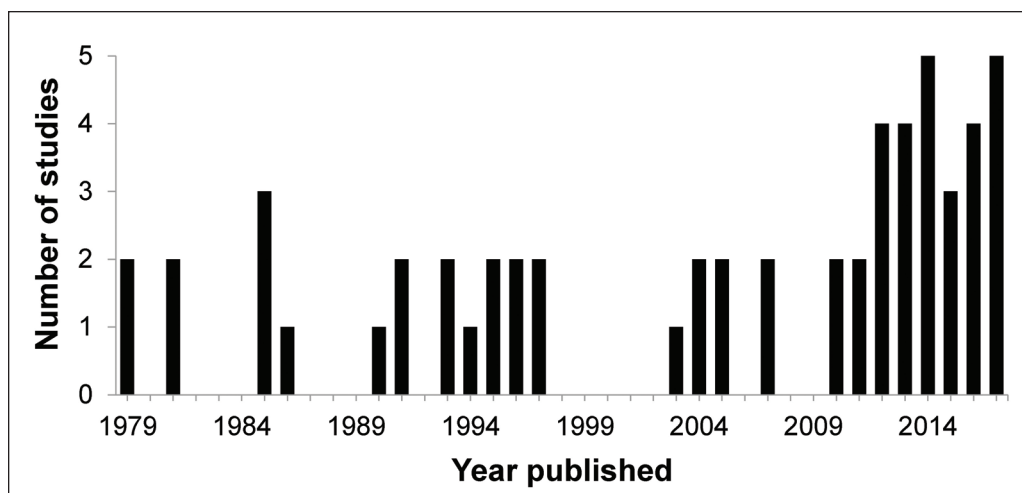


Figure 1. Years in which the urban tree mortality studies reviewed were published (1979 to 2017).

& *Urban Forestry*, and thirteen were published in *Urban Forestry & Urban Greening*. The publication dates spanned thirty-eight years (1979 to 2017) with thirty-one published between 2007 and 2017 (Figure 1). Forty-one of the studies were conducted in the continental United States (Table 1). Almost a third of the studies examined trees in urban areas located in the warm temperate–fully humid–hot summer climate zone (Kottek et al. 2006; Figure 2). There was a lack of studies in equatorial, arid, and very cold climates. Despite searching using the “all language” function, we did not find non-English studies meeting our criteria for review. Twenty-five of the studies focused solely on street trees, four studied trees on private residential properties (e.g., lawns/yards), three studied park trees, twenty studied trees on a mix of these three planting site types, and four did not specify site types. Street trees were the most common, likely because municipal or non-profit street tree planting and inventory records are often more readily available than records for park trees, and public street trees are logistically easier to monitor than trees on private properties, as the latter require permission to access.

Thirty-three articles provided sufficient information for us to calculate annual mortality rates, which we grouped according to study type: repeated inventory of uneven-aged trees or planting cohort of relatively even-aged trees (Table 2). Some articles provided data on both types of tree studies. Eighteen discussed repeated inventories (summarized in detail in Appendix Table 2), and twenty-one discussed planting cohort monitoring studies (Appendix Table 1). Of the planting cohort monitoring studies, sixteen examined trees within five

Table 1. Countries where urban tree mortality studies were conducted.

Country	Number of studies
U.S.A.	41
Canada	3
China	3
New Zealand	2
South Africa	1
Chile	1
Belgium	1
Thailand	1
Australia	1
Finland	1
England	1

years of planting (i.e., establishment phase) and eight examined trees planted over five years prior (i.e., post-establishment phase; Table 2). Forty-one studies provided sufficient information for categorizing the human and biophysical factors significantly associated with mortality. Twenty-six studies also examined growth, which we did not examine in-depth in this review.

Mortality Definitions

When gathering and reviewing urban mortality and survival data, it is imperative to clearly define mortality and survival. Almost all of the studies in our review define mortality as death or removal of the original tree (e.g., a tree that was listed in a prior inventory or planting record), but this was not always explicitly stated. The only study which did not include removals in the definition of mortality was Jack-Scott

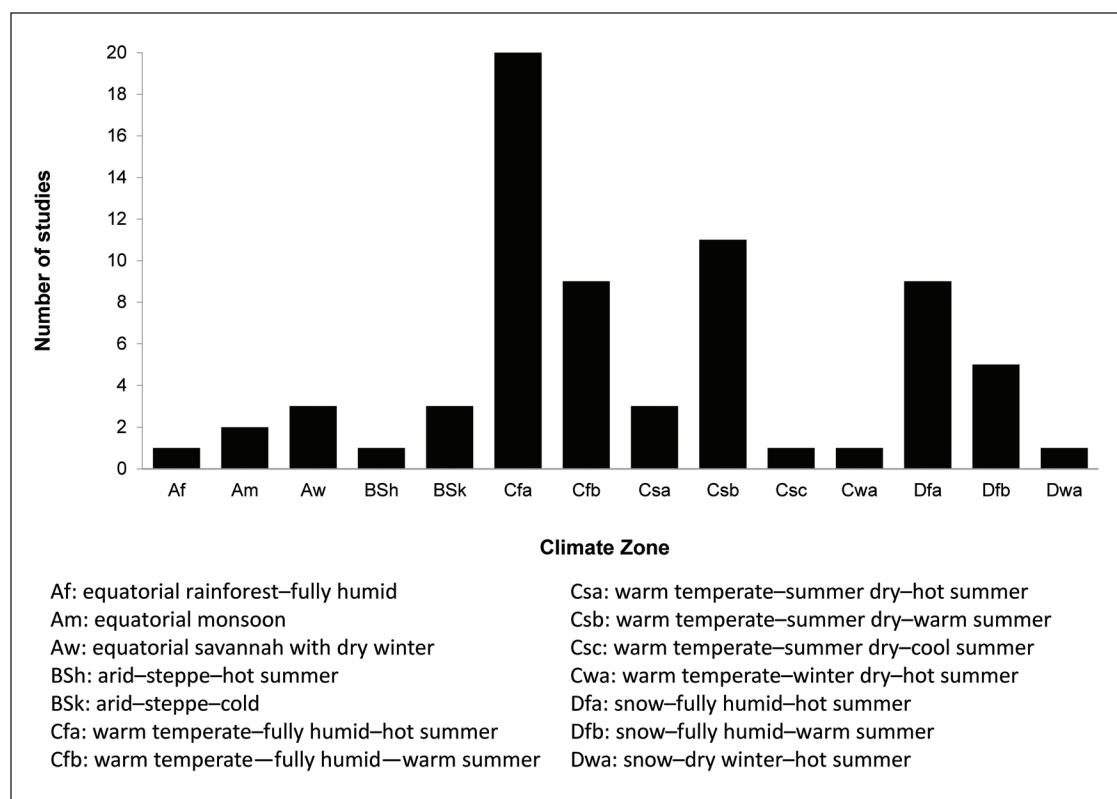


Figure 2. Climate zones where data was collected for the reviewed studies. Climate zones are based on the Köppen-Geiger climate classification system where the 3-letter abbreviations correspond to main climate, precipitation, and temperature (after Kottek et al. 2006).

Table 2. Quartiles of annual mortality rates for different study types: repeat inventory of mixed-aged existing trees vs. planting cohort. Planting cohort studies are further broken down into all studies, those reporting establishment mortality (≤ 5 years after planting) and those reporting post-establishment mortality (> 6 years post-planting). When a given study reported a range of years or a range of mortality values, we used the lower annual mortality value in the “lower” row and the higher annual mortality value in the “higher” row.

Study type	Number of studies	Lower or higher annual mortality results used	Annual mortality (%) range and quartile				
			Min.	1st	Median	3rd	Max.
Repeat inventory	18	lower	0.00	1.57	2.28	3.02	30.00
		higher	0.00	1.59	2.59	3.30	30.00
Planting cohort							
all	21	lower	0.60	2.81	4.40	7.08	68.47
		higher	0.60	3.76	6.48	9.33	68.47
establishment	16	lower	1.25	3.96	6.60	9.33	68.47
		higher	2.74	5.02	7.00	10.43	68.47
post-establishment	8	lower	0.60	1.50	2.76	3.81	4.60
		higher	0.60	1.53	3.76	4.73	11.22

(2012), which analyzed mortality of planted trees in terms of only the trees observed standing dead (i.e., not removals). In another example of defining mortality that differed somewhat from the norm, Koeser et al. (2014) studied trees that were part of a Florida Forest Service planting program that has a policy of inspecting and replacing trees that die within the first year; survival of replacement trees was included with survival of the original trees in that study's analysis. This procedure may be responsible for the high survival rate of the trees. Lu et al. (2010) also included replacement trees in survival calculations for New York City, NY, such that street trees replaced during the initial contractor guarantee were tracked alongside original trees for survival monitoring after two years (N. Sonti, personal communication), although this was not explicitly stated in the article. For yard tree giveaway programs, definitions of mortality can be complicated by the fact that distributed trees are planted by residents and thus might never get planted at all, leading to mortality rate calculations that use the number of trees distributed (not the number planted) as the denominator (Roman et al. 2014b; Ko et al. 2015a; Roman et al. 2016). For instance, with yard tree monitoring for the same shade tree program in Sacramento, CA, Ko et al. (2015a) used trees distributed as the denominator, whereas Roman et al. (2014b) used trees planted, largely due to practicalities of the Ko et al. (2015a) analysis being unable to discern whether trees observed "missing" in the early 1990s were cases of post-planting mortality vs. failure to plant.

Mortality Rates

We summarized information from studies providing annual mortality rates (or sufficient information for us to calculate rates) and time periods in Appendix Tables 1 and 2. For the eighteen studies of repeated inventories of uneven-aged trees, we found the annual mortality rates ranged from 0% (Nowak 1986; Staudhammer et al. 2011; Roman et al. 2014a) to 30% (Lima et al. 2013) with a median of 2.3 to 2.6%. Note that throughout the results, when a range of annual mortality rates is reported, that corresponds to studies which themselves reported ranges of mortality rates or time intervals, as explained in the methods. Five of the studies of repeated inventories of uneven-aged trees and fourteen of the studies of relatively even-aged planting cohorts reported ranges of mortality rates or time intervals. For the twenty-one studies of relatively even-aged planting cohorts, annual mortality rates ranged from 0.6% (Roman et al. 2015) to 68.5% (Yang and McBride 2003) with a median of 4.4 to 6.5%. For articles that studied planted cohort tree survival in the first five years after planting (sixteen articles), the median annual mortality rate was 6.6 to 7%. Of the literature that studied planted cohort trees past the establishment phase (eight articles), the median annual mortality rate was 2.8 to 3.8%. Notably, the median annual mortality for planted cohort trees older than five years (2.8 to 3.8%), and the median for repeated inventories of uneven-aged trees (2.3 to 2.6%), are both on the high end of the 1 to 3% annual mortality typically reported for mature canopy

Table 3. Quartiles of annual mortality rates for different tree planting locations. When a given study reported a range of years or a range of mortality values, we used the lower annual mortality value in the "lower" row and the higher annual mortality value in the "higher" row. Studies that did not specify the location or did not examine mortality rates were left out, so the "number of studies" reflects only those used in calculations.

Planting location	Number of studies	Lower or higher annual mortality results used	Annual mortality (%) range and quartile				
			Min.	1st	Median	3rd	Max.
Street	20	lower	0.00	1.59	2.54	4.60	68.47
		higher	0.00	1.60	2.61	5.45	68.47
Mixed	14	lower	0.00	2.22	4.30	6.77	30.00
		higher	0.00	2.99	5.10	7.49	30.00
Residential yards	3	lower	3.82	4.21	4.60	5.60	6.60
		higher	3.82	4.21	4.60	5.60	6.60
Park	2	lower	1.28	1.74	2.19	2.65	3.10
		higher	1.28	1.74	2.19	2.65	3.10

trees in natural forests (e.g., Harcombe and Marks 1983; Condit et al. 1995; Lorimer et al. 2001).

When looking at all of the study designs, annual mortality rates for private residential property yard trees (three studies gave sufficient mortality information) ranged from 3.8% (Ko et al. 2015a) to 6.6% (Roman et al. 2014b) with a median of 4.6%, whereas street tree mortality (twenty studies) ranged from 0% (Nowak 1986 and Roman et al. 2014a) to 68.5% (Yang and McBride 2003) with a median of 2.5 to 2.6% (Table 3). The lower median mortality rate for street trees is noteworthy given the common assumption that street trees face tougher conditions than other types of urban trees (e.g., Moll 1989; Skiera and Moll 1992). Additionally, there were substantially fewer private property studies of yard trees; therefore, understandings of how street and lawn tree mortality compare will improve as further research is conducted.

Explanations for Exceptionally High and Low Mortality Rates

Study location and design, as well as the planting program policies, may have had a role in exceptionally high and low mortality rates. For example, Nowak et al. (1990) reported 19% mortality, but the study focused on street trees in a busy transportation corridor in Oakland, CA and noted high rates of vandalism and automobile damage (although these two factors could not be pinpointed as the cause of mortality in their analysis due to limited data). Trees studied by Yang and McBride (2003) in Beijing, China were severely pruned prior to transplanting, likely contributing to the high mortality rate of 68.5%. On the other extreme, as an example of a study with low annual mortality, Koeser et al. (2014) reported 1.31 to 3.25% mortality, but the trees studied were part of a Florida state planting program that replaces trees that die within the first year, and many trees were irrigated,

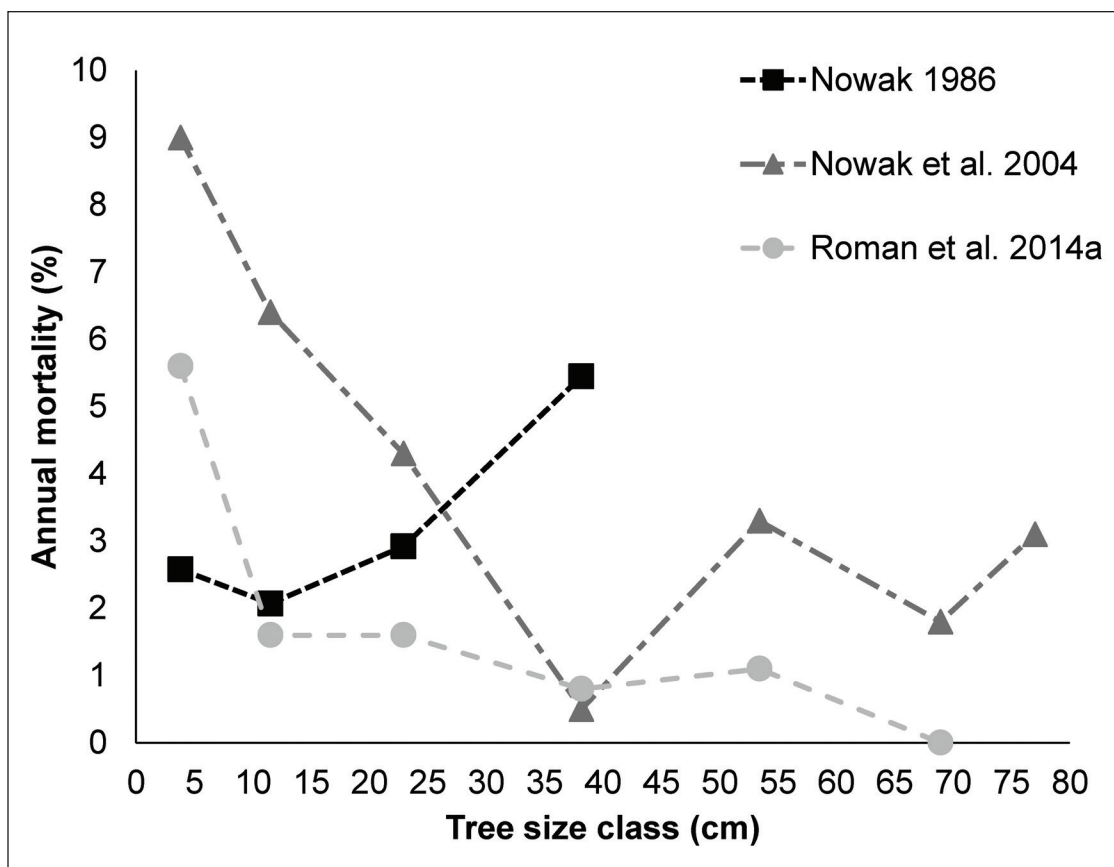


Figure 3. Mortality curves for studies that provide size-based mortality rates. Annual mortality rates are plotted at the mid-point of the size class interval.

which may have influenced the resulting low rate. It is important that reviews look carefully at procedures like tree replacement since they might lead to overstated mortality outcomes, or at the very least mortality rates that are not directly comparable to programs without replacement policies. Roman et al. (2015) reported a low annual mortality rate published for a planting cohort study, 0.6%, for street trees in East Palo Alto, CA. This site was designed by an International Society of Arboriculture Board Certified Master Arborist and had a high level of maintenance, including a drip irrigation system and regular stewardship activities by trained volunteers and paid interns.

Mortality Curves

A few articles provided enough information for us to graph mortality curves, which illustrate trends in mortality rates over tree size or age (i.e., time since planting). We graphed annual mortality against size classes for the three studies that provided size class-specific mortality rates (Figure 3) and found several distinct patterns. Mortality rates from Nowak's (1986)

study of street trees in Syracuse, NY, display a Type I mortality curve, with higher mortality rates in larger size classes. However, that study differs from the others we assessed. Indeed, other urban tree mortality studies point to Type III or U-shaped mortality curves. In the Nowak et al. (2004) study of randomly located i-Tree Eco plots in Baltimore, MD, we found U-shaped mortality curves, in which mortality was highest for the smallest and largest tree size classes and lower in the middle. The Roman et al. (2014a) study of street trees in Oakland best fits a Type III curve, with highest rates of mortality for the smallest trees. We also graphed reported annual mortality rates against time since planting (i.e., age-based planting cohort mortality) for two studies (Figure 4): New York City street trees (Lu et al. 2010) and Sacramento yard trees (Roman et al. 2016). Both of these studies were similar to a Type III curve. However, these studies only included young trees that had been in the ground fewer than ten years, and planting cohort monitoring studies over longer time periods could show whether the Type III pattern persists or whether a U-shaped curve appears once older trees are included. Based on

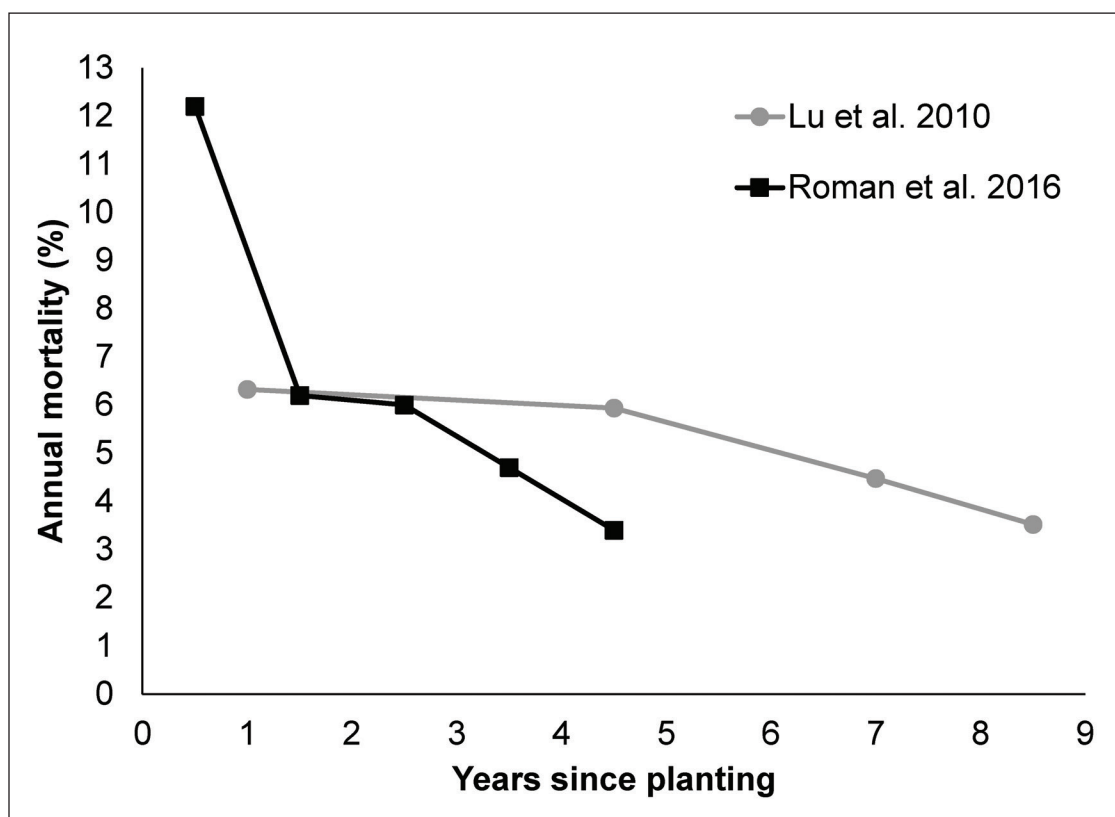
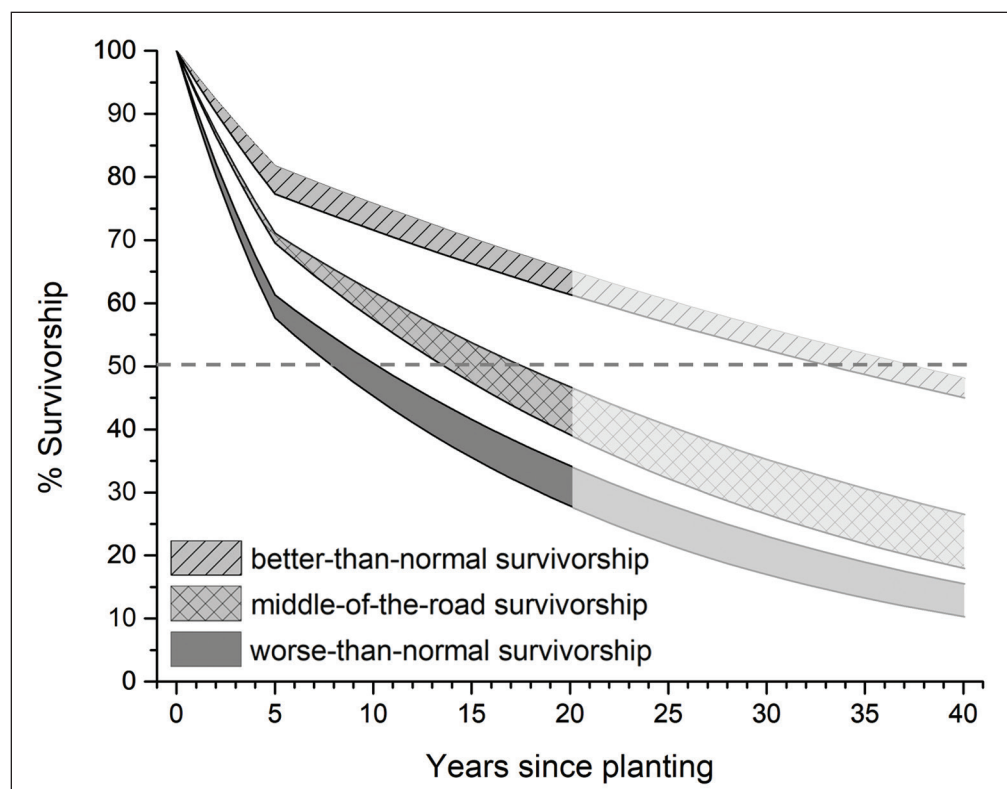


Figure 4. Mortality curves for studies that provide age-based mortality rates. Annual mortality rates are plotted at the mid-point of the age (i.e., time since planting) interval.

