CITY COMMISSION AGENDA ITEM
City of Fernandina Beach

SUBJECT:	Ordinance 2022-04 Land Development Code Amendment - Landscape Requirements
ITEM TYPE:	Ordinance (w/ fiscal impact)

REQUESTED ACTION: Consider Ordinance 2022-04 at First Reading

SYNOPSIS: The City Commission directed additional amendments to its tree protection and landscape ordinances at its annual goal-setting meeting on January 27, 2021. The City's Planning & Conservation Department staff formed a Tree Committee, which provided recommendations for code amendments. The City Commission adopted the Tree Committee's plan via Resolution 2021-123 on August 3, 2021. In addition, the committee provided an Urban Forestry Management Plan to direct specific actions for increasing canopy coverage within the City. This Ordinance serves to fulfill the City Commission's desired action for code amendments.
The Planning Advisory Board (PAB), at its December 8, 2021, Regular Meeting, issued a recommendation of approval.

FISCAL IMPACT: No fiscal impact.

CITY ATTORNEY COMMENTS: No additional comments.

CITY MANAGER RECOMMENDATION(S): I recommend that the City Commission approve proposed Ordinance 2022-04 at First Reading.

Kelly Gibson, Planning Director	12/30/2021
Monica Benischeck, Administrative Services Manager	12/30/2021
Dale Martin, City Manager	1/10/2022
Tammi E. Bach, City Attorney	1/10/2022

Sylvie McCann

Date: December 15, 2021

Submitted By: Sylvie McCann, Administrative Coordinator

COMMISSION ACTION: Approve

ORDINANCE 2022-04

AN ORDINANCE OF THE CITY COMMISSION OF THE CITY OF FERNANDINA BEACH, FLORIDA, AMENDING THE LAND DEVELOPMENT CODE (LDC) BY UPDATING TREE PROTECTION AND LANDSCAPE REQUIREMENTS BY AMENDING SECTION 4.05.03 LANDSCAPE REQUIREMENTS, AMENDING SECTION 4.05.05 MINIMUM REQUIREMENTS FOR RESIDENTIAL DEVELOPMENT, AMENDING SECTION 4.05.10 STANDARDS FOR RETENTION AND DETENTION PONDS, CREATING SECTION 4.05.16 ESTABLISHING A TREE FUND; CREATING SECTION 10.03.01(C) ADMINISTRATIVE WAIVERS FOR TREE PROTECTION, AMENDING SECTION 11.05.03 INSTALLATION AND MAINTENANCE GUARANTEES FOR LANDSCAPING; PROVIDING FOR SEVERABILITY; AND PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the City of Fernandina Beach has applied for a text amendment to modify multiple Land Development Code Sections acting on City Commission directed amendments which serve to increase the City's Urban Forest Canopy Coverage as determined through Resolution 2021-123 accepting the City's Tree Committee Recommendations for Code Amendments; and

WHEREAS, the City Commission adopted a unified Land Development Code (LDC) on September 5, 2006, which became effective on October 1, 2006; and

WHEREAS, the City's adopted 2030 Comprehensive Plan directs changes to the Land Development Code for consistency with State Laws and current planning methods for growth and economic development; and

WHEREAS, the Planning Advisory Board held public hearings on September 8, 2021, September 22, 2021, October 13, 2021, October 27, 2021, and November 10, 2021 to discuss and consider public comment on the requested LDC Text Amendments;

WHEREAS, the Planning Advisory Board (PAB), acting as the City's Local Planning Agency, considered the application at its Regular Meeting on Wednesday, December 8, 2021 and issued a recommendation of approval for the requested amendments; and

WHEREAS, notice of public hearing on such Land Development Code amendments was published in the News Leader, a newspaper of general circulation in Fernandina Beach, Nassau County, Florida, on November 24, 2021.

NOW, THEREFORE, BE IT ENACTED BY THE CITY COMMISSION OF THE CITY OF FERNANDINA BEACH AS FOLLOWS:

SECTION 1. PURPOSE AND INTENT. The City Commission finds that the amendments attached hereto as Exhibit "A," amending multiple LDC Sections to address amendments which serve to increase the City's urban forest canopy coverage.

SECTION 2. SEVERABILITY. If any section, sentence, clause or phrase of this Ordinance is held to be invalid or unconstitutional by any Court of competent jurisdiction, the holding shall in no way affect the validity of the remaining portions of this Ordinance.

SECTION 3. This Ordinance shall become effective immediately upon enaction.

ENACTED this 15th day of February, 2022.

CITY OF FERNANDINA BEACH

____
MICHAEL A. LEDNOVICH
Mayor - Commissioner

ATTEST:

____
CAROLINE BEST
City Clerk

APPROVED AS TO FORM AND LEGALITY:

____
TAMMI E. BACH
City Attorney

Date of First Reading: January 18, 2022
Date of Second Reading/Final Hearing: __________
Date of Publication:

ORDINANCE 2022-04
EXHIBIT "A"

Chapter 4 Changes

4.05.03 Landscape Material Standards

E. Maintenance requirements

1. All plantings ~~shall~~ must be continually maintained in an attractive and healthy condition. Maintenance ~~shall~~ must include, but not be limited to, watering, tilling, fertilizing and spraying, mowing, weeding, removal of litter and dead plant material, and necessary pruning and trimming.
2. Required plants that become diseased or die ~~shall~~ must be replaced not later than three (3) months following the loss of the plant.
3. Replacement trees ~~shall~~ must be maintained and warranted to survive for a period of ~~one (1)~~ three (3) years from installation. Trees which do not survive ~~one (1)~~ three (3) years must be replaced with new trees of the same size. Replacement trees ~~shall~~ must 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.

4.05.05 MINIMUM REQUIREMENTS FOR RESIDENTIAL DEVELOPMENT

It is the intent of this section to provide minimum landscaping requirements for residential development. Existing plant materials, other than invasive species, may be counted toward meeting the landscaping requirements set forth in this section.

A. **Single-family Detached and Two-family Duplex Residential Development**

Single-family and two-family development ~~shall~~ must include, at a minimum, ~~one (1)~~ two (2) native, shade trees for every 2,500 square feet of lot area or fraction thereof. At least ~~two (2)~~ four (4) native trees ~~shall~~ may be located in the front, side or rear yard. Relocation of existing healthy trees on the project site measuring at least 2.5" DBH and at least 8 feet tall may be relocated on the site and utilized as a credit to satisfy minimum landscape requirements. Tree identification and placement ~~shall~~ must be shown on a site plan but ~~shall~~ may not be required to meet the requirements of 4.05.04(A) above.

B. **Tri-plex and Multi-family Residential Development**

Multi-family residential development sites ~~shall~~ must meet the following standards, in addition to the requirements set forth in Section 4.05.04(A) above:

1. There ~~shall~~ must be ~~not less than~~ at least ~~one (1)~~ two (2) native, shade trees for each 1,500 square feet, or fraction thereof, of development site. Relocation of existing healthy trees on the project site measuring at least 2.5" DBH and at least 8 feet tall may be relocated on the site and utilized as a credit to satisfy minimum landscape requirements. There ~~shall~~ must be a planting area not less than ten (10) feet in width between the building walls and parking areas. Landscape materials ~~shall~~ must be provided as follows:
   a. One (1) tree for every 200 square feet of planting area or fraction thereof;
   b. At least fifty (50) percent of the trees ~~shall~~ must be shade trees; and
   c. A continuous hedge ~~shall~~ must be placed along the building walls.

2. There ~~shall~~ must be a planting area not less than ten (10) feet in width between an abutting right-of-way and parking areas. Landscape materials ~~shall~~ must meet the following standards:
   a. One (1) tree ~~shall~~ must be provided for every 250 square feet of planting area or fraction thereof;
   b. At least seventy-five (75) percent of the trees ~~shall~~ must be shade trees;
   c. A continuous hedge or a berm with native plantings, at least three (3) feet in height, ~~shall~~ must be provided; and
   d. The entire site, outside of the planting areas immediately surrounding the trees and shrubs, ~~shall~~ must contain grass or ground cover.

4.05.10. RETENTION AND DETENTION PONDS

Stormwater retention/detention ponds ~~shall~~ are required be naturally shaped (without geometric straight sides) and ~~shall~~ must meet the following minimum requirements:

A. All wet detention ponds ~~shall~~ must incorporate a combination of aquatic and non-aquatic native plants to completely surround the perimeter to filter runoff of fertilizers, herbicides, and pesticides.

B. Wet detention ponds ~~shall~~ must incorporate, at a minimum, a littoral zone or a littoral zone alternative Per Chapter 40C-42, Florida Administrative Code.

C. At a minimum, one water-tolerant native tree per 50 linear feet of pond frontage is required. Trees may be grouped to create clusters to meet minimum requirements. A five (5) foot natural barrier is required around each tree or cluster of trees.

4.05.16 Tree Fund

In support of the City's commitment to tree protection, the continued health of its mature canopy, and to grow the urban forest, the City Manager must establish within the operating budget of the City a special account that includes all funds derived from donations, Tree Removal penalties or fines, and all fees collected from the issuance of tree removal permits into the special fund. The special account may also include funds derived from violations of landscape requirements. Funds in the special account must only be spent for the following activities:

- Heritage Tree nomination, inspection, and protection measures;
- Relocation of protected trees;
- Monitoring and special treatment (such as cabling or root injections) of protected trees within City Rights-of-way and public lands;
- Up to 1/3 of the salary of a City Employee serving as the Urban Forester/ City Arborist;
- The salary of a seasonal intern;
- Purchase of replacement trees and supplies including irrigation to support newly installed trees within the City;
- Education and outreach materials about trees;
- Equipment required to support new or replacement trees; and
- Staff and volunteer training activities.

The special fund will not be used to defer costs of routine maintenance activities (such as pruning or pesticide application) supporting City trees beyond two (2) years following their initial installation.

Chapter 10 Changes

10.03.01 Authority and Limitations

The City Manager is authorized to reduce specific site design and development standards of this LDC where the intent of the LDC can be achieved and equal performance obtained by granting a waiver. The authority to grant a waiver ~~shall be~~ is limited to the following:

A. A reduction in the parking requirement, provided the following standards are met:
   1. The reduction is necessary in order to implement tree protection standards of this LDC;
   2. The reduction is limited to either one (1) space or two (2) percent of the parking requirement, whichever is more; and
   3. The reduction does not limit the availability or location of required handicapped parking.

B. A reduction in a dimensional standard, other than a setback as set forth in Section (A) above, provided that all of the following conditions are met:
   1. A property owner inadvertently fails to comply with the dimensional requirements and such failure is identified after the start of construction;
   2. The difference between the required dimensional standard set forth in this LDC and the actual measurement is not more than three (3) inches; and
   3. Failure to comply with the required dimensional standard ~~shall~~ must not result in an adverse health, safety, or welfare impact.

C. A reduction in the minimum front, side, or rear yard setbacks for a single residential lot for the exclusive purpose of protecting mature, healthy shade trees on a property provided the following standards are met:
   1. The reduction is necessary to protect a healthy native shade tree measuring at least 25 inches DBH; and
   2. The reduction does not result a structure placed less than five (5) feet from the front, side, or rear property lines; and
   3. The protected tree will not require pruning cuts any greater than 20% as recommended by ISA bestmanagement practices during construction or within 2 years following construction activities; and
   3. Where the applicant has provided a certified arborist statement attesting to the health of the tree and its worthiness for deviation from typical setback standards, a detailed protection schematic to secure and inspect the tree during construction activities, consideration of designation as heritage tree to extend protection requirements, and recommendations for post development inspections and treatments; and
   4. A recorded agreement between the property owner and the City which binds future owners to tree replacement requirements should the preserved tree fail in the future.

Chapter 11 Changes

11.05.03 Installation and Maintenance Guarantees for Landscaping, Irrigation, and Replacement Trees

A maintenance guarantee ~~shall~~ must be provided to ensure that required landscaping, and irrigation system, or protected trees are perpetually maintained in accordance with the provisions of this LDC. For all development projects receiving a Local Development Order, the applicant ~~shall~~ must provide legal documents, approved by the City, which insure such protection after building construction has occurred on the site. Such documents may include, but are not limited to, conservation easements, dedication of common open space, tree protection easements, deed restrictions, and homeowner association documents. The City requires an assessment provided by a certified arborist at the end of the warranty period before remitting funds or releasing the obligation documents.