Figure 5. Survivorship curves based on quartiles of mortality rates in planting cohort studies (Table A1). Better-than-normal survivorship reflects 1st quartile, middle-of-the-road reflects median, and worse-than-normal reflects 3rd quartile. The first five years used establishment mortality rates, while years 6+ used post-establishment rates. The range of values for each curve reflects high and low values for studies that reported a range of mortality rates and/or years. The dashed horizontal line shows 50% survivorship, also known as population half-life. After twenty years, the more transparent grey color reflects the fact that most published planting cohort studies were under twenty years post-planting, therefore post-twenty years annual mortality rates are extrapolations.



these five studies, it would seem that urban trees generally follow either a U-shaped or Type III pattern, similar to trees in natural forests (e.g., Coomes and Allen 2007; Lorimer et al 2001; Metcalf et al. 2009; Lines et al. 2010). Yet more studies reporting mortality rates by age or size class could confirm or refute this generalization, which is admittedly based on just a few studies. It would be helpful if more urban tree mortality studies reported mortality by age or size class to aid in improved understandings of typical mortality curve patterns.

A handful of other studies did not provide explicit data on mortality rates by tree age or size class but still provide interesting information on trends over time. Miller and Miller (1991) provide cumulative percent mortality data for cities in Wisconsin that shows the highest mortality (removals) occurred in the first year, with slightly less mortality in year two, and then mortality stabilized around four years. These data point towards a Type III mortality curve. Ko et al. (2015a) provided a survival curve for twenty-two years of planted yard trees that shows the steepest decline in survivorship between planting and year one, then a steady but less steep decline for the remaining years of observation, suggesting a Type III curve. However,

year one losses in the Ko et al. (2015a) study include trees not planted from a yard tree giveaway program.

While our studies differed too greatly to conduct a true meta-analysis, we were able to graph assumed survivorship curves using age-based life tables we created from the mortality rate quartiles for cohort studies (Figure 5; Table 2 and Appendix Table 4). The first five years used establishment mortality rates, while years 6+ used post-establishment rates. The range of values for each curve reflects high and low values for studies that reported a range of mortality rates and/or years. We graphed better-than-normal, middle-of-the-road, and worse-than-normal survivorship scenarios using 25th percentile, 50th percentile, and 75th percentiles of the annual mortality rates, respectively. The curves (Figure 5) follow a Type III survivorship curve shape due to the nature of the input data which does not include annual mortality rates for very old trees. Life tables and associated survivorship curves like these can provide useful information for practitioners. For example, one could estimate when half the cohort will be dead, known as the population half-life (i.e., 50% survivorship), and create a tree replacement strategy accordingly. For example, the population half-life using the quartile

annual mortality rates from planting cohort studies (Table 2) would be around 7 to 11 years, 13 to 18 years, and 33 to 38 years for worse-than-normal, middle-of-the-road, and better-than-normal survivorship scenarios (Figure 5). It is important to note that these curves are not meant for extrapolation to other cities and planting programs, but rather to display a general trend in the survivorship curves derived from reported mortality rates in the published literature.

Factors Associated with Mortality

Quantitative Associations with Mortality for Field-Based Monitoring Studies

The literature cited a variety of statistically significant factors associated with mortality (Table 4 and Appendix Table 3). Of the articles that used field-based monitoring studies and quantitatively examined factors, the most commonly cited biophysical factors were size/age and taxa (e.g., species or cultivar). The most commonly cited human-related factors associated with urban tree death were stewardship, maintenance, and vandalism. Land use and socioeconomic measurements (e.g., net property value, income, and homeownership) were also commonly cited as significant. Trees typically experienced higher mortality when located on properties with unstable homeownership (such as rental, foreclosed, and vacant properties) and when located in neighborhoods with lower incomes and property values. Stewardship and maintenance activities play a positive role in tree survival. Three studies did not find any statistically significant relationships between observed mortality rates and factors examined quantitatively (Thompson et al. 2004; Conway 2016; Martin et al. 2016).

The studies that quantitatively analyzed predictors of mortality share many associated factors, but differ on whether some common factors increase or decrease mortality rates, with sometimes contradictory results. For example, Roman et al. (2014b) associated smaller mature tree size with lower mortality, while Ko et al. (2015a) associated it with a higher mortality when compared to medium-sized mature trees, yet both focus on the same residential lawn tree program in Sacramento. It is unclear why these two studies found different results; other issues related to those taxa or planting sites could be more relevant than mature tree stature. Land use, while cited as statistically significant in many studies (Table 4), does not have a clear mechanism of impact on mortality,

and land use categories may also covary with other important factors. For instance, Nowak et al. (2004) reported high mortality for transportation land use, but this land use had a high prevalence of *Ailanthus altissima*, which the authors speculated might explain that finding. Single-homeowner properties had decreased mortality rates in several studies (Nowak et al. 1990; Lu et al. 2010; Jack-Scott et al. 2013), but the causal explanations for this association are unclear. Various land uses may reflect different planting site conditions and/or maintenance regimes across studies. For example, a tree recorded as single-family residential could alternatively be a yard or street tree, and trees recorded as multi-family residential could be managed by the municipality (such as street trees adjacent to a downtown apartment building) or by landscaping crews hired by an apartment manager (such as lawn trees in a suburban apartment complex). In general, it is not clear whether land use is associated with mortality due to biophysical characteristics of particular land use categories and planting sites, governance of tree stewardship, or some other phenomena.

Most older studies (e.g., Nowak et al. 1990; Miller and Miller 1991) tested for significant influential factors using univariate statistical techniques such as Chi-Square tests, but some more recent studies also relied on univariate techniques (e.g., Nowak et al. 2004; Lu et al. 2010). In contrast, most studies after 2010 (e.g., Staudhammer et al. 2011; Lawrence et al. 2012; Roman et al. 2014a; Koeser et al. 2014; Ko et al. 2015a; Vogt et al. 2015a; van Doorn and McPherson 2018) used more sophisticated multivariate analyses such as logistic regression and non-parametric conditional inference trees. For instance, Roman et al. (2014a) examined the interaction between tree condition and size class using multivariate logistic analysis. When summarizing the papers, no factors stood out as being related to a specific size or life stage in the papers we reviewed, with the possible exception of maintenance or stewardship for recently planted trees.

The prevalence of the most common factors used in quantitative analyses could be due to their relative ease of measurement, since such data can be gathered from planting records, quick field evaluations, and the United States census. Multiple studies followed protocols outlined by the United States Forest Service i-Tree Eco or Forest Inventory and Assessment

Table 4. Categories of biophysical and human factors associated with mortality based on forty-one papers that provided sufficient information about mortality factors or mechanisms. Within each major category (biophysical or human), factors are listed in order of the frequency with which they appear in the mortality studies reviewed. Studies marked with an (*) used statistical analysis to quantitatively examine factors (see Appendix Table 3), while unmarked studies examined factors qualitatively (e.g., case studies or surveys of residents). Studies marked with a (#) examined trees affected by a natural disturbance.

Factor	Number of studies	Citations
Biophysical factors		
<i>Taxa (e.g., genus, species, cultivar)</i>	15	Nowak 1986*; Miller and Miller 1991*; Hauer et al. 1993#; Duryea et al. 1996*; Duryea 1997#; Nowak et al. 2004*; Duryea et al. 2007*#; Lu et al. 2010*; Jack-Scott 2012*; Lawrence et al. 2012*; Koeser et al. 2013*; Lima et al. 2013*; Koeser et al. 2014*; Roman et al. 2015; Boukili et al. 2017*
<i>Size/age</i>	13	Nowak 1986*; Polanin 1991*; Hauer et al. 1993; Duryea et al. 1996*#; Nowak et al. 2004*; Duryea et al. 2007*#; Jack-Scott et al. 2013*; Koeser et al. 2013*; Lima et al. 2013*; Roman et al. 2014a*; Roman et al. 2014b*; Ko et al. 2015a*; Morgenroth et al. 2017*
<i>Site characteristics (e.g., planting space, site type, tree density)</i>	12	Jim 2005*; Duryea et al. 2007*#; Lu et al. 2010*; Staudhammer et al. 2011*; Lawrence et al. 2012; Koeser et al. 2013*; Lima et al. 2013*; Roman et al. 2014a*; Roman et al. 2014b*; Ko et al. 2015a*; Roman et al. 2015; Vogt et al. 2015a*
<i>Condition/vigor/health</i>	6	Nowak 1986*; Hickman et al. 1995*; Nowak et al. 2004*; Koeser et al. 2013*; Roman et al. 2014a*; Roman et al. 2015
<i>Planting season</i>	4	Miller and Miller 1991*; Roman et al. 2014b*; Ko et al. 2015a*; Vogt et al. 2015a*
<i>Nursery (e.g., source, stock, type, size)</i>	3	Koeser et al. 2014*; Roman et al. 2015; Vogt et al. 2015*
Human factors		
<i>Stewardship, maintenance, vandalism</i>	15	Sklar and Ames 1985; Nowak 1986*; Gilbertson and Bradshaw 1985; Struve et al. 1995; Duryea et al. 1996*#; Sullivan 2005; Boyce 2010*; Lu et al. 2010*; Jack-Scott et al. 2013*; Koeser et al. 2014*; Richardson and Shackleton 2014; Roman et al. 2014b*; Ko et al. 2015a*; Roman et al. 2015; Vogt et al. 2015a*
<i>Socioeconomic measures</i>	8	Gilbertson and Bradshaw 1985; Nowak et al. 1990*; Lu et al. 2010*; Jack-Scott et al. 2013*; Lima et al. 2013*; Roman et al. 2014b*; Ko et al. 2015a*; Vogt et al. 2015a*
<i>Land use</i>	6	Nowak et al. 1990*; Nowak et al. 2004*; Jim 2005*; Lu et al. 2010*; Lawrence et al. 2012*; Steenberg et al. 2017*
<i>Construction and redevelopment activity</i>	6	Nowak 1986*; Miller and Miller 1991*; Hauer 1994*; Koeser et al. 2013*; Steenberg et al. 2017*; Morgenroth et al. 2017*
<i>Infrastructure conflict (e.g., overhead utilities, sidewalks, transportation)</i>	5	Nowak et al. 1990*; Nowak et al. 2004*; Lu et al. 2010*; Jack-Scott 2012*; van Doorn & McPherson 2018*
<i>Landscaping norms and behavior</i>	2	Kirkpatrick et al. 2013; Conway 2016

(FIA) systems (Nowak et al. 2004; Staudhammer et al. 2011; Lawrence et al. 2012; Lima et al. 2013; Roman et al. 2014a), which could explain the prevalence of variables like land use (and the specific land use categories observed). While these systems are useful for outlining potential variables to measure, researchers should think critically about which variables are best for their specific mortality studies. For instance, locally-relevant land use and planting site categories could be more informative. Tree health and vigor evaluations, as well as soil characteristics, might be uncommon in urban tree mortality studies because they require more time, training, and equipment to measure. There is ample evidence that soil quality and available soil volume are critical to tree growth and health (e.g., Urban 2008; Rahman et al. 2013; Layman et al. 2016; Scharenbroch et al. 2017). Yet only three of the mortality studies we reviewed (Impens and Delcarte 1979; Lawrence et al. 2013; Koeser et al. 2014) examined soil characteristics in relationship to growth, and none of the studies tested whether soil properties were associated with mortality and survival. Additionally, tree condition and health evaluations are not well-defined and consistently applied (Bond 2010). In terms of human factors influencing mortality, parcel-level ownership data (Roman et al. 2014b; Ko et al. 2015a) and construction or renovation permitting data (Steenberg et al. 2017) show promise for understanding the process of tree mortality, yet these data sets have thus far been rarely applied to statistical modeling of urban tree mortality.

Qualitative Analyses of Factors Associated with Mortality for Field-Based Monitoring Studies

Some of the studies that reported mortality data from field-based monitoring studies drew conclusions about influential factors based on qualitative data and observations of trends (e.g., Rhoads et al. 1981; Sklar and Ames 1985; Polanin 1991; Richardson and Shackleton 2014; Roman et al. 2015), and many of these findings complement research with statistical analyses. Rhoads et al. (1981) studied a cohort of street trees in Philadelphia, PA and determined the cumulative survivorship to be approximately 85% for each species, therefore concluding that species is not a significant factor. This study contradicts the many other studies that found taxa to be significant, but the following were in more agreement with the studies that used statistical analysis. Ip (1996) documented

the mortality of a cohort of community-planted trees in the Northwest Region of Canada, gathering information on the cause of mortality or injury to seedlings when they were encountered. Approximately half of the urban and rural projects reported damage to seedlings by people, lawn care equipment, and snowmobiles, so Ip (1996) concluded that smaller tree size could be associated with higher mortality. Sullivan (2004) studied trees planted by a nonprofit in San Francisco, CA, and found that many residents and neighbors cited vandalism as a reason for tree death or removal. Richardson and Shackleton (2014) assessed the condition of newly planted street trees in eleven towns in Eastern Cape, South Africa, in order to understand more about vandalism, finding 42% of recently planted street trees totally snapped, and no difference between snapped trunks for trees with or without protective structures. In a case study of tree planting programs with high survival rates in East Palo Alto and Philadelphia, Roman et al. (2015) concluded that appropriate species selection and planting techniques, small geographic areas, and time-intensive maintenance explained low annual mortality during establishment, ranging from 0.6 to 4.6%. They also found that for the planting project with the lowest published urban tree mortality, East Palo Alto, the few instances of tree deaths were attributed to car accidents and site conditions.

Other Study Designs

The aforementioned planting cohort studies (Appendix Table 1) clearly examined changes in a cohort from time of planting to the time of monitoring. Similarly, the repeated inventory studies (Appendix Table 2) examined changes between inventories conducted at two different times. Those are all field-based monitoring that produced mortality data based on analyses of change over time. However, some articles used other study designs and more indirect measures of mortality. We reviewed fourteen studies that made use of data from a single point in time. These studies included surveys of homeowners or other individuals who could provide indirect information about tree mortality, one-time inventories after storms or other major disturbances, and other unique designs. These studies did not have before-and-after data that can be used to estimate rates of loss, but they provide insight into associated factors and are therefore included in the review.

Three of these fourteen studies conducted surveys of individual people in order to learn more about

urban tree mortality. The earliest of these that we found was a study by Beatty and Heckman (1981) in which the authors surveyed urban forest managers responsible for urban forest programs across the United States on the major causes of tree health and survival issues. The most commonly cited issues were lack of water, nutrient deficiency, and vandalism. Some respondents also provided basic mortality information, from which those studies' researchers concluded that larger cities experience higher mortality, while western states and regions with milder climates experience lower mortality. Notably, such conclusions concerning regional mortality trends have not been confirmed or refuted by more recent research. Kirkpatrick et al. (2013) examined residents' attitudes regarding trees in eastern Australia, the amount of removals over the previous five years, and reasons for removals. They found that the main impetus for removal of healthy trees were aesthetic and lifestyle choices. Similarly, Conway (2016) surveyed residents in a suburb of Toronto, Ontario, Canada, to understand motivations for planting and removing trees. The author found that most removals were due to concerns about poor tree health, and the second most common reason was property concerns, both perceived risk and actual damage caused by a tree.

An example of a one-time inventory is the study conducted by Gilbertson and Bradshaw (1985) on trees in northern England. They observed site factors that could have impacted trees, concluding that vandalism (18% of dead trees showed signs) and water and nutrient stress (56% of dead trees showed signs) likely played a role, and that it is possible that the stress from weeds and tie strangulation could have been weakening the trees and predisposing them to vandalism. However, it was not made clear whether these observations were made on standing dead trees or severely impaired trees. Seven studies investigated the effects of natural disasters like storms and earthquakes by conducting one-time inventories following the event. Hauer et al. (1993) conducted an inventory of street tree condition and removals after a major ice storm in Urbana, IL, finding that species, tree form, branch architecture, and the presence/absence of defects all impacted the severity of damage. Jim and Liu (1997) conducted an inventory of trees damaged after a major storm in Guangzhou, China, noting the severity of damage, and found that species, trees size, and development history all influenced storm damage susceptibility. Duryea et al. (1996; 1997; 2007)

combined information from surveys of homeowners and residents along with field visits to properties to assess damage done to trees following eight major hurricanes hitting Florida and Puerto Rico. Those studies concluded that taxa, nativity, wood density, crown density, growth form, pruning, and growing in a cluster were all significantly associated with mortality (Table 4). Earthquake damage to trees was investigated by Morgenroth and Armstrong (2012), who studied removal records of trees in city parks in Christchurch, New Zealand. They found that the removed trees comprised of 9% juvenile, 9% semi-mature, 61% mature, and 21% over-mature trees and that 88% of all leaning trees were mature or over-mature. Leksungnoen et al. (2017) studied trees in Bangkok, Thailand following severe flooding in 2011. The researchers categorized trees as either flood susceptible ($> 50\%$ mortality), tolerant (less than or equal to 50% mortality), or highly tolerant (no mortality after the flood). They found 18% of species to be flood susceptible, 75% tolerant, and 7% highly tolerant.

In addition to survey-based studies and one-time inventories, we found three other unique studies. Polanin (1991) studied a sample of trees that had removal records in Jersey City, NJ, and found that *Platanus × acerifolia* were most often removed due to sidewalk upheaval (i.e., the tree was removed while it was still alive due to infrastructure conflicts), and *Acer platanoides* were more often removed due to death. Helama et al. (2012) conducted a dendrochronology study on Scots pine (*Pinus sylvestris* L.) trees in a park lawn in Helsinki, Finland, in which they concluded that competition from other trees was a likely predisposing factor for mortality and drought as inciting factor. Morgenroth et al. (2017) compared the presence and absence of individual trees before and after earthquake-related demolition to examine removals. Using aerial imagery and field visits, they concluded that 78.4% of the original trees remained after demolition activity.