Print

Planning Advisory Board (PAB) - Submission #8359

Date Submitted: 11/19/2021

Planning Advisory Board (PAB) Application

USE THIS FORM TO Request actions to affect changes to property (zoning changes, annexations, allowable uses, subdivisions).

Fees

Once application is submitted it will be reviewed for completeness. Once verified complete, an invoice will be emailed to the applicant.

- [ ] Zoning Map Amendment (â‰¤ 10 acres $2,500 / > 10acres $5,000)
- [ ] Land Use Map Amendment (â‰¤ 10 acres $2,500 / > 10acres $5,000)
- [x] LDC Text Amendment ($1,500)
- [ ] Comp Plan Amendment ($5,000)
- [ ] Subdivision Plat â€“ Preliminary (â‰¤ 20 units $3,000 / > 20 units $5,000)
- [ ] Subdivision Plat â€“ Final ($1,500)
- [ ] Vacation of R.O.W. ($3,500)
- [ ] Small Cell Outside R.O.W. (per application) ($500)
- [ ] Voluntary Annexation ($2,000)
- [ ] Development of Regional Impact: Amend Development Order ($1,500)
- [ ] New Telecommunications Structure ($2,000)
- [ ] Revision to each PAB Application - 1/2 cost of original application fee (To offset additional display ad fee)

2022 Submission Deadlines + Meetings Calendar

pab 2022

IMPORTANT NOTES

Pre-Application Meeting

To guide you through the process and ensure that your application is understood and properly processed, youâ€™ll need to meet with a City Planner prior to submitting your application. Completed applications are due 30 days prior to the Planning Advisory Board meeting date.

Please see the Land Development Code (LDC) for detailed information:

- [x] LDC Text Amendment â€“ see LDC Section 11.01.08.
- [ ] Preliminary Subdivision Plat â€“ see LDC Section 11.01.05.
- [ ] Final Subdivision Plat â€“ LDC Section 11.01.05.
- [ ] Zoning Map Changes â€“ See LDC Section 11.01.07.

The LDC is available for review at

www.fbfl.us/LDC

Application Requirements

- [ ] A complete application filed at least forty-five (45) days before the date of the Planning Advisory Boardâ€™s public hearing;
- [ ] Proof of Ownership (copy of deed or tax statement);
- [ ] A current survey of the property (no older than two years);
- [ ] If applying as an agent, Ownerâ€™s Authorization for Agent Representation form needs to be signed/ notarized and included in application;
- [ ] A detailed letter of intent stating the following:
- [ ] o The consistency of the proposed amendment(s) or action(s) with the Cityâ€™s Comprehensive Plan.
- [ ] o A justification for the proposed amendment(s) or action(s).

Have you met with a planner for a pre-application meeting?*

Yes

What was the date of your pre-application meeting?*

11/19/2021

If you have yet to have a pre-application meeting, please choose a date and time to schedule your meeting now. Every Tuesdays are reserved for pre-application appointments.*

mm/dd/yyyy hh:mm am/p

PROPERTY INFORMATION

Property information can be found at the Nassau County Property Appraiserâ€™s Website â†' Map Search

Site Address*

204 Ash Street

City*	State*	Zip*
Fernandina Beach	FL	32034

Parcel ID #(s)*

0

Lot*	Block*	Subdivision*
0	0	0

Zoning District*	Future Land Use Designation*
C-1	8th St Mixed Use

REVIEW TYPE*

- [ ] Zoning Map Amendment â‰¤ 10 acres
- [ ] Zoning Map Amendment > 10 acres
- [x] LDC Text Amendment
- [ ] Comp Plan Amendment
- [ ] Subdivision Plat â€“ Preliminary â‰¤ 20 units
- [ ] Subdivision Plat â€“ Preliminary > 20 units
- [ ] Subdivision Plat â€“ Final
- [ ] Vacation of R.O.W.
- [ ] Voluntary Annexation
- [ ] Revision to PAB Application

OWNER OF RECORD

As recorded with the Nassau County Property Appraiser

First Name*	Last Name*
Dale	Martin

Company (if applicable)

City of Fernandina Beach

Mailing Address*

204 Ash Street

City*

Fernandina Beach

State*

Florida

Zip*

32034

Telephone Number*

9043103100

Email Address*

dmartin@fbfl.city

OWNER'S AGENT

If other than owner. If an agent will be representing the owner, an Ownerâ€™s Authorization For Agent Representation form must be included

First Name

Last Name

Mailing Address

City

State

Zip

Telephone Number

E-mail Address

PROJECT INFORMATION

Previous Planning/Zoning Approvals

Summary of Request (more detailed information to be provided in required letter of intent)*

LDC Text Amendment - Tree Ordinance Updates

Certification*

☑

By signing below, I certify that the information contained in this application is true and correct to the best of my knowledge at the time of the application.

☑

I acknowledge that I understand and have complied with all of the submittal requirements and procedures.

Applicant First Name*

Dale

Applicant Last Name*

Martin

Today's Date*

11/19/2021

Upload Supporting Documentation*

City of FB logo NEW Reflex.jpg

Upload 2

Choose File No file selecte

Upload 3

Choose File No file selecte

Upload 4

Choose File No file selecte

DEPARTMENT OF PLANNING & CONSERVATION

204 Ash Street | Fernandina Beach, Florida 32034 | 904 310-3480 | www.fbfl.us/planning

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.

RESOLUTION 2021-123

A RESOLUTION OF THE CITY COMMISSION OF THE CITY OF FERNANDINA BEACH, FLORIDA, ACCEPTING THE CITY TREE COMMITTEE FINAL REPORT; AND PROVIDING FOR AN EFFECTIVE DATE.