Relating Urban Tree Mortality to the Disease-Decline Model

To relate the urban tree mortality literature to the Manion's (1981) disease-decline model, we propose a new framework for urban tree mortality which groups human and biophysical factors as predisposing, inciting, and contributing (Figure 6). Some factors that we listed as inciting might function as

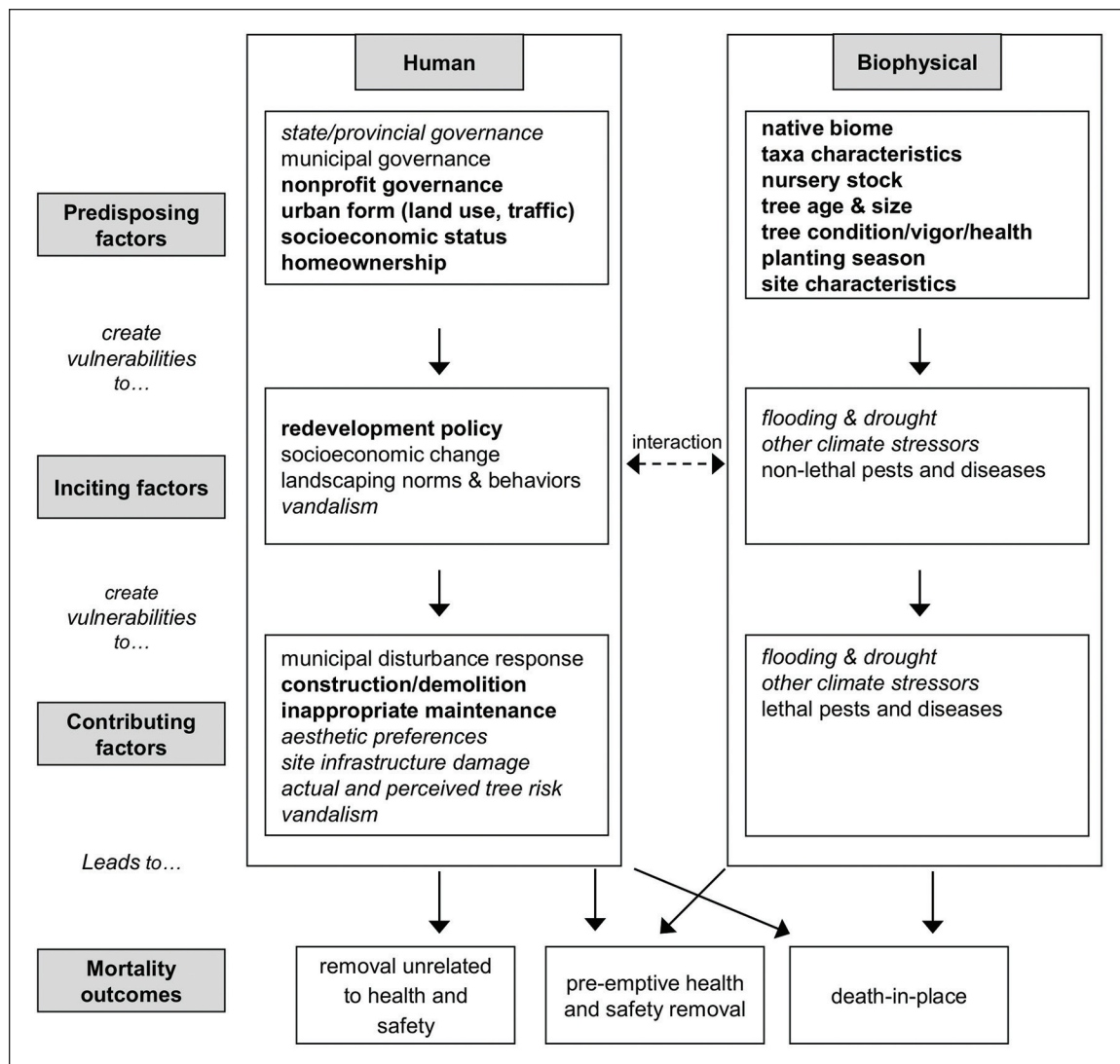


Figure 6. Urban tree mortality framework outlining predisposing, inciting, and contributing factors. The predisposing and inciting factors create vulnerabilities for trees to die or be removed due to the final contributing factors. Solid one-way arrows indicate that predisposing and inciting factors create vulnerabilities, while contributing factors directly lead to mortality outcomes. The two-way dashed arrow between human and biophysical factors represents interactive effects. Within each text box, factors are ordered from larger scales at the top (e.g., regional, municipal) to smaller scales at the bottom (e.g., parcel, planting site); spatial scale indicates the scale at which the factors could be measured or observed. Factors found to be statistically significant in the studies are bolded, while those that were qualitatively important are italicized.

contributing factors in certain circumstances, and vice versa, depending on the temporal sequence of stressors (e.g., a tree could be stressed by drought and later killed by a pest, or vice versa). Our framework also orders each set of factors according to spatial scale, from region to planting site. Other authors writing about residential ecosystems (e.g., Roy Chowdhury et al. 2011; Cook et al. 2012; Grove et al. 2015) and urban forest institutions (Mincey et al. 2013) have likewise stressed the importance of multi-scalar

factors. Some of the studies we reviewed noted the spatial scale of the factors they examined (e.g., Roman et al. 2014b; Conway 2016; Morgenroth et al. 2017; Steenberg et al. 2017) but others did not.

Importantly, while conceptual models for tree mortality in natural forests assume that trees die in-place from an accumulation of stresses (Franklin et al. 1987; Das et al. 2007), for urban tree mortality, trees can also be removed while still alive (Figure 7). Such removals can be due to health or risk concerns,

either based on thorough evaluation of the tree or perceived problems (Koeser et al. 2015; Conway 2016; Koeser and Smiley 2017; Klein et al. 2019). Alternatively, removals can be entirely unrelated to health and risk, such as trees removed during construction activities or due to aesthetic preferences (Kirkpatrick et al. 2013; Steenberg et al. 2017). We therefore propose three types of mortality outcomes for urban trees: death-in-place, preemptive removal for tree health and safety reasons, and removal unrelated to health or safety (Figure 6). Biophysical contributing factors, such as hurricanes, lethal pests, and accumulating site stressors, can result in death-in-place or preemptive removals. Human contributing factors can result in any of the three mortality outcome types. For example, mature *Fraxinus* spp. street trees threatened by EAB experience death-in-place if they are not treated with insecticide, and some municipalities are removing untreated *Fraxinus* spp. trees preemptively before the disease hits when they have chosen not to treat (Hauer and Peterson 2017). In another example, site stressors and lack of maintenance can lead to death-in-place for recently planted trees (Roman et al. 2014b; Koeser et al. 2014; Vogt et al. 2015a), but if those mechanisms stress a tree without killing it, preemptive removals could occur because the tree was deemed unhealthy or undesirable. Humans may also make tree removal decisions independent of any health or safety considerations, such as removals due to construction, renovation, and aesthetic preferences (Kirkpatrick et al. 2013; Conway 2016; Steenberg et al. 2017). Notably, while we emphasized earlier that

urban tree mortality studies have typically defined mortality as a combination of trees observed standing dead and removed, the studies we reviewed here were generally not able to differentiate between the three mortality outcome types. During monitoring field work, it is not usually feasible to be certain whether a removed tree was healthy, unhealthy, or dead at the time of removal. Surveys of residents have yielded important information in this regard (Kirkpatrick et al. 2013; Conway 2016), and surveys of municipal arborists might likewise provide insights into the health status of trees at the time of removal.

While this framework builds directly from our review, in that most of the factors listed were statistically significant (bolded in Figure 6) or qualitatively important (italicized in Figure 6) in the studies we reviewed (Table 4; see also Appendix Table 3), there are a few factors listed which were not prominent in our review. For instance, native biome, and the associated precipitation and temperature patterns, is a logical predisposing factor that could relate to species suitability and therefore likelihood of stress and later mortality. This issue was lightly touched upon in a yard tree mortality study in Sacramento (Roman et al. 2014b), where lack of irrigation combined with the seasonal drought in a Mediterranean climate, and species drought tolerance, appeared related to young tree losses, but most studies did not explicitly link biome to mortality since trees within each study were most typically within a single biome. The papers we reviewed also did not raise the issue of landscaping norms and behaviors (an inciting factor in Figure 6),

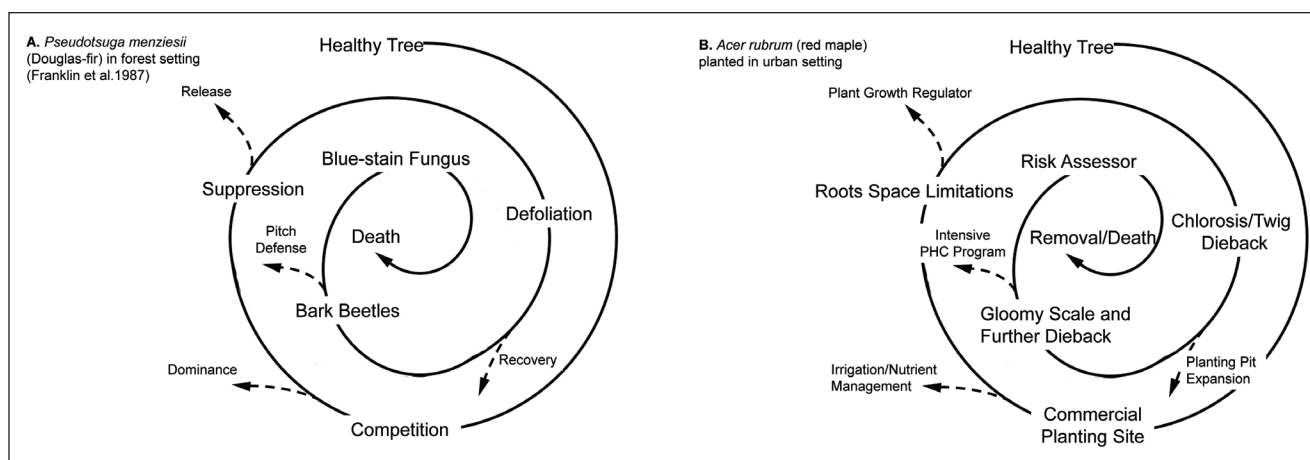


Figure 7. Tree mortality spirals depicting an example tree in a natural forest (adapted from Franklin et al. 1987) and an example planted urban tree.

but such behaviors have been studied in the residential ecosystems literature (Cook et al. 2012), and presumably relate to tree maintenance and therefore mortality vulnerability. Other factors listed in Figure 6 which did not come up in our review are pests and diseases, which are widely acknowledged to cause major tree losses, both through death-in-place and preemptive removals based on management responses (Hauer 2012; Kovacs et al. 2014; Sadof et al. 2017). Contemporary and historical examples include *Anoplophora glabripennis* (Asian longhorned beetle, Faccoli and Gatto 2016), *A. planipennis* (EAB, VanNatta et al. 2012; Sadof et al. 2017), *Phytophthora ramorum* (sudden oak death, Rizzo and Garbelotto 2003), and *Ophiostoma ulmi* (Dutch elm disease, Cannon and Worley 1976; Ganley and Bulman 2016). However, this body of literature was not included in our review, therefore the mortality rates summarized in our review (Table 2) do not include catastrophic losses from pests and diseases.

As urban forestry scholars move forward with new lines of tree mortality research, it will be valuable to understand the relative contributions to these various predisposing, inciting, and contributing factors to tree mortality in different regions and programs, and furthermore, to disentangle the processes and interactive effects linking factors together.

Comparison of Factors Affecting Urban Tree Mortality to the Disease-Decline Model of Tree Death for Non-Urban Trees

Overall, the prevalence of studies citing multiple significant factors for mortality supports the disease-decline model of tree mortality typically applied to non-urban trees (Manion 1981; Franklin 1987; Das et al. 2007). However, the literature we reviewed did not generally tease apart which factors should be considered as pre-disposing, inciting, or contributing (Manion 1981; Franklin 1987), nor did the urban tree mortality literature discuss how causes of or factors associated with tree death and removal vary across age classes (Franklin et al. 1987). One exception is the Helama et al. (2012) publication, a dendrochronology study of trees in an urban park lawn which investigated the disease decline theory and the possible role of competition as a predisposing factor and drought as an inciting factor. The second exception is Boyce's (2010) study of the effect of stewardship on survival for all ages, new trees, and established trees. Additionally, the decline spiral for urban trees may be

cut short by removal of live trees due to perceived or actual risk, construction, or human preference.

LIMITATIONS

The results of this literature review—and in particular the summarized mortality rates and the factors that influence mortality (Tables 2, 3, 4, Appendix Tables 1, 2, and 3)—are not without limitations. First, our review concentrated on published studies available through online searches. We did not include reports or unpublished data that might be gathered by urban forestry practitioners for internal use, such as repeat street tree inventories conducted for management purposes or monitoring of cohorts to track planted tree survival over time (see Roman et al. [2013] on urban tree monitoring data collection performed by practitioners). Greater insights into mortality trends and processes could be obtained by reaching out directly to urban forest managers for datasets.

Second, this literature review has a relatively limited set of geographies and climates. The bulk of our studies were from the United States (Table 1) and from warm temperate climates with hot or warm summers (Cfa, Csb, as categorized by Kottek et al. 2006) or snowy climates (Dfa; see also Figure 2). It is possible that a larger sample size from many different regions or climates could reveal trends in mortality rates and factors not found in this review.

Third, we are limited in making conclusions about trees planted on various site types. Street trees were the best represented site type in the studies we reviewed. Residential yard tree planting and distribution programs are fairly new (Nguyen et al. 2017), and monitoring yard trees is logistically complicated and time-consuming, as it requires cooperation from numerous private residents. Urban tree mortality research could benefit from further studies of trees in residential yards, other private properties, and landscaped parks; or random plot-based studies could better differentiate between planting site types in addition to land use categories.

Fourth, our review was limited because we assumed a constant rate of mortality when calculating mortality and survivorship percentages from cumulative survival rate data presented in cohort studies, which may not be appropriate for all scenarios (Roman et al. 2016). Recent research integrates concepts from demography into urban forest population studies, drawing attention to limitations like this and offering

suggestions such as data censoring (Roman et al. 2014b; Roman et al. 2016; van Doorn and McPherson 2018). More research needs to be conducted to determine whether constant rates of mortality are realistic and applicable to various urban tree data. For planting cohort mortality studies, we did break-down the annual mortality data into establishment (under five years post-planting) and post-establishment (over five years), however, this is a somewhat arbitrary cut-off. Further research could indicate when the key inflection points are for urban tree survivorship and mortality curves towards better explaining the establishment phase in terms of reduction in annual survival rates (Roman et al. 2014a; Sherman et al. 2016).

Fifth, the studies we reviewed did not examine biophysical factors like soil characteristics and pests, which have been shown to influence tree mortality. Soil characteristics like structure, bulk density, and organic matter content have been shown to influence tree growth and health (Day and Bassuk, 1994; Xiao and McPherson 2011; Grabosky and Bassuk 2016; Scharenbroch et al. 2017). However, most of the urban tree studies that account for these soil differences are experimental plantings, which we did not include in our review. There is also an abundance of urban forestry literature on pests and diseases (e.g., Cannon and Worley 1979; Aukema et al. 2011; Vannatta et al. 2012), but such studies do not generally address rates of mortality or predictive factors, therefore they were not included in our analysis.

Finally, and related to the last point, our results and conclusions are limited to trees planted and managed *in situ*, i.e., in actual urban areas and real-world conditions, as we intentionally excluded experimental planting studies. Though we did find a number in our searches (e.g., Insley 1980; Buckstrup and Bassuk 2000; Gilman 2004; Gerhold 2007; Gerhold 2008; Grabosky and Bassuk 2008; Etemadi et al. 2013; Oldfield et al. 2015; Grabosky and Bassuk 2016), we chose to leave out controlled experimental plantings in order to stay focused on straightforward comparison of mortality rates and factors in real-world conditions. Nonetheless, experimental planting trials can pinpoint both biophysical (e.g., species, cultivar, nursery stock, soil characteristics) and human (e.g., stewardship or maintenance regimes, neighborhood sociodemographic characteristics) factors that observational studies may miss due to confounding variables. For example, studies by Gerhold (1994; 2008) document the performance of different species and

cultivars in urban settings. More recently, McPherson et al. (2018) outlined a method for selecting and evaluating the performance of “climate ready trees” in California. This experimental study and others (e.g., Roloff et al. 2009) provide critical mortality information about new and underutilized urban species within the context of a changing climate. A separate review of mortality rates and factors in experimental plantings could be conducted to illuminate gaps in the literature where future experimental and *in situ* studies could complement each other.

IMPLICATIONS FOR RESEARCH AND PRACTICE

Despite the limitations described above, this review has some clear implications for research and practice. First and most importantly, for both research and practice, researchers, arborists, and urban forest practitioners should *explicitly define* mortality, survival, and the procedures used to measure and calculate each. Second, not only should definitions be clear, procedures should be *standardized*. The standardization issue has been recently discussed in a primer on urban tree mortality by Roman et al. (2016), an essay on the importance of standardizing at-planting data by Vogt et al. (2015b), and a report on software and data standards for urban tree monitoring by Boyer et al. (2016). Third, methods for calculating and analyzing empirical survival and mortality data from fields like ecology (Woodall et al. 2005; Das et al. 2007; Siccama et al. 2007; van Doorn et al. 2011; Fahey et al. 2013; Cleavitt et al. 2014; Levine et al. 2016) should be applied to urban forest mortality studies to gain a better understanding of population dynamics. Such demographic analytical techniques—like age-based life tables, survivorship and mortality curves, and lifespan metrics—can be applied to urban tree mortality data (Roman et al. 2016).

Fourth, urban forestry programs can benefit greatly by conducting well-designed, long-term monitoring programs that address specific research questions (Lindenmayer and Likens 2010). Variables collected should relate directly to those questions to avoid being “snowed by a blizzard of ecological details” resulting from a “laundry list” of items being monitored (Lindenmayer and Likens 2010).

Finally, a word of caution is warranted about use of the mortality rate ranges presented in this paper. It would be desirable for both researchers and practitioners if the mortality rates summarized in this

review could be used to model urban tree population change over time, for example, in order to project the benefits resulting from planting trees in a particular location (as done in Widney et al. 2016), or predict and plan for urban forest management needs and costs in the future (as suggested by Vogt et al. 2015b; Vogt et al. 2015c). In addition, the survivorship curves (Figure 5) and life tables (Appendix Table 4) provide an example of how population demography approaches can be applied to urban forestry settings in order to maximize management strategies. However, defining and even standardizing calculation methods for mortality rates is insufficient for creating accurate tree population models or scenario-building tools. Instead, we need much more data on urban tree mortality rates in various circumstances—particularly for the under-studied human and biophysical facets of the urban environment: different land use types, socio-economic factors, municipal management strategies, stewardship regimes, types of planting locations, geographies and climates, and pests and diseases (Figure 6).

More long-term mortality studies should be conducted to test for the significance of factors such as soil and microclimate, community and institutional structures (e.g., tree stewardship programs), sociodemographic characteristics, and resident behaviors. Such future studies should focus on both existing and newly planted trees in many different planting sites and include regular monitoring. Municipal tree removal records like those used by Polanin (1991) and Morgenroth and Armstrong (2012) are an underused yet potentially helpful data source for mortality studies. Mixed methods research incorporating both rigorous statistical analysis of predictive factors (both biophysical and human) along with qualitative assessments of communities and institutions would provide a holistic understanding of mortality processes in the anthropogenically constructed urban forest. Further, studies should be conducted to investigate the survival and mortality of large, old trees, perhaps exploring relationships between site and soil characteristics, as well as the role that removal practices and tree protection policies play in creating a population of large, unusually healthy or protected trees. Eventually, with enough data, models could be built to aid in the management of forests in many different cities and scenarios. Given the pace of urban tree mortality research over the past decade, the next

decade will likely be very promising to further advance our understanding of the urban tree mortality process and capacity to build empirically-grounded population projection models.

CONCLUSION

This review yielded a handful of important take-away points:

- Urban tree mortality studies span a range of quantitative and qualitative study designs, with a dramatic increase in the number of published studies over the past ten years.
- For planting cohort studies, annual mortality tended to be higher during the first five years after planting, aligning with the establishment phase concept.
- Based on mortality rates reported in planting cohort studies, the population half-life for planted urban trees (i.e., when survivorship is 50%) is around 7 to 11 years, 13 to 18 years, and 33 to 38 years for worse-than-normal, middle-of-the-road, and better-than-normal survivorship scenarios.
- The 1st, 2nd, and 3rd quartiles of annual mortality for repeated inventories of uneven-aged trees were more similar to cohort study annual mortality rates of the post-establishment phase (i.e., six or more years after planting) than those of the establishment phase (i.e., first five years after planting).
- Characterizing the factors that influence mortality into categories according to biophysical versus human influences, and predisposing, inciting, and contributing factors (as outlined in Figure 6) is helpful to understanding the urban tree disease-decline spiral.
- Future research could examine topics that are understudied in the current literature, such as microclimate, soil characteristics, institutional structures related to stewardship regimes, parcel-level sociodemographic factors, and resident behaviors.

LITERATURE CITED

- Aukema, J.E., B. Leung, K. Kovacs, C. Chivers, K.O. Britton, J. Englin, S.J. Frankel, R.G. Haight, T.P. Holmes, A.M. Liebhold, D.G. McCullough, and B. Von Holle. 2011. Economic impacts of non-native forest insects in the continental United States. *PLoS One* 6, e24587. doi:10.1371/journal.pone.0024587.

- Bartsch, F.A., J. Hook, E. Prince, and D. Schrom. 1985. Using computer simulation to plan a sustained-yield urban forest. *Journal of Forestry* 83:372–375.
- Beatty, R.A., and C.T. Heckman. 1981. Survey of urban tree programs in the United States. *Urban Ecology* 5:81–102.
- Bond, J. 2010. Tree condition: Health. *Arborist News* 19(1):34–38.
- Booth, A. 2008. Unpacking your literature search toolbox: On search styles and tactics. *Health Information and Libraries Journal* 25:313–317.
- Boukili, V.K.S., D.P. Bebbler, T. Mortimer, G. Venicx, D. Lefcourt, M. Chandler, and C. Eisenberg. 2017. Assessing the performance of urban forest carbon sequestration models using direct measurements of tree growth. *Urban Forestry & Urban Greening* 24:212–221.
- Boyce, S. 2010. It takes a stewardship village: Effect of volunteer tree stewardship on urban street tree mortality rates. *Cities and the Environment* 3(1): article 3, 8 pp.
- Cannon, W.N., and D.P. Worley. 1976. Dutch elm disease control: Performance and costs. USDA Forest Service Research Paper No. NE-345. USDA Forest Service Northeastern Forest Experiment Station. 8 pp.
- Clark, J.R., N.P. Matheny, G. Cross, and V. Wake. 1997. A model of urban forest sustainability. *Journal of Arboriculture* 23:17–30.
- Cleavitt, N.L., J.J. Battles, T.J. Fahey, and J.D. Blum. 2014. Determinants of survival over 7 years for a natural cohort of sugar maple seedlings in a northern hardwood forest. *Canadian Journal of Forest Research* 44:1112–1121.
- Cook, E., S.J. Hall, and K.L. Larson. 2012. Residential landscapes in an urban socio-ecological context: A synthesis of multi-scalar interactions between people and their home environment. *Urban Ecosystems* 15:19–52.
- Condit, R., S.P. Hubbell, and R.B. Foster. 1995. Mortality rates of 205 neotropical tree and shrub species and the impact of a severe drought. *Ecological Monographs* 65(4):419–439.
- Conway, T.M. 2016. Tending their urban forest: Residents' motivations for tree planting and removal. *Urban Forestry & Urban Greening* 17:23–32.
- Coomes, D.A., and R.B. Allen. 2007. Mortality and tree-size distributions in natural mixed-age forests. *Journal of Ecology* 95(1):27–40.
- Das, A.J., J.J. Battles, N.L. Stephenson, and P.J. van Mantgem. 2007. The relationship between tree growth patterns and likelihood of mortality: a study of two tree species in the Sierra Nevada. *Canadian Journal of Forest Research* 37:580–597.
- Dawson, J.O., and M.A. Khawaja. 1985. Change in street-tree composition of two Urbana, Illinois neighborhoods after fifty years: 1932–1982. *Journal of Arboriculture* 11(11):344–348.
- Dislich, R., and V.R. Pivello. 2002. Tree structure and species composition changes in an urban tropical forest fragment (São Paulo, Brazil) during a five-year interval. *Boletim de Botânica da Universidade de São Paulo* 20:1–12.
- Duryea, M.L., G.M. Blakeslee, W.G. Hubbard, and R.A. Vasquez. 1996. Wind and trees: A survey of homeowners after hurricane Andrew. *Journal of Arboriculture* 22(11):44–50.
- Duryea, M.L. 1997. Wind and Trees: Surveys of Tree Damage in the Florida Panhandle after Hurricanes Erin and Opal. UF/IFAS Extension, Circular 1183.
- Duryea, M.L., E. Kampf, and R.C. Littell. 2007. Hurricanes and the Urban Forest: I. Effects on Southeastern United States Coastal Plain Tree Species. *Arboriculture & Urban Forestry* 33(2):83–97.
- Dwyer, J.F., E.G. McPherson, H.W. Schroeder, and R.A. Rowntree. 1992. Assessing the benefits and costs of the urban forest. *Journal of Arboriculture* 18(5):227–234.
- Escobedo, F.J., S. Palmas-Perez, C. Dobbs, S. Gezan, and J. Hernandez. 2016. Spatio-Temporal Changes in Structure for a Mediterranean Urban Forest: Santiago, Chile 2002 to 2014. *Forests* 7(121).
- Faccoli, M., and P. Gatto. 2016. Analysis of costs and benefits of Asian longhorned beetle eradication in Italy. *Forestry: An International Journal of Forest Research* 89(3):301–309.
- Fahey, T.J., R.E. Sherman, and D.A. Weinstein. 2013. Demography, biomass and productivity of a northern hardwood forest on the Allegheny Plateau. *Journal of the Torrey Botanical Society* 140:52–64.
- Franklin, J.F., H.H. Shugart, and M.E. Harmon. 1987. Tree death as an ecological process. *BioScience* 37:550–556.
- Ganley, R.J., and L.S. Bulman. 2016. Dutch elm disease in New Zealand: Impacts from eradication and management programmes. *Plant Pathology* 65(7):1047–1055.
- Gates, S., and J. Lubar. 2007. TreeVitalize Tree Mortality Study. Morris Arboretum of the University of Pennsylvania, Philadelphia, PA.
- Gerhold, H.D. 2007. Crabapple cultivars tested as street trees: Third report. *Arboriculture & Urban Forestry* 33(2):176–181.
- Gilbertson, P., and A.D. Bradshaw. 1985. Tree survival in cities: the extent and nature of the problem. *Arboricultural Journal* 9:131–142.
- Grove, J.M., M.L. Cadenasso, S.T.A. Pickett, G.E. Machlis, and W.R. Burch. 2015. *The Baltimore School of Urban Ecology: Space, Scale, and Time for the Study of Cities*. Yale, New Haven, CT. 248 pp.
- Haddaway N.R., A.M. Collins, D. Coughlin, and S. Kirk. 2015. The role of Google Scholar in evidence reviews and its applicability to grey literature searching. *PLoS ONE* 10(9):e0138237.
- Harcombe, P.A. 1987. Tree life tables. *BioScience* 37:550–597.
- Harris, J.R., and S.D. Day. Navigating the establishment period: a critical period for new trees. *Routledge Handbook of Urban Forestry*. Eds. Francisco Ferrini, Cecil C. Konijnendijk van den Bosch and Alessio Fini. New York: Routledge, 2017. 390–404. Print.
- Hauer, R.J., W.S. Wang, and J.O. Dawson. 1993. Ice storm damage to urban trees. *Journal of Arboriculture* 19:187–194.
- Hauer, R.J., R.W. Miller, and D.M. Ouimet. 1994. Street tree decline and construction damage. *Journal of Arboriculture* 20(2):94–97.
- Hauer, R. 2012. Emerald Ash Borer Planning Simulator—EAB-PLANS. University of Wisconsin Stevens Point, College of Natural Resources Extension. Microsoft Excel-based simulator available for download: <https://www.uwsp.edu/cnr/Pages/outreachExtension.aspx>.
- Hauer, R.J., and W.D. Peterson. 2016. Municipal Tree Care and Management in the United States: A 2014 Urban & Community Forestry Census of Tree Activities. Special Publication

- 16-1, College of Natural Resources, University of Wisconsin—Stevens Point. 71 pp.
- Helama, S., A. Laaneld, J. Raisio, and H. Tuomenvirta. 2012. Mortality of urban pines in Helsinki explored using tree rings and climate records. *Trees* 26:353–362.
- Hickman, G.W., E. Perry, and R. Evans. 1995. Validation of a tree failure evaluation system. *Journal of Arboriculture* 21(5):233–244.
- Impens, R.A., and E. Delcarte. 1979. Survey of urban trees in Brussels, Belgium. *Journal of Arboriculture* 5(8):169–176.
- Ip, D.W. 1996. Community tree planting: early survival and carbon sequestration potential. *Journal of Arboriculture* 22(5):222–228.
- Jack-Scott, E.J. 2012. Survival and growth factors affecting community-planted urban street trees. *Cities and the Environment* 4(1).
- Jack-Scott, E.J., M. Piana, B. Troxel, C. Murphy-Dunning, and M.S. Ashton. 2013. Stewardship success: How community group dynamics affect urban street tree survival and growth. *Arboriculture & Urban Forestry* 39(4):189–196.
- Jascó, P. 2005. As we may search? Comparison of major features of the Web of Science, Scopus, and Google Scholar citation-based and citation-enhanced databases. *Current Science* 89:1537–1547.
- Jim, C.Y., and H.H.T. Liu. 1997. Storm damage on urban trees in Guangzhou, China. *Landscape and Urban Planning* 38(1–2):45–59.
- Jim, C.Y. 2005. Monitoring the performance and decline of heritage trees in urban Hong Kong. *Journal of Environmental Management* 74:161–172.
- Kirkpatrick, J.B., A. Davion, and G.D. Daniels. 2013. Sinners, scapegoats or fashion victims? Understanding the deaths of trees in the green city. *Geoforum* 48(2013):165–176.
- Klein, R.W., A.K. Koeser, G. Hansen, and F.J. Escobedo. 2019. A review of urban tree risk assessment and risk perception literature. *Arboriculture & Urban Forestry* 45(1): 26–38.
- Ko, Y., J. Lee, E.G. McPherson, and L.A. Roman. 2015a. Factors affecting long-term mortality of residential shade trees: Evidence from Sacramento, California. *Urban Forestry & Urban Greening* 14:500–507.
- Ko, Y., J. Lee, E.G. McPherson, and L.A. Roman. 2015b. Long-term monitoring of Sacramento Shade program trees: Tree survival, growth and energy-saving performance. *Landscape and Urban Planning* 143:183–191.
- Koeser, A.K., R. Hauer, K. Norris, and R. Krouse. 2013. Factors influencing long-term street tree survival in Milwaukee, WI, USA. *Urban Forestry & Urban Greening* 12:562–568.
- Koeser, A.K., E.F. Gilman, M. Paz, and C. Harchick. 2014. Factors influencing urban tree planting program growth and survival in Florida, United States. *Urban Forestry & Urban Greening* 13(4):655–661.
- Koeser, A.K., R.W. Klein, G. Hasing, and R.J. Northrop. 2015. Factors driving professional and public urban tree risk perception. *Urban Forestry & Urban Greening* 14(4):968–974.
- Koeser, A.K., and E.T. Smiley 2017. Impact of Assessor on urban tree risk assessment ratings and prescribed mitigation measures. *Urban Forestry & Urban Greening* 24:109–115.
- Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel. 2006. World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15:259–263.
- Kovacs, K.F., R.G. Haight, R.J. Mercader, and D.G. McCullough. 2014. A bioeconomic analysis of an emerald ash borer invasion of an urban forest with multiple jurisdictions. *Resource and Energy Economics* 36(1):270–289.
- Laçan, I., and J.R. McBride. 2009. War and trees: The destruction and replanting of the urban and peri-urban forest of Sarajevo, Bosnia and Herzegovina. *Urban Forestry & Urban Greening* 8:133–148.
- Lawrence, A.B., F.J. Escobedo, C.L. Staudhammer, and W. Zipperer. 2012. Analyzing growth and mortality in a subtropical urban forest ecosystem. *Landscape and Urban Planning* 104(1):85–94.
- Leers, M., G.M. Moore, and P.B. May. 2018. Assessment of six indicators of street tree establishment in Melbourne, Australia. *Arboriculture & Urban Forestry* 44(1):12–22.
- Leksungnoen, N., W. Eiadthong, and R. Kjelgren. 2017. Thailand's catastrophic flood: Bangkok tree mortality as a function of taxa, habitat, and tree size. *Urban Forestry & Urban Greening* 22:111–119.
- Levine, C.R., F. Krivak-Tetley, N.S. van Doorn, J.-A.S. Ansley, and J.J. Battles. 2016. Long-term demographic trends in a fire-suppressed mixed-conifer forest. *Canadian Journal of Forest Research* 46(5):745–752.
- Levinsson, A., A.-M. Fransson, and T. Emilsson. 2017. Investigating the relationship between various measuring methods for determination of establishment success of urban trees. *Urban Forestry & Urban Greening* 28:21–27.
- Lima, J.M.T., C.L. Staudhammer, T.J. Brandeis, F.J. Escobedo, and W. Zipperer. 2013. Temporal dynamics of a subtropical urban forest in San Juan, Puerto Rico, 2001–2010. *Landscape and Urban Planning* 120:96–106.
- Lines, E.R., Coomes, D.A., and D.W. Purves. 2010. Influences of forest structure, climate and species composition on tree mortality across the eastern US. *PloS One* 5, e13212.
- Lorimer, C.G., S.E. Dahir, and E.V. Nordheim. 2001. Tree mortality rates and longevity in mature and old-growth hemlock-hardwood forests. *Journal of Ecology* 89(6):960–971.
- Lu, J.W.T., E.S. Svendsen, L.K. Campbell, J. Greenfeld, J. Braden, K.L. King, and N. Falxa-Raymond. 2010. Biological, social, and urban design factors affecting young street tree mortality in New York City. *Cities and the Environment* 3(1): article 5, 15 pp.
- Lugo, A.E., and F.N. Scatena. 1996. Background and catastrophic tree mortality in tropical moist, wet and rainforests. *Biotropica* 28:585–599.
- Manion, P.D. 1981. *Tree disease concepts*. Prentice-Hall, Englewood Cliffs NJ.
- Martin, M.P., C. Simmons, M.S. Ashton. 2016. Survival is not enough: The effects of microclimate on the growth and health of three common urban tree species in San Francisco, California. *Urban Forestry & Urban Greening* 19:1–6.
- McPherson, E.G., and J.R. Simpson. 2002. A comparison of municipal forest benefits and costs in Modesto and Santa Monica, California, USA. *Urban Forestry & Urban Greening* 1(2):61–74.

- McPherson, E.G., J.R. Simpson, Q. Xiao, and C. Wu. 2008. Los Angeles 1-Million tree canopy cover assessment. USDA Forest Service, Pacific Southwest Research Station. GTR-207.
- McPherson, E.G. 2014. Monitoring Million Trees LA: Tree performance during the early years and future benefits. *Arboriculture & Urban Forestry* 2014: 285–300.
- McPherson, E.G., and A. Kendall. 2014. A life cycle carbon dioxide inventory of the Million Trees Los Angeles program. *International Journal of Life Cycle Assessment* 19(9):1653–1665.
- Miller, R.H., and R.W. Miller. 1991. Planting survival of selected street taxa. *Journal of Arboriculture* 17(7):185–191.
- Miller, R.W., and M.S. Marano. 1984. URFOR/SIMULATION: an urban forest management computer simulation/game. *Journal of Arboriculture* 10:55–63.
- Miller, F.D., and D. Neely. 1993. The effect of trenching on growth and plant health of selected species of shade trees. *Journal of Arboriculture* 19(4):226–229.
- Mincey, S.K., M. Hutten, B.C. Fischer, T.P. Evans, S.I. Stewart, and J.M. Vogt. 2013. Structuring institutional analysis for urban ecosystems: A key to sustainable urban forest management. *Urban Ecosystems* 16:553–571.
- Morani, A., D.J. Nowak, S. Hirabayashi, and C. Calfapietra. 2011. How to select the best tree planting locations to enhance air pollution removal in the MillionTreesNYC initiative. *Environmental Pollution* 159:1040–7.
- Morgenroth, J., and T. Armstrong. 2012. The impact of significant earthquakes on Christchurch, New Zealand's urban forest. *Urban Forestry & Urban Greening* 11:383–389.
- Morgenroth, J., J. O'Neil-Dunne, and L.A. Apolaza. 2017. Redevelopment and the urban forest: A study of tree removal and retention during demolition activities. *Applied Geography* 82:1–10.
- Nguyen, V.D., L.A. Roman, D.H. Locke, S.K. Mincey, J.R. Sanders, E. Smith Fichman, M. Duran-Mitchell, and S.L. Tobing. 2017. Branching out to residential lands: Missions and strategies of five tree distribution programs in the U.S. *Urban Forestry & Urban Greening* 22:24–35.
- Nowak, D.J. 1986. Silvics of an urban tree species: Norway maple (*Acer platanoides* L.). M.S. thesis. State University of New York, College of Environmental Science and Forestry, Syracuse, NY. 148 pp.
- Nowak, D.J., J.R. McBride, and R.A. Beatty. 1990. Newly planted street tree growth and mortality. *Journal of Arboriculture* 16(5):124–129.
- Nowak, D.J., M.K. Kuroda, and D.E. Crane. 2004. Tree mortality rates and tree population projections in Baltimore, Maryland, USA. *Urban Forestry & Urban Greening* 2:139–147.
- Nowak, D.J., A.R. Bodine, R.E. Hoehne, D.E. Crane, A. Ellis, T.A. Endreny, Y. Yang, T. Jacobs, and K. Shelton. 2013. Assessing urban forest effects and values: The greater Kansas City region. Resource Bulletin NRS-75. USDA Forest Service, Northern Research Station, Newtown Sq., PA. 72 pp.
- Pataki, D.E., M.M. Carreiro, J. Cherrier, N.E. Grulke, V. Jennings, S. Pincetl, R.V. Pouyat, T.H. Whitlow, and W.C. Zipperer. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment* 9:27–36.
- Pickett, S.T.A., W.R. Burch, and S.E. Dalton. 1997. Integrated urban ecosystem research. *Urban Ecosystems* 1:183–184.
- Poland, T.M., and D.G. McCullough. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* Apr/May:118–124.
- Polanin, N. 1991. Removal history and longevity of two street tree species in Jersey City, New Jersey. *Journal of Arboriculture* 17(11):303–305.
- Rhoads, A.F., P.W. Meyer, and R. Sanfelippo. 1981. Performance of urban street trees evaluated. *Journal of Arboriculture* 7(5):127–132.
- Richards, N.A. 1979. Modeling survival and consequent replacement needs in a street tree population. *Journal of Arboriculture* 5:251–255.
- Richardson, E., and C.M. Shackleton. 2014. The extent and perceptions of vandalism as a cause of street tree damage in small towns in the Eastern Cape, South Africa. *Urban Forestry & Urban Greening* 13(3):425–432.
- Rizzo, D.M., and M. Garbelotto. 2003. Sudden oak death: Endangering California and Oregon forest ecosystems. *Frontiers in Ecology and the Environment* 1(4):197–204.
- Roman, L.A., and F.N. Scatena. 2011. Street tree survival rates: Meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA. *Urban Forestry & Urban Greening* 10:269–274.
- Roman, L.A., J.J. Battles, and J.R. McBride. 2014a. The balance of planting and mortality in a street tree population. *Urban Ecosystems* 17:387–404.
- Roman, L.A., J.J. Battles, and J.R. McBride. 2014b. Determinants of establishment survival for residential trees in Sacramento County, CA. *Landscape & Urban Planning* 129:22–31.
- Roman, L.A., L.A. Walker, C.M. Martineau, D.J. Muffly, S.A. MacQueen, and W. Harris. 2015. Stewardship matters: Case studies in establishment success of urban trees. *Urban Forestry & Urban Greening* 14:1174–1182.
- Roman, L.A., J.J. Battles, and J.R. McBride. 2016. Urban tree mortality: A primer on demographic approaches. GTR NRS-158. Newtown Sq., PA: USDA Forest Service, Northern Research Station. 24 pp.
- Roman, L.A., H. Pearsall, T.S. Eisenman, T.M. Conway, R.T. Fahey, S. Landry, J. Vogt, N.S. van Doorn, J.M. Grove, D.H. Locke, A.C. Bardekjian, J.J. Battles, M.L. Cadenasso, C.C. Konijnendijk van den Bosch, M. Avolio, A. Berland, G.D. Jenerette, S.K. Mincey, D.E. Pataki, and C. Staudhammer. 2018. Human and biophysical legacies shape contemporary urban forests: A literature synthesis. *Urban Forestry & Urban Greening* 31:157–168.
- Roy, S., J. Byrne, and C. Pickering. 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. *Urban Forestry & Urban Greening* 11:351–363.
- Roy Chowdhury, R., K. Larson, M. Grove, C. Polsky, E. Cook, J. Onsted, and L. Ogden. 2011. A multi-scalar approach to theorizing socio-ecological dynamics of urban residential landscapes. *Cities & the Environment*. 4(1) Article 6, 19p.
- Sadof, C.S., G.P. Hughes, A.R. Witte, D.J. Peterson, and M.D. Ginzler. 2017. Tools for staging and managing emerald ash borer in the urban forest. *Arboriculture & Urban Forestry* 43(1):15–26.
- Scharenbroch, B.C., D. Carter, M. Bialecki, R. Fahey, L. Scheberl, M. Catania, L.A. Roman, N. Bassuk, R.W. Harper, L. Werner,

- A. Siewert, S. Miller, L. Hutrya, and S. Raciti. 2017. A rapid urban site index for assessing the quality of street tree planting sites. *Urban Forestry & Urban Greening* 27:279–286.
- Sherman, A.R., B. Kane, W.A. Autio, J.R. Harris, and D.P. Ryan. 2016. Establishment period of street trees growing in the Boston, MA metropolitan area. *Urban Forestry and Urban Greening* 19:95–102.
- Siccama, T.G., T.J. Fahey, C.E. Johnson, T.W. Sherry, E.G. Denny, E.B. Girdler, G.E. Likens, and P.A. Schwarz. 2007. Population and biomass dynamics of trees in a northern hardwood forest at Hubbard Brook. *Canadian Journal of Forest Research* 37(4):737–749.
- Sklar, F., and R.G. Ames. 1985. Staying alive: street tree survival in the inner-city. *Journal of Urban Affairs* 7(1):55–66.
- Staudhammar, C., F. Escobedo, A. Lawrence, M. Duryea, P. Smith, and M. Merritt. 2011. Rapid assessment of change and hurricane impacts to Houston's urban forest structure. *Arbiculture & Urban Forestry* 37:60–66.
- Steenberg, J.W.N., P.J. Robinson, and A.A. Millward. 2018. The influence of building renovation and rental housing on urban trees. *Journal of Environmental Planning and Management* 61(3):553–567.
- Stilgenbauer, J., and J.R. McBride. 2010. Reconstruction of Urban Forests in Hamburg and Dresden after World War II. *Landscape Journal* 29(2):144–160.
- Struve, D.K., G. Kaster, and T. Smith. 1995. Tree replacement programs in Ohio. *Journal of Arbiculture* 21(6):296–301.
- Sullivan, M.J. 2005. Survey of 5 and 10 year old trees planted by FUF. Internal Report. Available at <www.sftrees.com>.
- Thompson, J.R., D.J. Nowak, D.E. Crane, and J.A. Hunkins. 2004. Iowa, U.S., communities benefit from a tree-planting program: Characteristics of recently planted trees. *Journal of Arbiculture* 30(1):1–9.
- Urban, J. 2008. *Up by Roots*. International Society of Arbiculture, Champaign, IL 479 pp.
- van Doorn, N.S., J.J. Battles, T.J. Fahey, T.G. Siccama, and P.A. Schwarz. 2011. Links between biomass and tree demography in a northern hardwood forest: a decade of stability and change in Hubbard Brook Valley, New Hampshire. *Canadian Journal of Forest Research* 41(7):1369–1379.
- van Doorn, N.S., and E.G. McPherson. 2018. Demographic trends in Claremont California's street tree population. *Urban Forestry & Urban Greening* 29:200–211.
- VanNatta, A.R., R.J. Hauer, and N.M. Schuettpelz. 2012. Economic Analysis of Emerald Ash Borer (Coleoptera: Buprestidae) Management Options. *Journal of Economic Entomology* 105(1):196–206.
- Vogt, J.M., and B.C. Fischer. 2014. A Protocol for Citizen Science Monitoring of Recently-Planted Urban Trees. *Cities and the Environment* 7:4, 26pp.
- Vogt, J.M., S.L. Watkins, S.K. Mincey, M.S. Patterson, and B.C. Fischer. 2015a. Explaining planted-tree survival and growth in urban neighborhoods: A socio-ecological approach to studying recently-planted trees in Indianapolis. *Landscape and Urban Planning* 136(2015):130–143.
- Vogt, J., S.L. Watkins, S. Widney, and B. Fischer, B., 2015b. The need to standardize at-planting data. *Arborist News* 24:27–13.
- Vogt, J., R.J. Hauer, and B.C. Fischer. 2015c. The Costs of Maintaining and Not Maintaining the Urban Forest: A Review of the Urban Forestry and Arbiculture Literature. *Arbiculture & Urban Forestry* 41(6):293–323.
- Widney, S., B.C. Fischer, and J. Vogt. 2016. Tree mortality undercuts ability of tree-planting programs to provide benefits: Results of a three-city study. *Forests* 7(3):65.
- Woodall, C.W., P.L. Grambsch, and W. Thomas. 2005. Applying survival analysis to a large-scale forest inventory for assessment of tree mortality in Minnesota. *Ecological Modelling* 189:199–208.
- Yang, J., and J. McBride. 2003. A unique method for street tree planting in Beijing. *Arbicultural Journal* 27:1–10.