WHEREAS, the City Commission, at their January 28, 2019 Goal Setting Workshop, established a goal to increase the City tree canopy coverage by five percent by 2024; and

WHEREAS, the Planning and Conservation Department provided the City Commission with a Tree Canopy Analysis and Tree Management Plan in August 2019 and August 2020; and

WHEREAS, the City Commission amended its Land Development Code in May 2020 to increase minimum mitigation requirements and set forth specific penalties for unpermitted tree removal in support of its 2019 established goal; and

WHEREAS, the City Commission recommitted to its 2019 goal and expanded interested in reexamining Land Development Code amendments at its annual Goal Setting Workshop on January 2021; and

WHEREAS, Planning and Conservation Department established an internal working group called the City Tree Committee (CTC), comprised of diverse community interests which serve to support the City's urban forest; and

WHEREAS, the CTC, comprised of seven members of the community, developed a framework for achieving the City Commission's goal; and

WHEREAS, the CTC, conducted open and noticed public meetings between April 2021- July 2021 in support of the Commission's established goals; and

WHEREAS, the CTC Final Report is a culmination of four months of data gathering, through various methods, from April 2021 through July 2021 and contains actionable recommendations focused on community partnerships, new planting strategies, education, and Land Development Code changes.

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COMMISSION OF THE CITY OF FERNANDINA BEACH, FLORIDA, THAT:

SECTION 1. The City Commission hereby has reviewed and accepts the City Tree Committee Final Report attached hereto as Exhibit "A".

SECTION 2. The City Commission hereby directs staff to submit amendments to the Land Development Code.

SECTION 3. The City Commission directs staff to work with community partners to act on planting trees within the identified areas described in the Final Report.

SECTION 4. This Resolution shall become effective immediately upon passage.

ADOPTED this 3rd day of August, 2021.

CITY OF FERNANDINA BEACH

MICHAEL A. LEDNOVICH
Commissioner – Mayor

ATTEST:

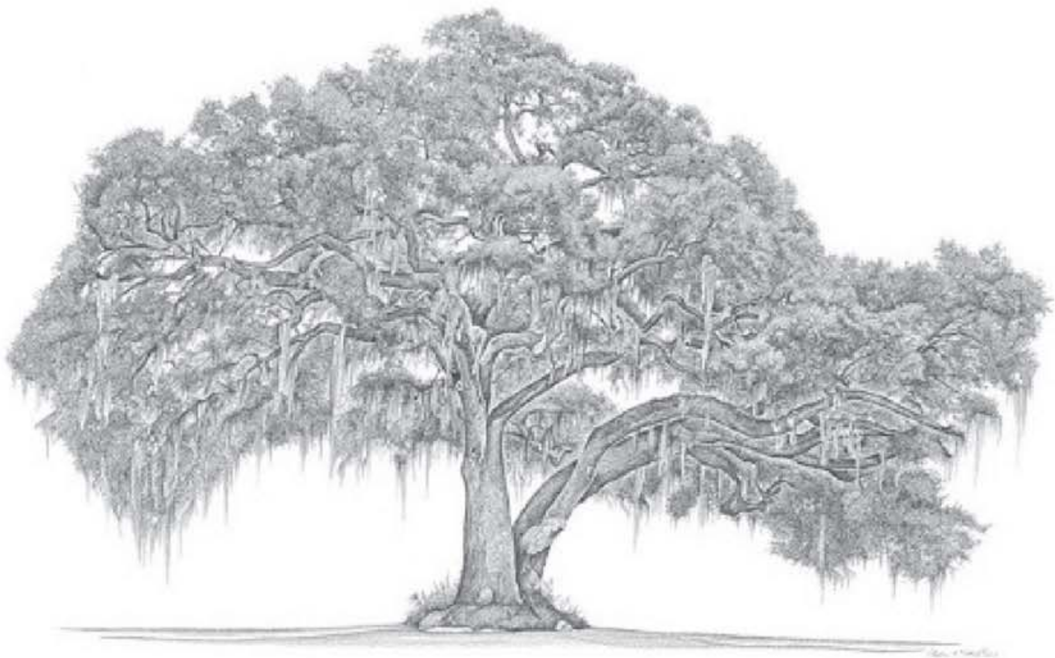
CAROLINE BEST
City Clerk

APPROVED AS TO FORM & LEGALITY:

TAMMI E. BACH
City Attorney

RESOLUTION 2021-123
EXHIBIT "A"

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

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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 does not provide ample time to plant or measure the growth of newly established trees. A revised goal and timeline to 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

Website Icons

Designation of Tree Holding Area

LARGE SCALE PLANTINGS (> 10 TREES)

The committee recognizes the need to establish interdepartmental coordination between 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.

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.

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.

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)

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)

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 Invasive 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, install 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

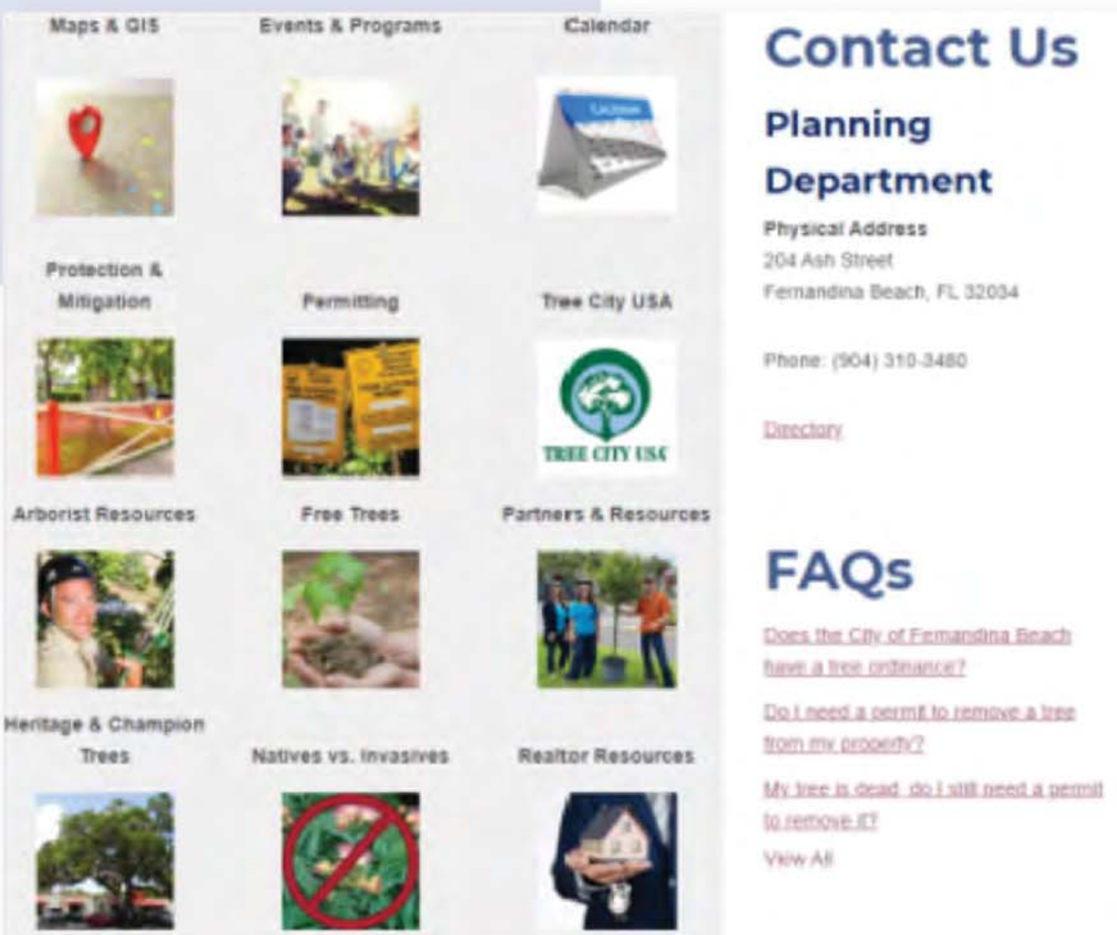
The City will increase the distribution of easy-to-read tree protection infographics and materials to real estate, design professionals, and advocacy groups