ACKNOWLEDGEMENTS

We thank the International Society of Arbiculture Science and Research Committee for sponsoring this review. We thank the University of Florida and the University's Center for Landscape Conservation and Ecology (CLCE) for providing graduate student funding. We also appreciate critiques on an earlier version of this manuscript from J. Henning. Lastly, we thank the many researchers who have studied urban tree mortality to advance the state of urban forest science, and the many urban forestry professionals interested in tree mortality and longevity who inspire us to continue this work.

Deborah R. Hilbert (corresponding author)
Department of Environmental Horticulture, CLCE, IFAS
University of Florida—Gulf Coast Research and Education Center
14625 Co. Rd. 672
Wimauma, FL 33598, U.S.A.
dhilbert@ufl.edu

Lara A. Roman
USDA Forest Service
Northern Research Station, Philadelphia Field Station
100 N. 20th St.
Philadelphia, PA 19103, U.S.A.

Andrew K. Koeser
Department of Environmental Horticulture, CLCE, IFAS
University of Florida—Gulf Coast Research and Education Center
14625 Co. Rd. 672
Wimauma, FL 33598, U.S.A.

Jess Vogt
Department of Environmental Science and Studies
College of Science and Health
DePaul University
1110 W Belden Ave.
Chicago, IL 60614, U.S.A.

Natalie S. van Doorn
USDA Forest Service
Pacific Southwest Research Station
800 Buchanan St.
Albany, CA 94710, U.S.A.

Résumé. La survie des arbres constitue une mesure de performance pour toute initiative en foresterie urbaine et une compréhension des facteurs qui ont un impact sur la mortalité peut aider les gestionnaires à cibler les ressources et améliorer leur survie. En outre, les investissements pour la plantation d'arbres urbains ont comme prémisses la survie des arbres afin de maximiser les services écosystémiques attendus. Dans cette revue de littérature, nous avons classé en catégories les facteurs fréquemment associés avec la mortalité des arbres urbains et fait un résumé du taux de mortalité publié dans 56 recherches mettant l'accent sur les études portant sur les arbres d'alignement, ceux dans les cours ainsi que dans les parcs aménagés. Les plans d'étude incluaient le suivi quantitatif sur le terrain de populations d'arbres d'âges différents et l'observation de cohortes d'arbres d'âge uniforme, aussi bien que des analyses qualitatives. Le taux de mortalité annuelle s'élevait à 0.6% à 68.5% pour les études de cohortes et de 0% à 30% pour celles portant sur les populations d'arbres aux âges variés. Les premiers, deuxième et troisième quartiles de mortalité annuelle étaient de 2.8% à 3.8%, de 4.4% à 6.5% et de 7.1% à 9.3% pour les cohortes d'âge uniforme tandis que pour les populations d'âges variés, ils étaient de 1.6%, 2.3% à 2.6% et de 3.0% à 3.3% (ces fourchettes reflètent les études qui signalaient une variation pour le période de temps ou le taux de mortalité). Pour les études de cohorte, la mortalité annuelle tendait à être la plus haute au cours des cinq premières années suivant la plantation. Les facteurs biophysiques les plus couramment mentionnés en association avec la mortalité furent les taxons (15 articles), la dimension ou l'âge des arbres (13 articles) et les caractéristiques du site (12 articles). Les facteurs d'origine humaine les plus couramment mentionnés furent la gestion, l'entretien et le vandalisme (15 articles). Davantage d'études à long terme sont nécessaires afin d'investiguer sur l'influence des caractéristiques du site sur la mortalité, incluant l'examen (rarement pratiqué) du sol et les caractéristiques du microclimat. Les futures recherches devraient également examiner les structures institutionnelles en lien avec les résultats en matière de mortalité, aussi bien qu'avec les facteurs des groupes sociodémographiques et les comportements des résidents.

Zusammenfassung. Das Überleben von Bäumen ist ein Leistungsmaß für urbane Forstinitiativen und ein Verständnis der Faktoren, die die Sterblichkeit beeinflussen, kann den Verantwortlichen helfen, Ressourcen anzusteuern und das Überleben zu verbessern. Darüber hinaus hängen die Investitionen der Baumpflanzung vom Überleben der Bäume ab, um deren Ökosystemleistungen zu maximieren. In dieser Literaturübersicht haben wir Faktoren kategorisiert, die gewöhnlich mit der Sterblichkeit von Straßenbäumen assoziiert werden und die Sterblichkeitsraten, wie sie in 56 Studien publiziert wurden zusammengefasst. Dabei lag der Fokus auf Bäumen entlang von Straßen, in Gärten und Landschaftsparkanlagen. Die Studienkonzepte enthielten quantitative Felderhebungen von Baumpopulationen unterschiedlichen Alters und ein Tracking von gleich alten Baumgruppen, genauso wie eine qualitative Analyse. Die annualen Sterberaten rangierten von 0.6% bis 68.5% bei Jahrgangsbäumen und 0% bis 30% für wiederholte Inventuren von Bäumen ungleichen Alters. Das erste, zweite und dritte Quartil der jährlichen Sterblichkeit war 2.8% bis 3.8%, 4.4% bis 6.5% und 7.1% bis 9.3% für Jahrgangsgruppen; und 1.6%, 2.3% bis 2.6%, und 3.0% bis 3.3% für

wiederholte Inventuren von Bäumen ungleichen Alters (die Spannen reflektieren Studien, die diese Spannen über die Zeitperiode oder die Sterblichkeitsrate berichten). Bei den Jahrgangstudien schien die annuelle Sterblichkeit während der ersten fünf Jahre nach der Verpflanzung am höchsten zu sein. Die meistzitierten biophysikalischen, mit der Sterblichkeit assoziierten Faktoren waren Taxa (15 Artikel), Baumgröße/-alter (13 Artikel) und Standortbedingungen (12 Artikel). Die meistzitierten, mit menschlichem Einfluss verbundenen Faktoren waren Patenschaften, Erhaltung und Vandalismus (15 Artikel). Es werden mehr Langzeitstudien gebraucht, um zu untersuchen, wie sehr die Standortbedingungen die Sterblichkeit beeinflussen, einschließlich der selten untersuchten Boden- und Mikroklimacharakteristika. Künftige Forschung sollte neben soziodemographischen Faktoren und Anwohnerverhalten auch institutionelle Strukturen in Verbindung mit der Mortalität beinhalten.

Resumen. La supervivencia de los árboles es una medida de rendimiento para las iniciativas de silvicultura urbana, y una comprensión de los factores que influyen en la mortalidad puede ayudar a los administradores a orientar los recursos y mejorar la supervivencia. Además, las inversiones en plantación de árboles dependen de su supervivencia para maximizar los servicios de los ecosistemas. En esta revisión de la literatura, clasificamos los factores comúnmente asociados con la mortalidad de árboles y resumimos las tasas de mortalidad publicadas en 56 estudios, centrándonos en los estudios de árboles a lo largo de las calles, en los patios y en los parques paisajísticos. Los diseños de los estudios incluyeron el monitoreo de campo cuantitativo de poblaciones de árboles de edad irregular y el seguimiento de las cohortes de plantación de árboles de edad igual, así como análisis cualitativos. Las tasas de mortalidad anual oscilaron entre el 0.6% y el 68.5% para los estudios de cohortes y entre el 0% y el 30% para los inventarios repetidos de árboles de edad irregular. El primer, segundo y tercer cuartil de mortalidad anual fue 2.8% a 3.8%, 4.4% a 6.5%, y 7.1% a 9.3% para las cohortes de plantación, y 1.6%, 2.3% a 2.6% y 3.0% a 3.3% para inventarios repetidos de árboles de edad irregular (los rangos reflejan estudios que informaron un rango para el período de tiempo o la tasa de mortalidad). Para los estudios de cohortes, la mortalidad anual tendió a ser más alta durante los primeros cinco años después de la plantación. Los factores biofísicos más comúnmente citados asociados con la mortalidad fueron los taxones (15 artículos), el tamaño y la edad de los árboles (13 artículos) y las características del sitio (12 artículos). Los factores relacionados con los humanos más comúnmente citados fueron la administración, el mantenimiento y el vandalismo (15 artículos). Se necesitan más estudios a largo plazo para investigar cómo las características del sitio influyen en la mortalidad, incluidas las características del suelo y el microclima rara vez examinadas. Las investigaciones futuras también deben examinar las estructuras institucionales relacionadas con los resultados de mortalidad, así como los factores sociodemográficos a nivel de parcela y los comportamientos de los residentes.

Appendix Table 1. Urban tree mortality rates for planting cohort monitoring studies.

Time period t is years since planting. Rates were reported directly in the studies, except those with †, which were calculated using data provided in the study. When a range of mortality and time periods were reported, the maximum and minimum values were used in calculations. Cohort studies that provided a range for time since planting are considered multi-year cohorts.

Citation	Location (City and state)	Sample type(s) and sample size (n_o)	Time t (yrs)	Annual mortality q_{annual} (%) [cumulative survivorship l_t (%)]	Study notes
Impens and Delcarte (1979)	Brussels, Belgium	Street trees 1974 (2300) 1975 (3710) 1976 (3148) 1977 (2463)	1	6.5 [93.5†] 10.3 [89.7†] 19.7 [80.3†] 8.7 [91.4†]	Mix of species. Newly planted and inventoried one year after stated planting year.
Rhoads et al. (1981)	Philadelphia, PA	Street trees (unk.)	14	1.2† [85]	
Nowak et al. (1990)	Oakland/Berkeley, CA	Street trees (480)	2	19 [66†]	Paper also provides mortality rates by species.
Miller and Miller (1991)	WI Milwaukee, redeveloped Milwaukee, not redeveloped Stevens Point Waukesha	Street trees (311) (692) (368) (677)	4-6 4-6 4-9 4	10.4-15.8† [51.8] 7.7-11.3† [62] 3.2-7.0† [74.9] 6.5† [76.5]	
Struve et al. (1995)	Multiple communities, OH	Curb lawn and lawn trees	2-3	7.2-10.6† [80]	Paper also provides mortality rates by species and city.
Ip (1996)	Northwest Region, Canada	Mixed 1 yr. old 2 yrs. old 3 yrs. old	1 2 3	10 [90†] 6.7 [87†] 2.7 [92†]	Includes urban, rural, and agricultural trees.
Sullivan (2004)	San Francisco, CA	Street trees (1987) (1869)	5 10	2.9† [86.5] 3.8† [67.9]	
Thompson et al. (2004)	IA, 21 communities	Trees in streets, parks, schoolyards (932)	2-6	6 [91]	Average annual mortality rate reported by source was 6%.
Gates and Lubar (2007)	Philadelphia, PA	Trees in parks and streets, all species (1326)	1-2	3.9-7.7† [92.3†]	
Boyce (2010)	New York City, NY	Street trees in pits With stewardship Without stewardship	≤ 4	1.25 4.17	

Citation	Location (City and state)	Sample type(s) and sample size (n_o)	Time t (yrs)	Annual mortality q_{annual} (%) [cumulative survivorship l_t (%)]	Study notes
Lu et al. (2010)	New York City, NY	Street trees Total (13,405) 3-6 yrs. cohort (2417) 6-8 yrs. cohort (2417) 8-9 yrs. cohort (5935)	3-9 3-6 6-8 8-9	3.2-9.4 [†] [74.3] 4.0-7.9 [†] [78.2] 3.9-5.1 [†] [73] 3.3-3.7 [†] [73.8]	
Roman and Scatena (2011)	Philadelphia, PA	Street trees (151)	2-10	2.4-11.2 [78.8 [†]]	Paper also provides survivorship for different planting years, each being its own cohort.
Koeser et al. (2013)	Milwaukee, WI	Street trees, 0-10 yrs. (793) No construction (391) Construction (402) 11-25 yrs. (895) No construction (686) Construction (219)	10 16	1.8 [†] [83.6] 2.5 [†] [77.9] 1.3 [†] [81.1] 1.2 [†] [82.6]	
Koeser et al. (2014)	FL, various cities	Trees in parking lots, highways, streets, lawns, parks (2354)	2-5	1.3-3.3 [†] [93.6]	Paper also provides survivorship by species.
McPherson (2014)	Los Angeles, CA	street trees (84) park trees (225) yard trees (70)	4-5 3.1 [90.7] 4.6 [77.1]	4.4 [79.8]	
Roman et al. (2014b)	Sacramento, CA	Single-family residential yard trees (370)	5	6.6 [70.9]	
Ko et al. (2015a)	Sacramento, CA	Lawn trees (317)	22	3.8 [42.4]	22-year post-plantin survivorship was 42.4%, taken from survival curve. Proportion of trees surviv- ing out of those actually delivered was 35.3%.
Roman et al. (2015)	East Palo Alto, CA Philadelphia, PA Philadelphia, PA	Street trees (568) (150) (94)	5.92 6.25 6.58	0.6 [96.3] 1.6 [90.7] 4.6 [73.4]	
Vogt et al. (2015)	Indianapolis, IN	Community planted street trees (1345)	2-6	1.9-5.5 [†] [89.4]	
Widney et al. (2016)	Detroit, MI Indianapolis, IN Philadelphia, PA	Street trees (4059)	3-5	7 [79] 7 [80] 13 [59]	Authors used half-years to designate the difference between fall and spring plantings.
Yang and McBride (2003)	Beijing, China	Street trees	11 wks.	68.5 [†] [75 [†]]	Severely pruned prior to transplanting.

Appendix Table 2. Urban tree mortality rates for repeated inventory studies of uneven-aged trees.

Time period t is years since planting. Rates were reported directly in the studies, except those with †, which were calculated using data provided in the study. When a range of mortality and time periods were reported, the maximum and minimum values were used in calculations.

Citation	City and state	Sample type(s) and sample size (n_o)	Time t (yrs)	Annual mortality q_{annual} (%)	Study notes
Impens and Delcarte (1979)	Brussels, Belgium	Street trees 1974 (75,653) 1975 (80,493) 1976 (82,374) 1977 (81,581)	1	2.8 2.6 3.3 1.9	
Dawson and	Urbana, IL	Street trees (1768)	50	1.1	
Nowak (1986)	Syracuse, NY Syracuse and Rochester, NY	Street trees (1454) Street trees (1160)	7 9	2.4† 2.3†	Paper also provides mortality rates for species, dbh, curbing, strip width, situation, adjacent land use, utilities, crown, ground disturbance, and condition.
Miller and Neely (1993)	Champaign, IL	Street trees, campus and city parkways (98)	5	1.5†	Trenched in 1987, annual growth and mortality data collected through 1991.
Hauer et al. (1994)	Milwaukee, WI	Street trees	10	2.3	Compared survival of street trees damaged by construction to those not damaged during 1981-1985.
Hickman et al.	Lodi, CA	Park trees (695)	7	1.28	
Nowak et al. (2004)	Baltimore, MD	All trees (1396) Transportation (33) Commercial/ industrial (15) Urban open (228) High density residential (77) Forest (728) Low-medium density residential (136) Institutional (4) Barren (7)	2	6.6 20.2 10.6 8.2 6.0 5.9 2.2 0 0	Paper also provides mortality for dbh class, condition, and species.
Jim (2005)	Hong Kong, China	Heritage trees in parks	10	1.5†	Performed post-mortem assessments to explain possible relationships between predisposing factors and eventual tree loss.
Boyce (2010)	New York City, NY	Street trees in pits With stewardship Without stewardship	> 4	0.49 1.9	Paper also provides mortality rates for new and established trees based on growing season.

Citation	City and state	Sample type(s) and sample size (n_o)	Time t (yrs)	Annual mortality q_{annual} (%)	Study notes
Staudhammer et al. (2011)	Houston, TX	All trees (305)	8	4.7	Paper also provides mortality rates for different size classes and a graph of average hurricane-related and non-hurricane mortality rates for these land use categories: developed low intensity, developed high intensity, developed open, woody wetlands.
Lawrence et al. (2012)	Gainesville, FL	All trees (754) Commercial Forest Institutional Residential	3-4	9.97 3.12 5.41 19.2 9.12	
Jack-Scot et al. (2013)	New Haven, CT	Community planted trees	4-16	1.9-7.3 [†]	
Lima et al. (2013)	San Juan, Puerto Rico	All trees (244)	9	30	Paper provides a graph of average annual plot-level mortality rates for these land use categories: commercial/industry/institution/transportation, residential, vacant, mangrove forest, upland secondary forest.
Roman et al. (2014a)	Oakland, CA	Street trees (995)	5	3.7	
Escobedo et al. (2016)	Santiago, Chile	Urban trees in inventory plots Broadleaf-deciduous (476) Broadleaf-evergreen (210) Conifer (43) Palm (20)	12 2.99 2.98 3.29 2.92		Inventory of plots on different land use classes: residential, commercial/industrial, green areas, agriculture, transportation.
Martin et al. (2016)	San Francisco, CA	Street trees <i>Arbutus</i> (135) <i>P. cerasifera</i> (136) <i>P. serrulata</i> (122)	17-2 2	1.2-1.5 [†] 1.1-1.5 [†] 2.0-2.6 [†]	
Boukili et al. (2017)	Cambridge, MA	Street trees (592)	3	3.6	This is the citywide annual mortality. Average street segment mortality is 6.7%.
Steenberg et al. (2018)	Toronto, Canada	Yard, street, public ROW (806)	6-7	2.6-3.0 [†]	
van Doorn and McPherson (2018)	Claremont, CA	Street, 21 species (community-level) (732)	14	1.03	The stated 1.03% is the “community-level median removal rate.”

Appendix Table 3. Statistically significant factors associated with mortality.

Results from cohort monitoring studies (C), repeated inventories (RI), and other study designs (O) that qualitatively examined associated factors. Time period *t* is years since planting. Factors followed by (+) had a positive correlation with survival. Factors followed by (–) had a negative correlation with survival. Factors followed by (/) were examined, but a nonsignificant relationship with survival was observed. Factors followed by (varies) had a more complex relationship (e.g., mortality differences for three or more species).

Citation	Location (City and state)	Sample type(s) and sample size (<i>n</i> _o)	Time <i>t</i> (yrs)	Significant factors
Gilbertson and Bradshaw (1985) ^O	England, multiple communities	N/A (10,000)	N/A “newly planted”	Human – Larger town size (–), new town (+)
Hickman et al. (1995) ^{RI}	Lodi, CA	Park trees (695)	7	Biophysical – Decline (–), trunk vigor (+), lean (–); higher risk rating for soil (/), wind (/), root (/), and butt (/) Human – Irrigation frequency (/)
Nowak (1986) ^{RI}	Syracuse, NY	Street trees (1454)	7	Biophysical – Total sample: <i>Acer saccharum</i> (–), <i>Acer platanoides</i> (+), strip width (/) Human – Total sample: curbing (/), type of utility wires (/), adjacent land use (/)
	Syracuse and	Street trees (1160)	9	Biophysical – Total sample: crown closure on 3 sides (+); <i>Acer platanoides</i> : decline class 1.0 (+), class 2-5 (–) Human – All maples: pruning (–); <i>Acer platanoides</i> : 1976 ground disturbance (–)
Nowak et al. (1990) ^C	Oakland/ Berkeley, CA	Street trees (480)	2	Human – Apartments (–), public greenspace (–), single family residence (+), subway station (+), unemployment rate (–)
Miller and Miller (1991) ^C	WI	Street trees		Biophysical – Taxa (varied), planted in fall season (+) (Waukesha only)
	Milwaukee, redeveloped	(311)	4-6	Human – Redeveloped area (–) vs. non-redeveloped area (+)
	Milwaukee, not redeveloped	(692)	4-6	
	Stevens Point	(368)	4-9	
Hauer et al. (1994) ^{RI}	Waukesha	(677)	4	
	Milwaukee, WI	Street trees	10	Human – Construction (–)
Duryea et al. (1996) ^O	Construction damage	(432)		
	No construction damage	(413)		
Duryea et al. (1996) ^O		Trees on streets and in yards after storm	N/A	Biophysical – Taxa (varies), nativity (+), size within species group (varies) Human – Pruning (varies)
		(18,200)		
Nowak et al. (2004) ^{RI}	Baltimore, MD	Trees within various land use classes (1396)	2	Biophysical – <i>Morus alba</i> , <i>Ailanthus altissima</i> , <i>Cornus florida</i> , <i>Acer negundo</i> (–), dbh class of 0-7.6 cm (–) and 30.6-45.7 cm (+), tree condition of poor, critical, or dying (–), tree condition of excellent (–) Human – Transportation (–), low-med. residential (+)

Citation	Location (City and state)	Sample type(s) and sample size (<i>n</i>)	Time <i>t</i> (yrs)	Significant factors
Thompson et al. (2004) ^C	IA, 21 communities	Trees in streets, parks, school-yards (932)	2-6	Biophysical – Taxa (/) Human – Quadrant (/), community size (/), project site location (/)
Jim (2005) ^{RI}	Hong Kong, China	Heritage trees in parks and roadsides (380)	10	Biophysical – Public greenspace habitat ² (–), roadside (–) Human – Open space (–), government (–), institutional (–), community (–)
Duryea et al. (2007) ^O	FL, various cities	Trees on streets and in yards after storm (18,200)	N/A	Biophysical – Taxa (varies), nativity (/), wood density (+), crown density (+), decurrent growth form (+), growing in cluster (+)
Boyce (2010) ^{C,RI}	New York City, NY	Street trees in pits With stewardship Without stewardship	≤ 4 (mixed-aged cohort) > 4 (repeated inventory)	Human – Stewardship (+)
Lu et al. (2010) ^C	New York, NY	Street trees		Biophysical – Taxa: <i>Pyrus calleryana</i> (+) Human – Industrial (–), open space (–), vacant (–), one- and two-family residential (+), stewardship index (+), low traffic area (+), tree pit enhancement (+)
		Total (13,405)	3-9	
		3-6 yrs. cohort (2417)	3-6	
		6-8 yrs. cohort (5053)	6-8	
		8-9 yrs. cohort (5935)	8-9	
Staudhammer et al. (2011) ^{RI}	Houston, TX	Trees within various land use classes ¹ (305)	8	Biophysical – Tree density (–), hurricane (–), developed open space (–), developed high-density (–)
Jack-Scott (2012) ^C	Philadelphia, PA	Community planted trees	~1-5	Biophysical – Taxa: <i>P. virginiana</i> and <i>Platanus × acerifolia</i> (+), <i>C. canadensis</i> (–) Human – Street traffic intensity (–)
Lawrence et al. (2012) ^{RI}	Gainesville, FL	Various land use classes (754)	3-4	Biophysical – Tree density (–), <i>Quercus nigra</i> and <i>Q. laurifolia</i> (–) Human – Institutional (–), commercial (+)
Jack-Scott et al. (2013) ^{RI}	New Haven, CT	Community planted trees (1393)	4-16	Biophysical – Tree age (–) Human – Percent homeownership (varies), group experience (+), group longevity (+), group size (varies), group type (varies)

Appendix Table 3. (continued)

Citation	Location (City and state)	Sample type(s) and sample size (<i>n_o</i>)	Time <i>t</i> (yrs)	Significant factors
Koeser et al. (2013) ^c	Milwaukee, WI	Street trees, 0-10 yrs. (793) No construction (391) Construction (402) 11-25 yrs. (895) No construction (686) Construction (219)	10 16	Biophysical – Taxa: <i>Gleditsia triacanthos</i> (+), <i>Acer saccharum</i> (–), trunk diameter (–), planting space width (+), tree condition (+) Human – Adjacent to construction (–)
Lima et al. (2013) ^{RI}	San Juan, Puerto Rico	Various land use classes (244)	9	Biophysical – Species nativity (varies), grass cover (+), species height, dbh, and CLE value (+), street tree (–), forested plots (+) Human – Higher income neighborhoods (+), higher neighborhood population (–)
Koeser et al. (2014) ^c	FL, various cities	Trees in parking lots, highways, streets, lawns, parks (2354)	2-5	Biophysical – Nursery stock: irrigated container-grown trees (+), taxa (varies) Human – In-ground irrigation (+)
Roman et al. (2014a) ^{RI}	Oakland, VA	Street trees (995)	5	Biophysical – Larger tree dbh (+), better foliage health rating (+) (for smallest size class), planted in sidewalk cut-out (vs. strip) (+)
Roman et al. (2014b) ^c	Sacramento, CA	Single-family residential yard trees (370)	5	Biophysical – Species water use demand (–), planted in front yard (+), planted in rainy season (+), mature tree size (–), days since planting (–) Human – Homeowner stability (+), maintenance rating (+), number of trees delivered (–), neighborhood income (varies), neighborhood educ. attainment (+)
Ko et al. (2015a) ^c	Sacramento, CA	Lawn trees (317)	22	Biophysical – Planted in backyard (–), small mature tree size (–), planted in rainy season (–) Human – Highest and lowest net property values (–), unstable homeownership (–), number of trees delivered (–)
Vogt et al. (2015a) ^c	Indianapolis, IN	Community planted street trees (1345)	3-6	Biophysical – Number of trees planted in project (–), fall planting season (–), percent impervious surface (–), planting year (+), nursery 3 (varies) Human – Median household income (\$1000) (+), percent renter occupied homes (+), percent moved in last 5 years (+), watering strategy (varies), watering strategy × fall planting (–)
Conway (2016) ^o	Mississauga, Canada	Survey of residents	N/A	Human – Neighborhood (/), length of residency (/), ownership status (/), university education (/), resident age (/), income (/), ethnicity (/)

Citation	Location (City and state)	Sample type(s) and sample size (<i>n</i>)	Time <i>t</i> (yrs)	Significant factors
Martin et al. (2016) ^{RI}	San Francisco, CA	Street trees on right-of-way	17-22	Biophysical – Tree health (/), tree age (/), microclimate (/)
Boukili et al. (2017) ^{RI}	Cambridge, MA	Street trees (592)	3	Biophysical – <i>A. platanoides</i> , <i>A. rubrum</i> , and <i>T. cordata</i> (+), initial tree diameter (/), percent permeable surface (/), growing season solar insolation (/) Human – Street segment (/)
Morgenroth et al. (2017) ^O	Christchurch, New Zealand	Mixed land use classes (1209)	n/a	Biophysical – Small trees (–), small trees closer than 0.7 m to demolished building (–), large trees closer than 20 m to driveway (–)
Steenberg et al. (2017) ^{RI}	Toronto, Canada	Yard, street, public ROW (806)	6-7	Human – Presence and number of building permits (–), multi-unit housing (street-level scale) (–)
van Doorn and McPherson (2018) ^{RI}	Claremont, CA	Street trees, 21 species (community-level) (732)	14	Biophysical – Tree size (/), tree condition (/), growing space (/) Human – Presence of overhead utility lines (+), sidewalk damage (/)

¹Staudhammer et al. (2011) conceptualize “developed open space” and “developed high-density” as “land use” categories, but for the purposes of consistency here, we consider these to be biophysical descriptions of the site (i.e., “Site characteristics” in Table 3 in the main text).

²Jim (2005) uses “public greenspace” to describe the planting habitat, which is biophysical in nature. Others (e.g., Nowak et al. 1990) use this term to describe a human-related land use category. We acknowledge discrepancies between terminologies and how authors used them, but chose to keep the wording for factors and their categorization the same as the original publication in order to best summarize the literature.

Appendix Table 4. Life table based on the mortality rates of planting cohort monitoring studies.

The worse-than-normal survivorship column uses the 75th percentile annual mortality rates, the middle-of-the-road survivorship column uses the 50th percentile values, and the better-than-normal survivorship column uses the 25th percentile values. When studies provided a range for the time period, we used the lower value and higher values of time to calculate the lower and higher mortality rates, respectively. The first five years used establishment mortality rates, while years 6+ used post-establishment rates. Approximate population half-lives are **bolded**.

Years since planting	Better-than-normal survivorship		Middle-of-the-road survivorship		Worse-than-normal survivorship	
	Lower	Higher	Lower	Higher	Lower	Higher
0	100.0	100.0	100.0	100.0	100.0	100.0
1	96.0	95.0	93.4	93.0	90.7	89.6
2	92.2	90.2	87.2	86.5	82.2	80.2
3	88.6	85.7	81.5	80.4	74.6	71.9
4	85.1	81.4	76.1	74.8	67.6	64.4
5	81.7	77.3	71.1	69.6	61.3	57.7
6	80.5	76.1	69.1	67.0	59.0	54.9
7	79.3	75.0	67.2	64.4	56.7	52.3
8	78.1	73.8	65.4	62.0	54.6	49.9
9	76.9	72.7	63.6	59.7	52.5	47.5
10	75.8	71.6	61.8	57.4	50.5	45.3
11	74.6	70.5	60.1	55.3	48.6	43.1
12	73.5	69.4	58.5	53.2	46.7	41.1
13	72.4	68.4	56.8	51.2	44.9	39.1
14	71.3	67.3	55.3	49.3	43.2	37.3
15	70.3	66.3	53.8	47.4	41.6	35.5
16	69.2	65.3	52.3	45.6	40.0	33.9
17	68.2	64.3	50.8	43.9	38.5	32.3
18	67.2	63.3	49.4	42.3	37.0	30.7
19	66.1	62.3	48.1	40.7	35.6	29.3
20	65.2	61.4	46.7	39.2	34.3	27.9
21	64.2	60.4	45.5	37.7	33.0	26.6
22	63.2	59.5	44.2	36.3	31.7	25.3
23	62.3	58.6	43.0	34.9	30.5	24.1
24	61.3	57.7	41.8	33.6	29.3	23.0
25	60.4	56.8	40.7	32.3	28.2	21.9
26	59.5	56.0	39.5	31.1	27.1	20.9
27	58.6	55.1	38.4	29.9	26.1	19.9
28	57.7	54.3	37.4	28.8	25.1	18.9
29	56.9	53.5	36.4	27.7	24.2	18.0
30	56.0	52.6	35.4	26.7	23.2	17.2
31	55.2	51.8	34.4	25.7	22.4	16.4
32	54.4	51.0	33.4	24.7	21.5	15.6
33	53.6	50.3	32.5	23.8	20.7	14.9
34	52.8	49.5	31.6	22.9	19.9	14.2
35	52.0	48.7	30.7	22.0	19.1	13.5
36	51.2	48.0	29.9	21.2	18.4	12.9
37	50.4	47.3	29.1	20.4	17.7	12.3
38	49.7	46.5	28.3	19.6	17.0	11.7
39	48.9	45.8	27.5	18.9	16.4	11.1
40	48.2	45.1	26.7	18.2	15.8	10.6

TREE REMOVAL REPORT

	2014	2015	2016	2017	2018	2019	2020	2021	TOTALS
EXISTING	376	329	315	409	341	225	451	85	2531
NEW HOMES	1724	886	990	2332	2096	820	762	765	10375

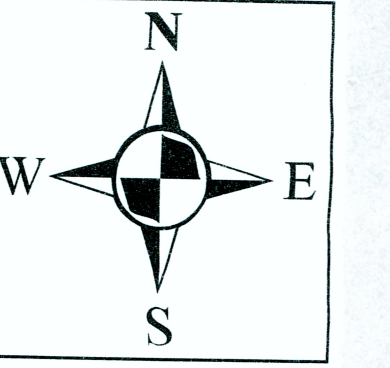
TOTAL REMOVED	12906
Average per year	1613.25

* This data was gathered through reports from created from the IMS system (from 2014 to 2018) and Energov (from 2019 to 2021 YTD)

FUTURE PLANTING PROJECTS – 2021-2022

Hickory Corridor, ROW (planned)	Along Hickory Street Park and leading into Greenway between Shell Cove and Egans Creek	Planned (150 trees)
Baptist Church, Hickory Street	To be contacted	
Housing Authority, Hickory Street	On-going project	
Amelia Oaks Road, Retention Ponds	To be contacted	
Main Beach Parking lot (planned)	Replacement of concrete island with curbed landscaped beds for trees and cabbage palm and muhly grass	Planned
Sunrise Park, ROW		
Franklin Street, ROW		
Central Park, ROW		
Lighthouse grounds		
Egans Creek Park		
Atlantic Rec Center		
MLK Center		
Peck Center		
Jasmine + Lime Streets	City Maintained Side / Coordinated with adjoining property owners	
S. 10 th + S. 11 th Streets	Along Date, Elm, Fir and Hickory Streets	
1303 Jasmine Street	In front of Barnabas	
<i>Open Space Opportunities</i>	<i>Apartment Complexes receiving HUD funding</i>	
<i>CES 2019 data</i>	<i>Find where City needs to focus tree replacement efforts</i>	

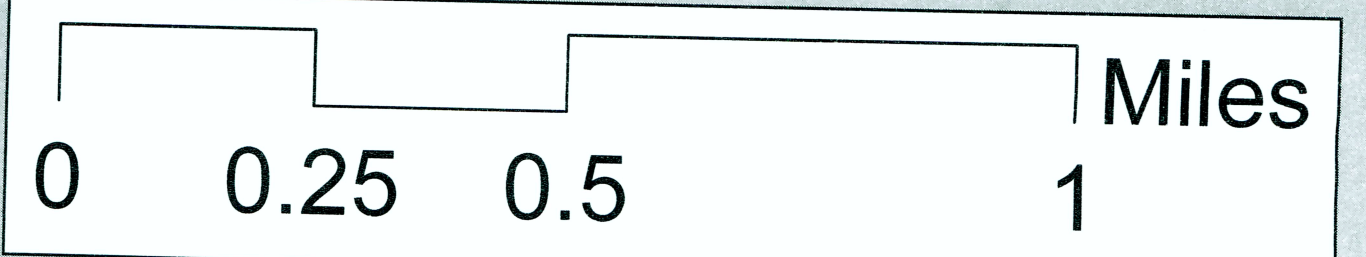
City Right of Way - Tree Planting Opportunity?



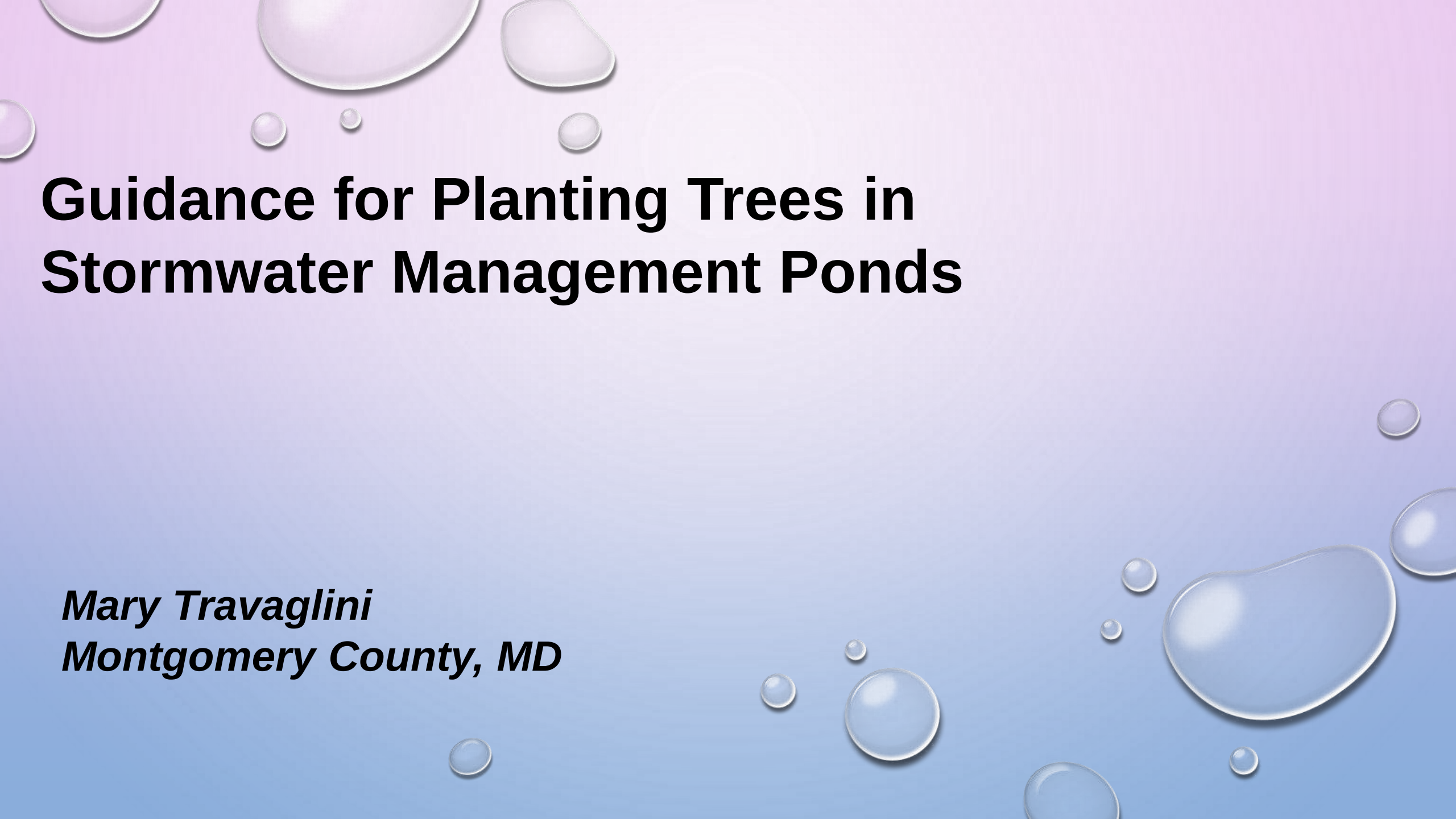
Choose
your
AREA

ATE

- Matt Acklin
- David Jensen
- TAMMI ROSACK
- JOHN HILLMAN
- Lynda Bell
- Lisa Finkelstein



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNR/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Guidance for Planting Trees in Stormwater Management Ponds

***Mary Travaglini
Montgomery County, MD***



**First understand your pond, and
what it's for...**

**Stormwater function will take priority over any habitat
value, aesthetics, or recreation.**

Sorry.



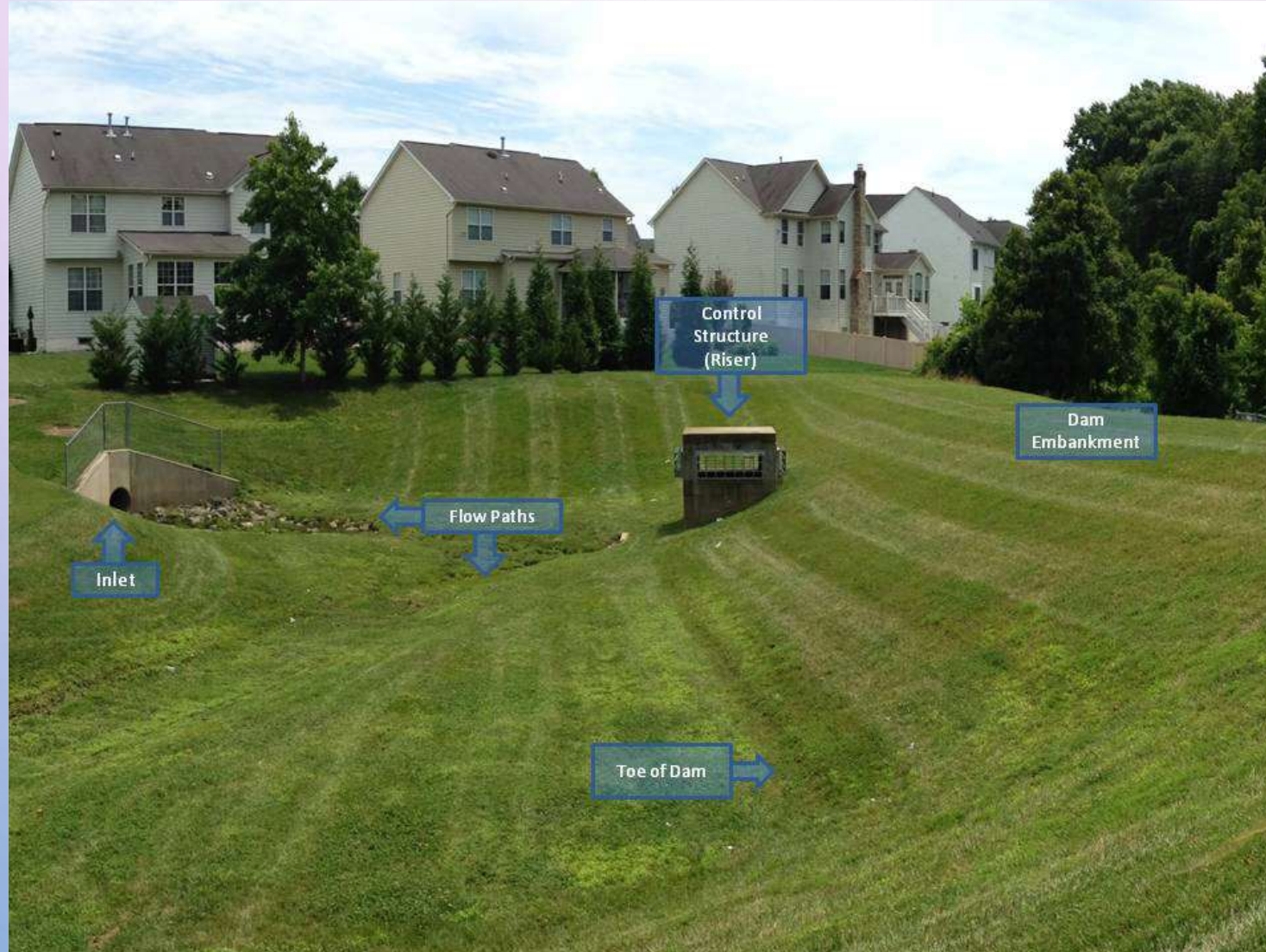
Dry or wet? Different opportunities



How a stormwater pond works



Critical features that constrain planting



What plants can do that ponds cannot do alone (go biology, go!)