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 SUPPLY

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)

ESTIMATED BUDGET 2021-2022*

ACCOUNT	2022 BUDGET
PROGRAM	$132,200.00
SALARY	$ 27,970.00
PROF SERV	$ 53,500.00
OP SUPPLIES	$ 63,750.00
EQUIPMENT (AUGER + SPADE)	$ 15,000.00
TOTAL	$292,420.00
2022 REVENUE	$130,000.00
2022 RESERVE	$122,676.00

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

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		

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

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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). (3,137now / 2,979then x 100) - 100 = **5.3%**

The assessment based on the 2009 aerials suggests the canopy DECREASED by 5.3 percentage points (a 12.3% difference). (3,137now / 3,577then x 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

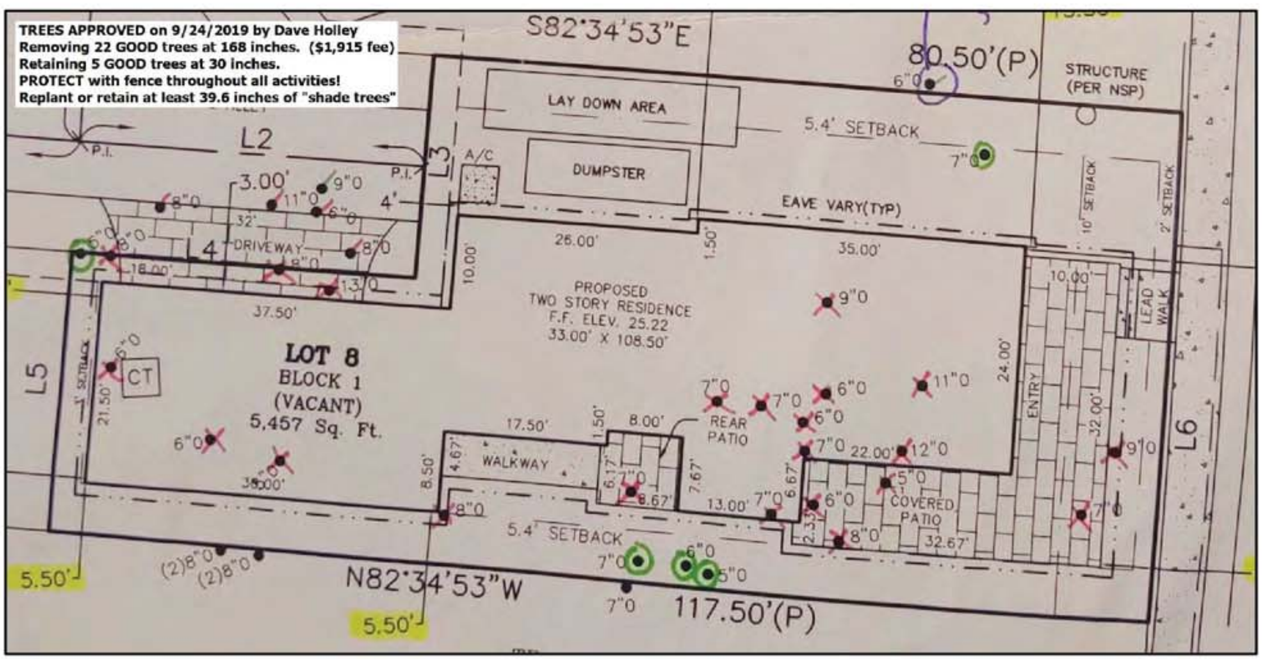
Trees provide a variety of services to people, wildlife, and the environment such as:

- 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:

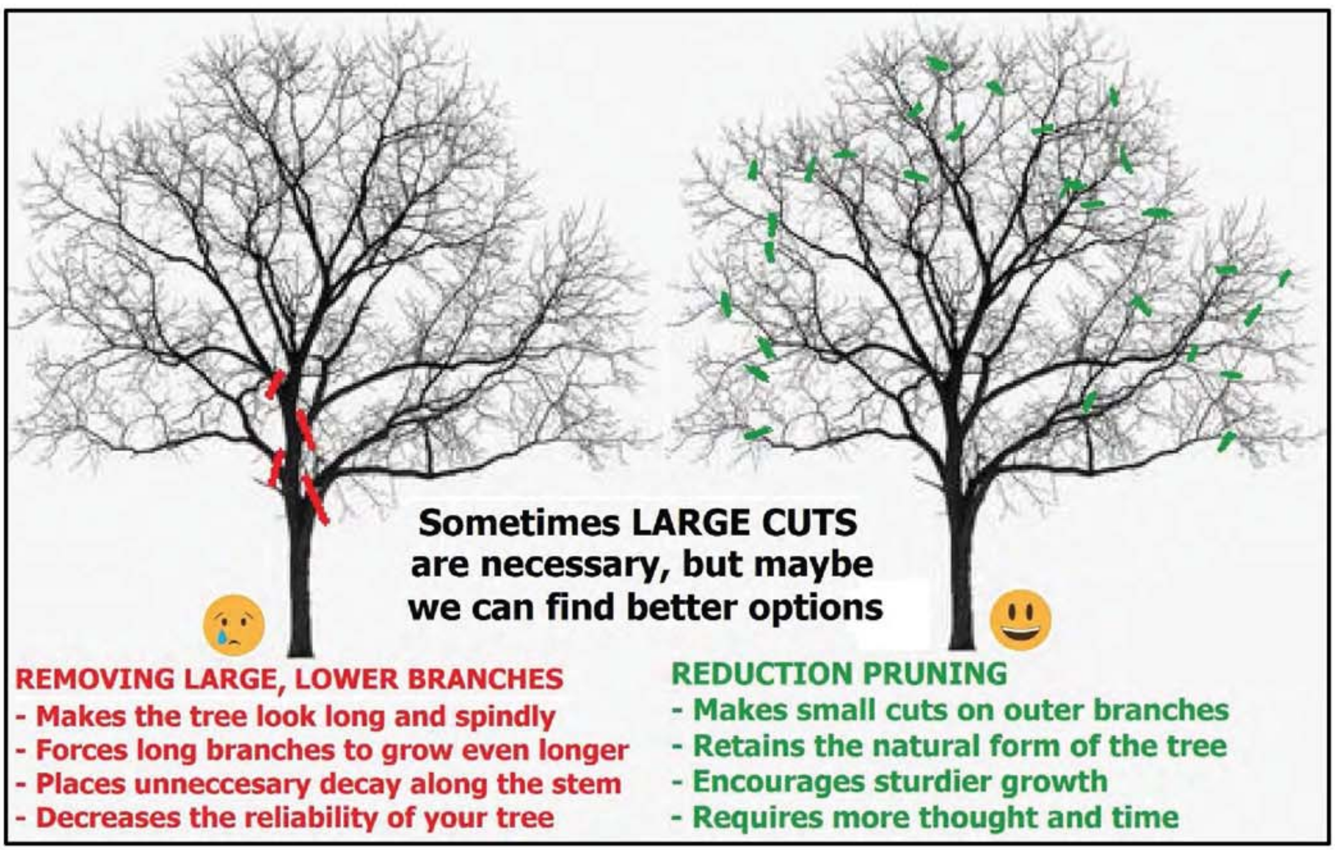
- Arbor Day Plantings – We celebrate FLORIDA Arbor Day in January and NATIONAL in April. In 2020, we celebrated by planting 32 trees at MLK Park and 1 tree at City Hall.
- Emma Love Planting – In February of 2020, we planted 20 trees with students and teachers at Emma Love Hardee. Schools can be excellent 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 14^{th} 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 3rd 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 2nd 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

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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

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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 aerials became available canopy cover estimation could be done to track changes over time.

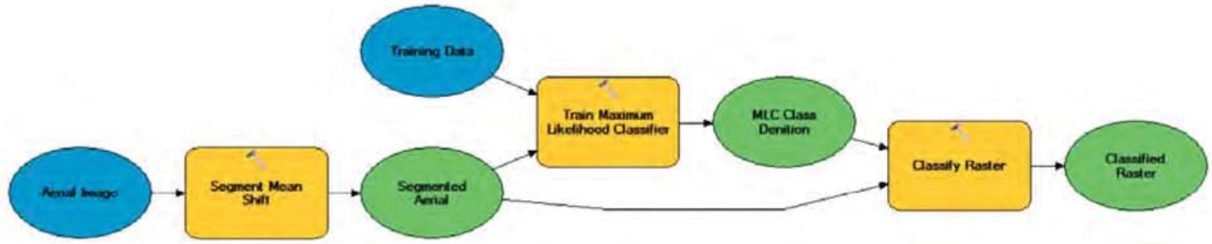
This analysis continues the work of the 2009 assessment, using Geographic Information Systems (GIS) and statistical algorithms to estimate tree canopy coverage from 2009 to 2019. A GIS-based feature extraction model was created to assess canopy change from 2009 – 2019. Essentially an exercise in computer 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