- *Infiltrate water—roots loosen soil and provide channels*
- *Evapotranspiration*
- *Pollutant transformation through soil biology*
- *Shade and cool runoff*



Other benefits of planting

- *Habitat (including predator habitat)*
- *Aesthetics*
- *Reduce mowing*
- *Buffer toxic runoff*
- *Prevent erosion*
- *Reduce geese*



Where can you (not) plant? General guidance



Where can you (not) plant?—Control structure, inlets, outlets

Stay 25' away, plus
outfall pipes



Keep flowpaths
clear



Don't block inlets



Where can you (not) plant?—Dam embankments



Where can you (not) plant?—Sand filter bottoms



No planting in sand filters or over pipes

Great opportunities to plant—pond slopes



Great opportunities to plant—dry bottoms



Great opportunities to plant—wet edges



Floating islands



Types of plants/opportunities

Native plants when possible

Wet edges

- Need to handle some drought/low water levels
- Can be subject to salt or pesticides

Dry bottoms

- Will be temporarily submerged
- Most susceptible to maintenance activity damage

Shallow water

- Emergent aquatics
- Do not use invasives

Pond Slopes

- Dry conditions



Lofty Goals...



How to maximize a limited budget?

- ***Reduce water temperature on edges of wet ponds, or wet channels***
- ***Choose locations that block or enhance views***
- ***Choose trees***
- ***Dense edge plantings to reduce geese***
- ***Funding support from grant or municipal resources***

How much planting makes a difference?



Deer, beaver, geese, ducks, humans-- protection



Maintenance and inspection

- *No mulching*
- *Remove heavy leaf accumulations and debris*
- *Low flow drains may need more frequent cleaning*
- *Monitor and remove invasives*
- *Keep access paths clear*
- *Keep dams mowed*
- *Remove captured trash*
- *Weeding*

Some good pond “plantings”













This guidance document provides information to property owners who want to plant around their existing stormwater management pond.

A Montgomery County Owner's Guide To Adding Plantings Around Your Stormwater Pond

This guide answers the following questions as well as provides examples and additional resources:

- Why?** Why should I add plantings?
- Where?** Where am I allowed to plant?
- What?** What should I plant?
- How?** How should I plant?
-  Planted pond example



Working together for a cleaner, greener economically vibrant community

Stormwater Facility Maintenance Program
www.montgomerycountymd.gov/stormwater

Plant lists

What?

Many native plants adapt well to pond conditions. Listed below are just some of the plant species you might consider for stormwater ponds in Montgomery County.

Selecting plants

When possible, choose native plants that have adapted to the local climate, rainfall, and soil conditions. For plant selection, visit:

Native Plants for Wildlife Habitat and Conservation
Landscaping: Chesapeake Bay Watershed
<http://www.fish.gov/conservation/landscaping/>
The National Park Service's "Plant Lists for Maryland Regions"
<http://www.nps.gov/plants/landscaping/MD/MD.htm>

Plants for wet edges:

Trees

Acer rubrum (Red maple)
Platanus (American sycamore)
Salix (Willow)
Taxodium (Bald cypress)

Shrubs

Caprillastrum (Blackberry)
Cornus amomum (Silky dogwood)

Grasses and flowers

Andropogon scoparius (Coville reedgrass)
Carex (Sedge), Juncus, Iris, and other wet sedges
Eupatorium dubium or purpureum (Joe-Pye weed)
Helianthus maximiliani (Swamp rose mallow)
Iris versicolor (Blueflag)
Juncus (Rush)

Plants for drier edges:

Grasses and flowers

Iris versicolor (Blueflag)
Andropogon scoparius (Coville reedgrass)
Carex (Sedge), Juncus, Iris, and other wet sedges
Eupatorium dubium or purpureum (Joe-Pye weed)
Helianthus maximiliani (Swamp rose mallow)
Iris versicolor (Blueflag)
Juncus (Rush)

A Montgomery County
2014 - Montgomery

What should I plant?

Select native plants to encourage aquatic habitats

Aquatic plants filter out pollutants, produce oxygen, and provide food, shelter, and breeding sites for fish, amphibians, pollinators, birds, and mammals. Vegetative buffers around stormwater management facilities prevent disruptive soil erosion, prevent herbicides and pesticides from entering the pond, and provide habitat for a variety of wildlife. Buffers can extend into the pond using emergent wetland plants.



A plant buffer zone along the pond's edge can discourage geese and reduce nutrient flow into the pond, which helps to minimize algae blooms and mosquito breeding.

Design plantings to enhance habitat

A well-functioning wet pond or constructed wetland maintains a healthy, living ecosystem. It supports a diverse population of fish and other aquatic animals, such as birds, bats, and amphibians, maintains water with adequate and stable levels of oxygen, has stable banks, and is surrounded by adequate plant cover. Buffers discourage geese (that prefer open shorelines) and trap nutrients from herbicides, pathogens from animal droppings, and toxins from pesticides.

Prevent mosquitoes

Native plants attract wildlife such as dragonflies that are natural predators of mosquitoes. Petals, seed pods, and green droppings can lead to algae blooms and kill submerged aquatic vegetation, which can increase mosquito breeding in ponds. A pond with a healthy ecosystem will naturally reduce or eliminate mosquito larvae.



Native plants such as viburnum (shown) and cornus (shown) will help your pond site blend well into the surrounding natural environment.



Floating islands

A floating island of plants can help beautify your pond and absorb pollutants from stormwater runoff, reducing algae problems. The roots provide a biological filter for disease transmission of harmful microorganisms, and bacteria colonies growing on the roots absorb the water of nutrients, suspended solids, and some heavy metals. These same nutrients provide the food source that the plants need for growth. The result is a "naturalized ventricle" effect. These islands are usually anchored in place.

Where can I plant in and around ponds?

Where?

Planting Dos and Don'ts

Don't Plant Trees or Shrubs in These Places

Around the control structure, inlets, and outlets

Do not plant trees or shrubs on dam embankments or within 15 feet of the toe (bottom) of the embankment, or within 10 feet of the rise or other structure.

Dam embankment

Only plant turf grass on the pond side of the embankment. The pond dam embankment is required to be mowed at least twice a year. No decorative rocks or structures may be placed on an embankment. If any structures designed for erosion control may be the embankment.

Do Plant Native Non-Woody Plants Here

Pond side slopes (outside of the dam embankment)

Plant lower areas with plants tolerant of frequent flooding. Plants used in higher areas should be tolerant of less frequent flooding and drier conditions. If planting below the flooding elevation, don't use mulch, as it will wash away during storms.

Refer to the drawing of a planted dry pond on page 12 to visualize what a pond might look like when it is well planted.

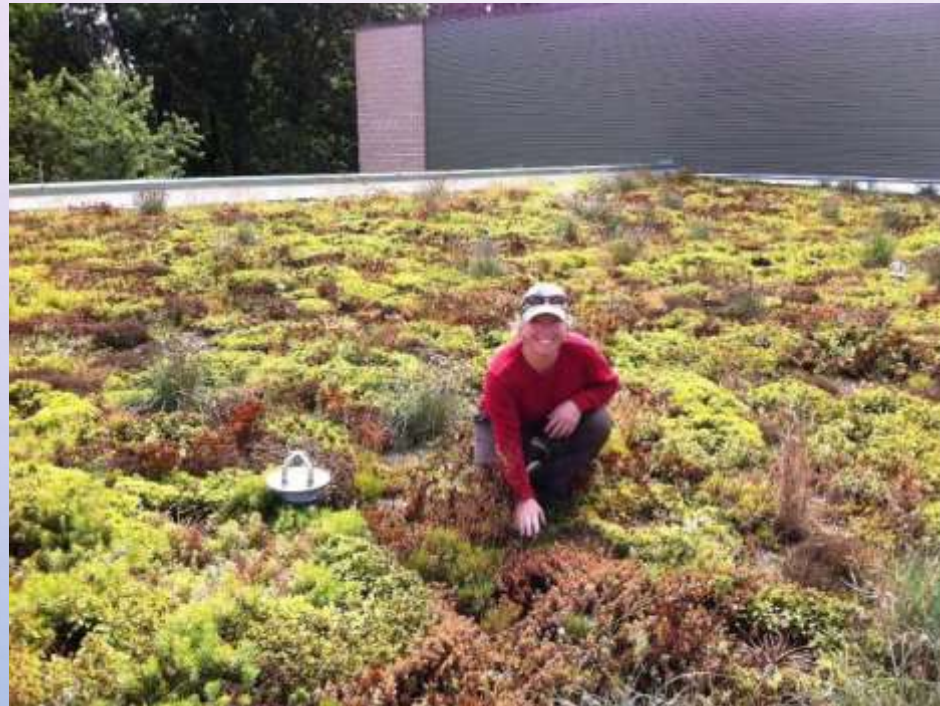


is shown in red are off-limits for trees and shrubs. It may be planted on dam embankment, which must be mowed twice-a-year.

By Planting Around Your Pond
Source: Department of Environmental Protection, Stormwater Facility Maintenance Program | www.montgomerycountymd.gov/stormwater

Questions/Comments?

montgomerycountymd.gov/stormwater



Mary.Travaglini@montgomerycountymd.gov

LDC Code-based Amendments

Current Code Section	Current Code	Proposed Amendment	Benefit of Amendment
10.03.01	“A reduction in a dimensional standard, other than a setback...”	Allow for deviation from standard setback requirements, when such a deviation would preserve a protected tree	Removes the need for a Variance. Homeowners are more likely to pursue this less expensive and less time-consuming process. It will also promote environmentally friendly designs.
1.07.00 (B)	“Protected tree means any existing, healthy tree having a five (5) inch DBH, or greater and not identified on the most recent Florida Exotic Pest Plant Council Invasive Plant list (Category I or II) and any tree that was planted or preserved in compliance with an approved development order or to mitigate removal of a protected tree.”	Include any newly planted trees as part of the LDC’s minimum landscape requirements.	Reinforces section 4.05.03(E)(3)
4.05.10	“All wet detention ponds shall incorporate a combination of aquatic and non-aquatic native plants...”	Require a minimum of one (1) 2.5” DBH water-tolerant tree per 50 linear feet of pond frontage. Creating clusters of trees is permissible so long as the minimum requirements are met. A 5 FT barrier at 3” deep, created by mulch or other natural material, must be placed around each tree and/or cluster	Softens the landscape, allows for better absorption of stormwater, filter runoff, additional wildlife habitats,
4.05.14 (D) (4)	An applicant shall be permitted to pay a fee to the City Tree Replacement Fund for up to fifty (50) percent of the cumulative DBH of protected trees removed, less the credits accumulated	Maintain the \$500 Tree Removal Fee for the first 3 trees, but increase “Each Additional Tree” fee from \$100 to \$150	Revised fee is more in line with what it would currently cost the City to replace removed trees

	from preservation of trees on the site. The fee will be set by resolution of the City Commission and will be based on the average cost for the City to replace the tree with the same species, excluding invasive species, the fiscal year in which the permit is issued.		
Table 4.02.01(J)	Maximum impervious surface ratio for residential lots is currently 60%.	Reduce Impervious Surface Ratio to 45% for all residential development. Applies to zoning districts R-1, R-2, RLM, R-3, and MU-1 and MU-8 where exclusively residential is developed.	Encourages greater tree preservation, increases open space, minimizes impervious surfaces.
No current code section	N/A	Require permits for all concrete slabs and all pavers exceeding 50 square feet.	Provides a method for ensuring LDC compliant impervious surface ratios, oversight of lot coverage
4.05.05(A)&(B)	Single-family and Two-family Residential Development Single-family and two-family development shall include, at a minimum, one (1) shade tree for every 2,500 square feet of lot area or fraction thereof. Multi-family Residential Development 1. There shall be not less than one (1) shade tree for each 1,500 square feet, or fraction thereof, of development site.	Single-family and Two-family Residential Development Increase the minimum landscape requirement to 2 native trees per 2500 sq. ft. Multi-family Residential Development Increase the minimum landscape requirement to 2 native trees per 1500 sq. ft.	Greater diversification of native species, doubles the total number of trees required per lot.

No current code section	N/A	Existing healthy trees onsite that are 2.5 inches DBH or greater and at least 8 ft. tall that are relocated and that would otherwise be removed from the site because of development may be utilized as credit towards the assessed mitigation, if relocated onsite.	Preserving well established trees and existing mature canopy onsite.
No current code section	N/A	At the property owner's expense, they must analyze the condition of each tree, 3 years after the tree was preserved, relocated, or planted. Assessment may be provided in the form of an arborist evaluation or onsite inspection performed by the City. This analysis must be submitted to the city for inspection and approval within 30 days of being made. Should any tree die or be in a state of decline within 3 years of being preserved, planted, or relocated, the property owner must be required to replace the tree within 60 days of that determination. The three-year monitoring and approval period must begin anew whenever a tree is replaced. If that replacement tree is found not to be viable at the end of the second monitoring period, the property owner can pay the appropriate amount into the tree fund in lieu of planting a third replacement tree. If the property owner fails to replace the tree or to pay the appropriate amount into the tree fund within 60 days, the property owner will be in violation of this chapter. The City has the authority during the required 3-	An enforcement mechanism to ensure mitigation and landscape trees are compliant with the code. Upon approval this section would become a sub-section of 4.05.03(E)(3).

		year maintenance period to conduct on-site maintenance inspections subsequent to final inspection and notice of completion, and to require correction of all deficiencies and violations. Note: To create a stamp with this language on all landscape plan approvals at time of permitting.	
4.05.03(E)(3)	Replacement trees shall be maintained and warranted to survive for a period of one (1) year from installation. Trees which do not survive one (1) year must be replaced with new trees of the same size. Replacement trees shall comply with the same maintenance and replacement warranty as the original replacement tree(s) and the warranty period will restart at the date of planting.	Expand the minimum tree health guarantee timeframe from 1 to 3 years.	Encourages healthy tree maintenance, allows for longer tree establishment period
No current code section	N/A	Incorporate specific language relating to tree trust fund.	Provide clarification of fund usage within the LDC.

TREE PLANTING RECORD 2018-2021

(LAST UPDATE 07/12/2021)

DATE	PLANTED	City (C) Residence (R)	SPECIES	LOCATION/ADDRESS	VENDOR	P - Purchased D - Donated	DESCRIPTION	ESTIMATED SQFT CANOPY GROWTH @ MATURITY	COMMENTS	
5/1/2018	3	C	Live Oak	Atlantic Avenue - Central Park				60-100	Surrounding tennis court	TOTAL
11/16/2018	4	C	Live Oak	Ash Street - Across City Hall				60-100	ROW on North Side	7
1/18/2019	11	C	Cedar	Elm + S. 3rd Street			FL Arbor Day	40-60		
1/18/2019	14	C	Wax Myrtle	Elm + S. 3rd Street			FL Arbor Day	35		
4/26/2019	2	C	Oak	Peck Center			National Arbor Day	60-100		
4/26/2019	1	C	Orange Tree	Peck Center			National Arbor Day	20-40		
8/2/2019	1	C	Live Oak	Peck Center			50th Class Reunion	60-100	N.W. Corner	
12/9/2019	6	C	Live Oak	Atlantic Avenue - Central Park				60-100	Between Tennis Courts + Heritage Oak	
12/17/2019	1	C	Palm	Central Park				?	Tranplant	TOTAL
2/18/2019	1	C	Live Oak	Central Park			Keep Nassau Beautiful	60-100	N.W. of Gazebo	37
1/17/2020	4	C	Cabbage Palm	MLK Park	Liberty Landscape	P	FL Arbor Day	10-15 ft		
1/17/2020	1	C	Ginkgo	MLK Park			FL Arbor Day	50-60		
1/17/2020	2	C	CrabApple	MLK Park			FL Arbor Day	?		
1/17/2020	2	C	Loquat	MLK Park	Gore's Nursery	P	FL Arbor Day	30-40		
1/17/2020	3	C	Orange Tree	MLK Park			FL Arbor Day	20-40		
1/17/2020	3	C	Pear Tree	MLK Park	Gore's Nursery	P	FL Arbor Day	30-40		
1/17/2020	6	C	Pecan	MLK Park			FL Arbor Day	50-70		
1/17/2020	3	C	Bottle Brush	MLK Park	Gore's Nursery	P	FL Arbor Day	10-15 ft	not on original list	
1/17/2020	2	C	Oakleaf Holly	MLK Park	Gore's Nursery	P	FL Arbor Day	?	not on original list	
1/17/2020	6	C	Cedar	MLK Park	Southern Tree	P	FL Arbor Day	?		
2/5/2020	2	C	Japanese Blueberry	Centre Street				35-50	Replaced 1 holly + 1 redbud	
2/21/2020	2	C	Poplar	Emma Love School	Gore's Nursery	P	Special Event	40-60		
2/21/2020	6	C	Redbud	Emma Love School	Gore's Nursery	P	Special Event	?		
2/21/2020	2	C	Bracken Magnolia	Emma Love School	Gore's Nursery	P	Special Event	15-20		
2/21/2020	10	C	Live Oak	Emma Love School	Gore's Nursery	P	Special Event	60-100		
2/21/2020	5	C	Pine	N. 14th Street - Boat Ramp				?		
4/24/2020	1	C	Bottle Brush	S. 2nd Street - Across City Hall			Junior Women's Club	10-15 ft	ROW south of S. 2nd Street	
4/30/2020	2	C	Live Oak	Egans Park			Keep Nassau Beautiful	60-100		
4/30/2020	2	C	Magnolia	City Hall Park			Keep Nassau Beautiful	40		
5/15/2020	2	C	Loquat	Res. Lot - Dunes of Amelia				30-40	Seedlings	
8/4/2020	2	C	Weeping Bottlebrush	Res. Lot - Citrona Drive				15-20	To replace tree removed in ROW	
8/7/2020	2	C	Pine	Northpark ROW				?	To replace tree removed near Azalea	
9/4/2020	6	C	Bald Cypress	N. 15th Street	Gore's Nursery	P		25-35	Stormwater Pond	
9/4/2020	5	C	Loquat	N. 15th Street	Gore's Nursery	P		30-40	Stormwater Pond	
9/4/2020	3	C	Oak	N. 15th Street	Gore's Nursery	P		60-100	Stormwater Pond	
9/4/2020	2	C	Magnolia	N. 15th Street	Gore's Nursery	P		40	Stormwater Pond	
9/28/2020	4	C	Crape Myrtle	Peck Center	Dreamscapes	P		6-15 ft	Front of gym + Stormwater pond	
9/28/2020	3	C	Laurel Oak	Peck Center	Dreamscapes	P		40-60	Front of gym + Stormwater pond	
9/28/2020	1	C	Laurel Oak	Atlantic Rec. Center	Dreamscapes	P		40-60	Btwn Building + Pirate Playground	
10/5/2020	8	C	Wax Myrtle	333 N. Fletcher Ave				20-25	Invasive program replacement	
10/22/2020	7	C	Dahoon Holly	S. 10th Street - Peck Field	Dreamscapes	P		8-12 ft	Along S. 10th Street	
10/26/2020	1	C	Live Oak	Southside Elementary			Keep Nassau Beautiful	60-100		
11/18/2020	4	C	Red Cedar	S. 11th Street - Peck Field				15-20	Along S. 11th Street	
11/18/2020	6	C	Red Maple	S. 11th Street - Peck Field				25-35	Along S. 11th Street	
12/9/2020	3	C	Japanese Blueberry	Peck Center - West Side				35-50	Btwn Building + Parking Area	
12/9/2020	1	C	Loquat	Near 19 N. 5th Street - ROW	Gore's Nursery	P	Replacement	30-40		
12/9/2020	8	C	Live Oak	Ocean View Villas + Dolphin St	Gore's Nursery	P		60-100	ROW - (diff then 2 on original report)	
12/9/2020	6	C	Wax Myrtle	Ocean View Villas + Dolphin St	Gore's Nursery	P		20-25	ROW - (diff then 10 on original report)	
12/9/2020	5	C	Live Oak	N. 13th Terrace - South end	Liberty Landscape	P		60-100	ROW	
12/9/2020	4	C	Wax Myrtle	N. 13th Terrace - South end	Liberty Landscape	P		20-25	ROW	
12/15/2020	1	C	Magnolia	502 Date Street - ROW	Liberty Landscape	D		40		
12/15/2020	2	C	Magnolia	House Authority - Hickory St	Liberty Landscape	D		40		
12/15/2020	1	C	Crape Myrtle	N. 15th St - Stormwater Pond	Liberty Landscape	D		6-15 ft	House Authority	