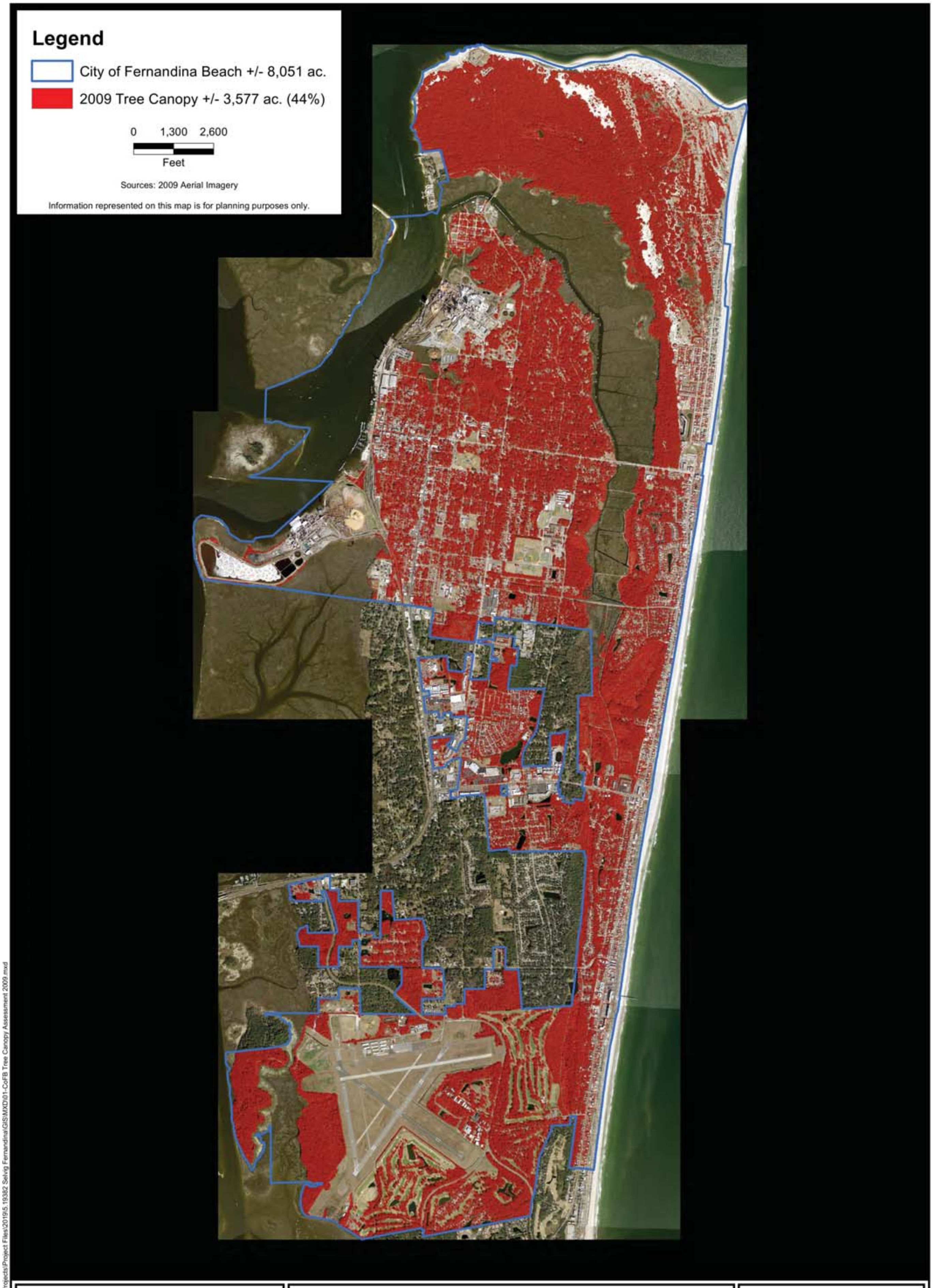
Creation of this sort of image classification model is part art and part science. Many different training algorithm types were explored to find the best results. Within each of the methodologies tried, a number of different input parameter scenarios were tested. Through this process the "Maximum Likelihood 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 disciples 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.



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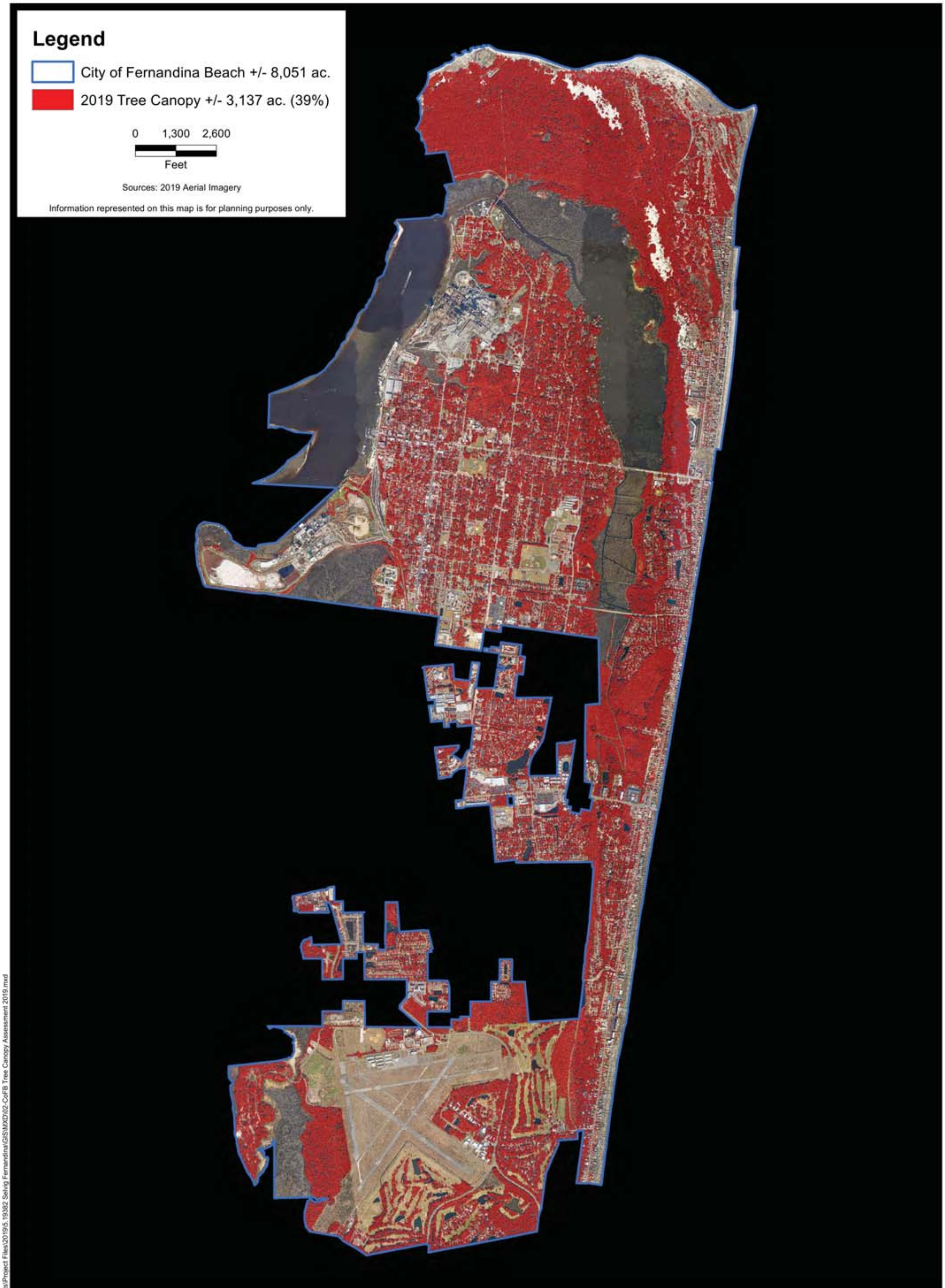
2009 Tree Canopy Model Results