12/15/2020	2	C	Laurel Oak	N. 15th St - Stormwater Pond	Liberty Landscape	D		40-60	House Authority
12/15/2020	1	C	Magnolia	N. 15th St - Stormwater Pond	Liberty Landscape	D		40	House Authority
12/15/2020	1	C	Blanchard Magnolia	N. 15th St - Stormwater Pond	Liberty Landscape	D		40	House Authority
12/15/2020	1	C	Schumard Oak	N. 15th St - Stormwater Pond	Liberty Landscape	D		40-50	House Authority
12/15/2020	1	C	Live Oak	N. 15th St - Stormwater Pond	Liberty Landscape	D		60-100	House Authority
12/15/2020	1	C	Live Oak	1202/1208 Beech Street - ROW			Replacement	60-100	Across from Central Park
12/16/2020	3	C	Crepe Myrtle	1416 Atlantic Ave - ROW	Gore's Nursery	P	Replacement	6-15 ft	for removal of 1 Pine
12/16/2020	1	C	Slash Pine	1416 Atlantic Ave - ROW			Replacement	35-50	Seedling
12/16/2020	1	C	Crepe Myrtle	Alachua Parking Lot	Gore's Nursery	P	Replacement	6-15 ft	Across from Putt-Putt
12/16/2020	3	R	Bald Cypress	1696 Blue Heron Lane	Gore's Nursery	P	Repl. of damaged trees	25-35	Damaged by herbicide by City
12/16/2020	2	R	Weeping Willow	1696 Blue Heron Lane	Gore's Nursery	P	Repl. of damaged trees	45-70	Damaged by herbicide by City
12/18/2020	2	R	Weeping Willow	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	45-70	Damaged by herbicide by City
12/18/2020	1	R	Bald Cypress	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	25-35	Damaged by herbicide by City
12/18/2020	1	R	Magnolia	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	40	Damaged by herbicide by City
12/18/2020	1	R	Roebelenii Palm	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	PALM	Damaged by herbicide by City
12/18/2020	2	R	Roebelenii Palm	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	PALM	Damaged by herbicide by City
12/18/2020	1	R	Sago	1696 Blue Heron Lane	Liberty Landscape	P	Repl. of damaged trees	PALM	Damaged by herbicide by City
12/18/2020	1		Pond Cypress		Liberty Landscape	P		10-15 ft	
12/18/2020	1	R	Citrus Tree	1622 Highland Dunes Way	Liberty Landscape	P		?	Request thru Facebook (Barrington)
12/18/2020	3	R	Pine	2504 Robert Oliver Avenue				?	Seedlings
12/21/2020	3	R	Orange Tree	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	20-40	
12/21/2020	1	R	Grapefruit Tree	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	?	
12/21/2020	1	R	Lemon Tree	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	?	
12/21/2020	3	R	Pear Tree	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	20	
12/21/2020	3	R	Loquat	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	30-40	
12/21/2020	1	R	Pecan Tree	Hickory Street - Housing Authority	Reflections of Nature	P	Arbor Day	50-70	
1/15/2021	2	R	Bottlebrush	Hickory Street - Housing Authority	Reflections of Nature	P	FL Arbor Day	10-15 ft	
1/15/2021	1	R	Wax Myrtle	Hickory Street - Housing Authority	Reflections of Nature	P	FL Arbor Day	6-16 ft	
1/15/2021	10	R	Shade Trees	Hickory Street - Housing Authority	FL Forest Service	P	FL Arbor Day	???	
1/15/2021	2	R	Oak	Hickory Street - Housing Authority	Liberty Landscape	P	FL Arbor Day	60-100	Large
1/15/2021	2	R	Magnolia	Hickory Street - Housing Authority	Liberty Landscape	P	FL Arbor Day	40	
4/17/2021	100	R	Crepe Myrtle	Various Locations	Gore's Nursery	P	Free Tree Give Away	6-15 ft	Recycling Event - Residents only
4/17/2021	50	R	Red Maple	Various Locations	Gore's Nursery	P	Free Tree Give Away	40	Recycling Event - Residents only
4/17/2021	50	R	River Birch	Various Locations	Gore's Nursery	P	Free Tree Give Away	40-60	Recycling Event - Residents only
4/17/2021	50	R	Loquat	Various Locations	Gore's Nursery	P	Free Tree Give Away	30-40	Recycling Event - Residents only
4/22/2021	3	C	Live Oak	Lake Park Drive	-	P	Planner Drive By	60-100	Amelia Park
4/22/2021	4	C	Live Oak	Northpark Drve	-	P	Planner Drive By	60-100	Amelia Park
4/22/2021	19	C	Live Oak	Park Avenue	-	P	Planner Drive By	60-100	Amelia Park
4/22/2021	2	C	Live Oak	Park Lane	-	P	Planner Drive By	60-100	Amelia Park
4/22/2021	4	C	Live Oak	School Street	-	P	Planner Drive By	60-100	Amelia Park
4/22/2021	3	C	Live Oak	Central Park	-	D	Dedication		Volunteers Grove - ATC Grant
4/22/2021	1	C	Magnolia Grandiflora	Central Park	-	D	Dedication		Volunteers Grove - ATC Grant
4/22/2021	1	C	Dahoon Holly	Central Park	-	D	Dedication		Volunteers Grove - ATC Grant
4/30/2021	2	C	Live Oak	N. 3rd Street	Liberty Landscape	P	Arbor Day	60-100	
4/30/2021	2	C	Weeping Yaupon	N. 3rd Street	Liberty Landscape	P	Arbor Day	6-12 ft	
5/7/2021	3	C	Live Oak	Lime Street + S. 8th Street	Gore's Nursery	P	City Property	60-100	
5/7/2021	6	C	Wax Myrtle	N. 3rd Street	Gore's Nursery	P		6-16 ft	Installed by Dreamscapes by Trey
5/14/2021	1	R	Red Maple	Alachua Street	Gore's Nursery	P		40	Stacy Smith (signed up at event)
5/17/2021	3	C	Red Maple	Greenway	Gore's Nursery	P	City Property	40	Planted next to Greenway
5/26/2021	1	C	Crape Myrtle	Centre Street	Dreamscapes	P	City Property	6-15 ft	
5/26/2021	7	C	Arapaho Crape Myrtle	S. 7th Street	Dreamscapes	P	City Property	6-15 ft	
5/26/2021	1	C	Arapaho Crape Myrtle	Pineland Bank	Dreamscapes	P	Commercial Property	6-15 ft	ROW

TOTAL
193

TOTAL
330

TOTALS planted per YEAR		
7		2018
37		2019
193		2020

330		2021
567		

TOTALS planted per FISCAL Year		
33		2018-2019
102		2019-2020
429		2020-2021
564		

TOTALS planted since 1/1/2019		
560		(for visual tree graphic)



PLANNING & CONSERVATION FEE SCHEDULE

Revised 10/01/20

FEES: Permit fees vary depending on the type of permit and the associated scope of work.

IMPORTANT NOTES: The Application Fee or Permit fee may not be the only fee you face for certain work. Exterior projects within the City's Historic Districts require receipt of a Certificate of Approval prior to permitting. A "Planning/HDC" application will need to be submitted prior to submitting a permit application.

KEY CONTACTS: The Planning & Conservation Department will guide your application through appropriate reviews with other departments. For instances of new construction and the installation of irrigation systems, please contact the City's Utilities Department at 904-310-3420 to discuss fees associated with connection to the City's water and sewer system. A

Application / Permit Type	Fee
<u>Board of Adjustment</u>	
Administrative Appeal	\$500.00
Variance - Residential	\$1,000.00
Variance - Non-Residential/Multi-Family/2 or more Residential units/Mixed Use	\$2,500.00
<u>Historic District Council</u>	
Certificate of Approval: Staff	\$25.00
Certificate of Approval Board – Residential (1 Single Family Home)	\$250.00
Certificate of Approval Board - Commercial Multi-Family/2 or more Residential units/Mixed Use	\$400.00
Demolition of Primary Structure - Non-Contributing	\$1,500.00
Demolition of Primary Structure - Contributing	\$7,500.00
Variance - Residential	\$850.00
Variance - Non-Residential Multi-Family/2 or more Residential units/Mixed Use	\$2,500.00
After-the-fact approval for Board C.O.A.	\$1,500.00
After-the-fact approval for Staff C.O.A.	\$100.00
Newsrack Fee (New Location)	\$15.00
Newsrack Fee (Annual Renewal)	\$15.00
HDC Amendment Fees (offset of staff time and advertising)	½ cost of original COA fee
<u>Planning Advisory Board</u>	
Large Scale Future Land Use Map Amendment	\$5,000.00
Small Scale Future Land Use Map Amendment	\$2,500.00
Comprehensive Plan Text Amendment	\$1,700.00
Change of Zoning Designation: Large Scale	\$5,000.00
Change of Zoning Designation: Small Scale	\$2,500.00
Land Development Code Text Amendment	\$1,500.00
Water/ Sewer Agreement	\$300.00

Voluntary Annexation	\$2,000.00
Development of Regional Impact: Amend Development Order	\$1,500.00
Re-Plat / Preliminary Plat (less than 20 units)	\$3,000.00
Re-Plat / Preliminary Plat (20+ units)	\$5,000.00
Re-Plat / Final Plat	\$1,500.00
Vacate/ Open Public right-of-way	\$3,500.00
New Telecommunications Structure	\$2,000.00
Collocation or Modification of Existing Structure	\$1,000.00
Small Cell outside ROW (per application)	\$500.00

Application Fee for Each Revision to PAB Applications
(offset of additional display ad fees)

½ cost of original application fee

Technical Review Committee

TRC Engineering Review (consultant hourly rate)
TRC Staff Review Application Fee:
Initial Submittal + 2 resubmittals

\$125.00

No fee for Pre-application submittals

\$400.00 + 2% of project

Construction cost (maximum \$5,500.00)

\$400 each

3rd and subsequent resubmittals

Change of Use Determination Letter

\$50.00

Site Infrastructure Permit

First \$1,000 of job cost

\$160.00

Plus, for each additional \$1,000 of job cost

\$14.00

Tree Protection and Site Inspection Fee

See cost for tree removal inspections

Tree Removal Permit Fees

Base Fee, up to 3 trees

\$500.00

Each Additional Tree

\$100.00

Tree Inspection Fees

Residential – Single lot

\$200.00

Subdivision – Mixed Use, Non-Residential

\$1,000.00

In Lieu Fee (Tree Replacement)

\$400.00

Zoning Review Permit

Non-structural fence

\$50.00

Exempted accessory structures

(< 12' ridge ht, ≤ 150 sf, non-aluminum)

\$100.00

All others require Gen Bldg Permit + fees

Exempted Residential Deck

(≤ 12" above grade and ≤ 150 s.f.)

\$100.00

All others require Gen Bldg Permit + fees

After-the-Fact Zoning Permit

\$200.00

Administrative

Plan Review (as connected to issuance of building permits)

\$250.00

Expedited Plan Review

(as connected to issuance of bldg permits (5 business days)

\$300.00

DEP Letter plus 1 Revision

\$200.00

DEP Letter – 2nd and later Revisions

\$35.00

Zoning sign off for alcoholic beverage license	\$50.00
Zoning Certification Letter	\$100.00
Due Diligence Letter	\$250.00
Minor Subdivision/ Lot Line Adjustment	\$600.00
Context Sensitive Review Determination	\$400.00
NSF Check Fee (up to)	\$40.00
Public School Concurrency Review Fee	\$250.00

Plan Copies

Hard Copy of Comprehensive Plan	\$50.00
Land Development Code	\$50.00
CRA Design Guidelines	\$50.00
Design Guidelines for Downtown or Old Town	\$50.00
Oversize Building plans (delivery to copy center + cost of copies)	\$25.00 + cost of copies

Maps

Map: 8 ½ x 11	\$2.00
Map: 11 x 17	\$5.00
Map: 17 x 22 (black and white only)	\$10.00
Map: 24 x 36 (black and white only)	\$20.00
Map: 34 x 42 (black and white only)	\$40.00
Additional Map copies	1/2 Price
SHAPE Files	\$35.00

Miscellaneous Fees

Administrative Waiver	\$400.00
Traffic Concurrency Determination	*Replace with code requirement to obtain a traffic study prepared by applicant and reviewed by appropriate agencies including Nassau County and FDOT. 1/2 of original application fee
Amendment to Development Order	
Parking in Lieu Fee (surface space) (to be paid at time of building permit issuance)	\$2,000.00
Parking in Lieu Fee (structured space) (to be paid at time of building permit issuance)	\$9,000.00

Temporary Use

As provided in LDC Section 5.02.00	
Seasonal Sales	\$100.00
Movable Module Storage Units (PODs) (15 day permit)	\$25.00
Construction Trailer / Model Home / Sales Office	\$100.00
Tent Permit (includes Seasonal Fee + Tent Fee + Fire Marshal Fee)	\$100.00 + \$35.00 + \$25.00

Signs

Based on Valuation of Sign:	
\$0-\$100.00	\$60.00
\$101.00-\$500.00	\$70.00
\$501.00-\$1,000.00	\$80.00
Addition per each \$1,000.00	\$7.00
Pickup of Illegal Signs	\$25.00

New home construction will require the following permit and/or fees:

- Address assignment (\$10) – *through the Fire Department at 904-277-7331 **prior to permitting***
- general building permit
- roofing permit
- trade permits
- driveway permit
- Zoning review fee (flat fee of \$250)
- School impact fee (\$5,430.60 – assessed for Nassau County per new residential unit)
- Mobility Fee (dependent on the usage of the property)
- *Municipal impact fees RES (\$3.952) *Municipal impact fees COM (\$1.068)

○ (conditioned sq. ft., see details below)

Fire Protection \$0.360

Police Protection \$0.264

Park & Recreation \$2.885

Public Facilities \$0.443

TOTAL: **\$3.952**

Fire Protection \$0.360

Police Protection \$0.264

Park & Recreation \$0.00

Public Facilities \$0.443

TOTAL: **\$1.068**

****Utilities Impact Fees**

(See Utilities Dept. 904-277-7331 for final calculations – fees are assessed independent of Building Dept. permitting.)

- Water / per Equivalent Residential Unit (ERU) \$959
- Sewer / per Equivalent Residential Unit (ERU) \$2,321

YEAR-TO-DATE BUDGET REPORT

EXPENSES

EXPENSES

FOR 2021 08

ACCOUNTS FOR: 125 TREE TRUST SPECIAL REV FUND			REVISED BUDGET	YTD EXPENDED	ENCUMBRANCE/REQ	AVAILABLE BUDGET	% USED
ORIGINAL APPROP	TRANS/ADJSMTS						
125 TREE TRUST SPECIAL REV FUND							
125 51200		SALARIES					
17,503.00	0.00		17,503.00	4,638.14	0.00	12,864.86	26.5%
125 52100		FICA					
1,339.00	0.00		1,339.00	324.64	0.00	1,014.36	24.2%
125 52200		RETIREMENT					
3,770.00	0.00		3,770.00	999.09	0.00	2,770.91	26.5%
125 52300		HEALTH INSUR					
4,579.00	0.00		4,579.00	993.09	0.00	3,585.91	21.7%
125 52301		LIFE INSUR					
95.00	0.00		95.00	24.35	0.00	70.65	25.6%
125 52400		WORKERS' COMP					
256.00	0.00		256.00	168.00	0.00	88.00	65.6%
125 53100		PROFESSIONAL SERVICES					
53,500.00	0.00		53,500.00	350.00	0.00	53,150.00	.7%
125 54630		R/M VEHICLES-LABOR					
0.00	0.00		0.00	0.00	0.00	0.00	.0%
125 54640		R/M VEHICLES-PARTS					
0.00	0.00		0.00	0.00	0.00	0.00	.0%
125 54970		PROGRAM COSTS					
12,650.00	37,999.00		50,649.00	30,221.54	18,750.00	1,677.46	96.7%
125 55200		OPERATING SUPPLIES					
11,500.00	0.00		11,500.00	6,957.89	0.00	4,542.11	60.5%
125 55230		GAS/OIL					
0.00	0.00		0.00	0.00	0.00	0.00	.0%
125 56400		EQUIPMENT					
0.00	0.00		0.00	0.00	0.00	0.00	.0%
125 59990		RESERVE					
237,736.00	-37,999.00		199,737.00	0.00	0.00	199,737.00	.0%
TOTAL TREE TRUST SPECIAL REV FUND							
342,928.00	0.00		342,928.00	44,676.74	18,750.00	279,501.26	18.5%
TOTAL TREE TRUST SPECIAL REV FUND							
342,928.00	0.00		342,928.00	44,676.74	18,750.00	279,501.26	18.5%
TOTAL EXPENSES							
342,928.00	0.00		342,928.00	44,676.74	18,750.00	279,501.26	

YEAR-TO-DATE BUDGET REPORT

EXPENSES

REVENUE

FOR 2021 08

ACCOUNTS FOR: 125 TREE TRUST SPECIAL REV FUND							
	ORIGINAL APPROP	TRANS/ADJSMTS	REVISED BUDGET	YTD EXPENDED	ENCUMBRANCE/REQ	AVAILABLE BUDGET	% USED
125 TREE TRUST SPECIAL REV FUND							
125 32219		TREE TRUST FUND RESERVE					
	-75,000.00	0.00	-75,000.00	-132,140.00	0.00	57,140.00	176.2%
125 36110		INTEREST					
	0.00	0.00	0.00	-1,630.54	0.00	1,630.54	100.0%
125 36990		OTHER REVENUE					
	0.00	0.00	0.00	0.00	0.00	0.00	.0%
125 38910		CASH BALANCE FORWARD					
	-267,928.00	0.00	-267,928.00	0.00	0.00	-267,928.00	.0%
TOTAL TREE TRUST SPECIAL REV FUND							
	-342,928.00	0.00	-342,928.00	-133,770.54	0.00	-209,157.46	39.0%
TOTAL TREE TRUST SPECIAL REV FUND							
	-342,928.00	0.00	-342,928.00	-133,770.54	0.00	-209,157.46	39.0%
TOTAL REVENUES							
	-342,928.00	0.00	-342,928.00	-133,770.54	0.00	-209,157.46	

125 TREE TRUST FUND

	ACTUAL 2019	ACTUAL 2020	BUDGET 2020	BUDGET 2021	PROJECTION 2021	BUDGET 2022	INCREASE / DECREASE
OPERATING REVENUE							
125 32219 TREE TRUST FUND RESERVE	59,458	124,110	52,380	75,000	129,940	130,000	73.3%
125 36110 INTEREST	294	1,800	-	-	1,411	1,400	0.0%
TOTAL	59,751	125,910	52,380	75,000	131,351	131,400	75.2%
TRANSFERS IN							
125 38101 FROM GENERAL FUND	-	-	-	-	-	-	0.0%
TOTAL	-	-	-	-	-	-	0.0%
CASH BALANCE FORWARD							
125 38910 CASH BALANCE FORWARD	108,617	168,223	124,007	267,928	280,036	283,696	5.9%
TOTAL	108,617	168,223	124,007	267,928	280,036	283,696	5.9%
TOTAL REVENUE AND CASH BALANCES	168,369	294,133	176,387	342,928	411,387	415,096	21.0%
OPERATING EXPENSES							
125 51200 SALARIES	-	-	-	17,503	17,503	15,675	-10.4%
125 52100 FICA	-	-	-	1,339	1,339	1,288	-3.8%
125 52200 RETIREMENT	-	-	-	3,770	3,770	3,541	-6.1%
125 52300 HEALTH INSUR	-	-	-	4,579	4,579	6,321	38.0%
125 52301 LIFE INSUR	-	-	-	95	95	96	1.1%
125 52400 WORKERS' COMP	-	-	-	256	256	290	13.3%
125 53100 PROFESSIONAL SERVICES	-	5,995	10,000	53,500	38,000	53,500	0.0%
125 54970 PROGRAM COSTS	-	3,740	6,900	12,650	50,649	132,200	945.1%
125 55200 OPERATING SUPPLIES	146	4,362	3,900	11,500	11,500	63,750	454.3%
TOTAL	146	14,097	20,800	105,192	127,691	276,661	163.0%
CAPITAL OUTLAY							
125 56400 EQUIPMENT	-	-	-	-	-	15,000	0.0%
TOTAL	-	-	-	-	-	15,000	0.0%
125 59990 RESERVE	168,223	280,036	155,587	237,736	283,696	123,435	-48.1%
TOTAL EXPENDITURES AND RESERVES	168,369	294,133	176,387	342,928	411,387	415,096	21.0%

- 27,211