Tree Canopy Assessment

City of Fernandina Beach, Florida

Project:	5.19382
Date:	Apr 14 2020
Figure:	1



CARTER ENVIRONMENTAL SERVICES, INC. CES 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

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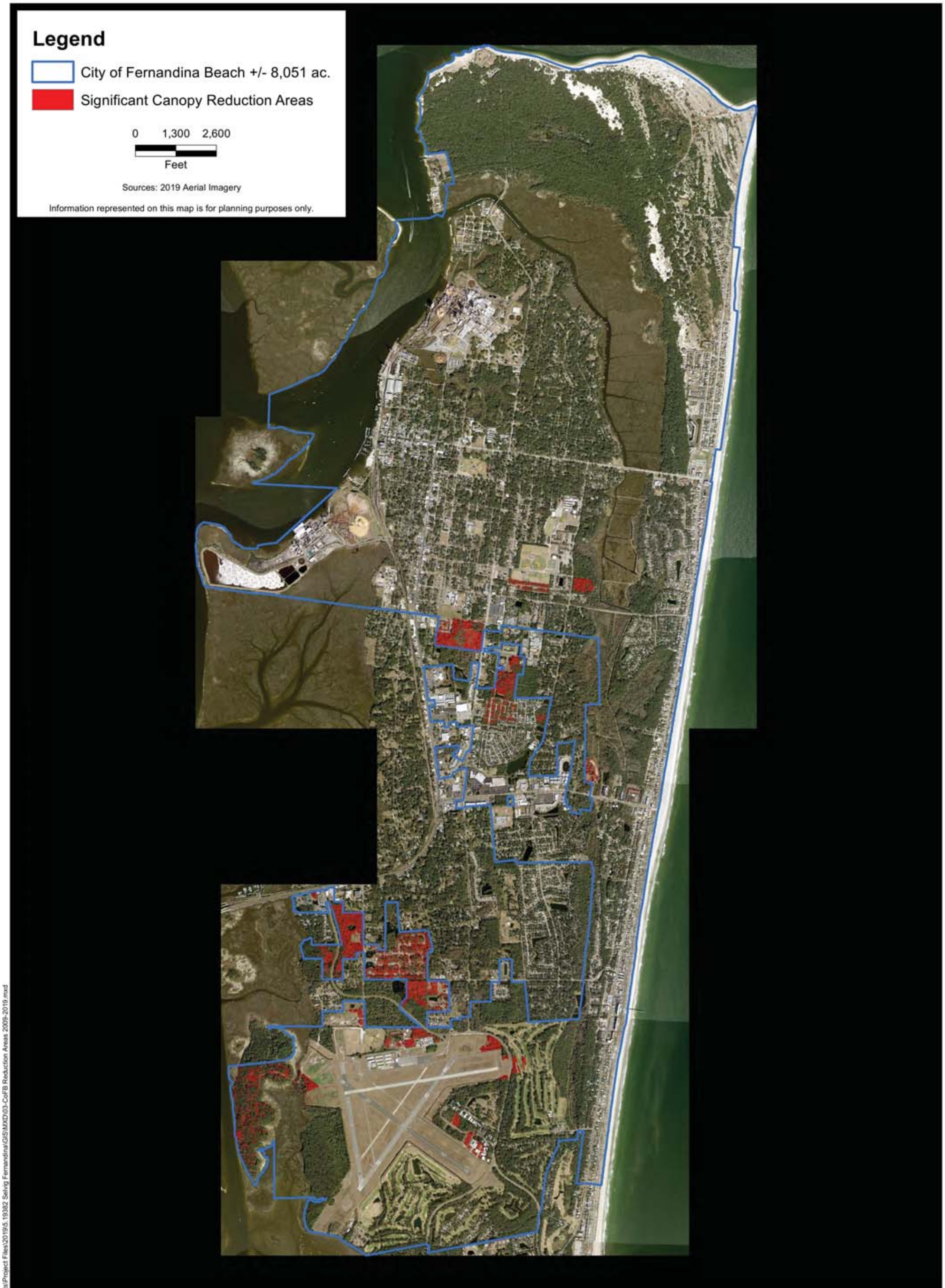

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Tree Canopy Significant Reductions 2009 - 2019

Tree Canopy Assessment

City of Fernandina Beach, Florida

Project:	5.19382
Date:	Apr 14 2020
Figure:	3

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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 x 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)

Arboriculture & Urban Forestry 2019. 45(5):167–200

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; Levinnson 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 streetscapes, 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

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

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

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

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

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

(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*

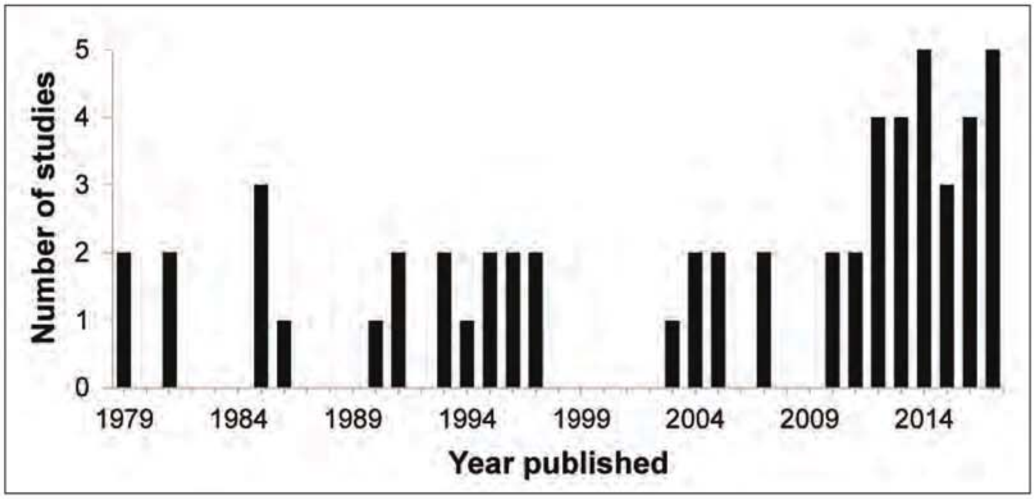

Figure 1. Years in which the urban tree mortality studies reviewed were published (1979 to 2017).

& 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 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.

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

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

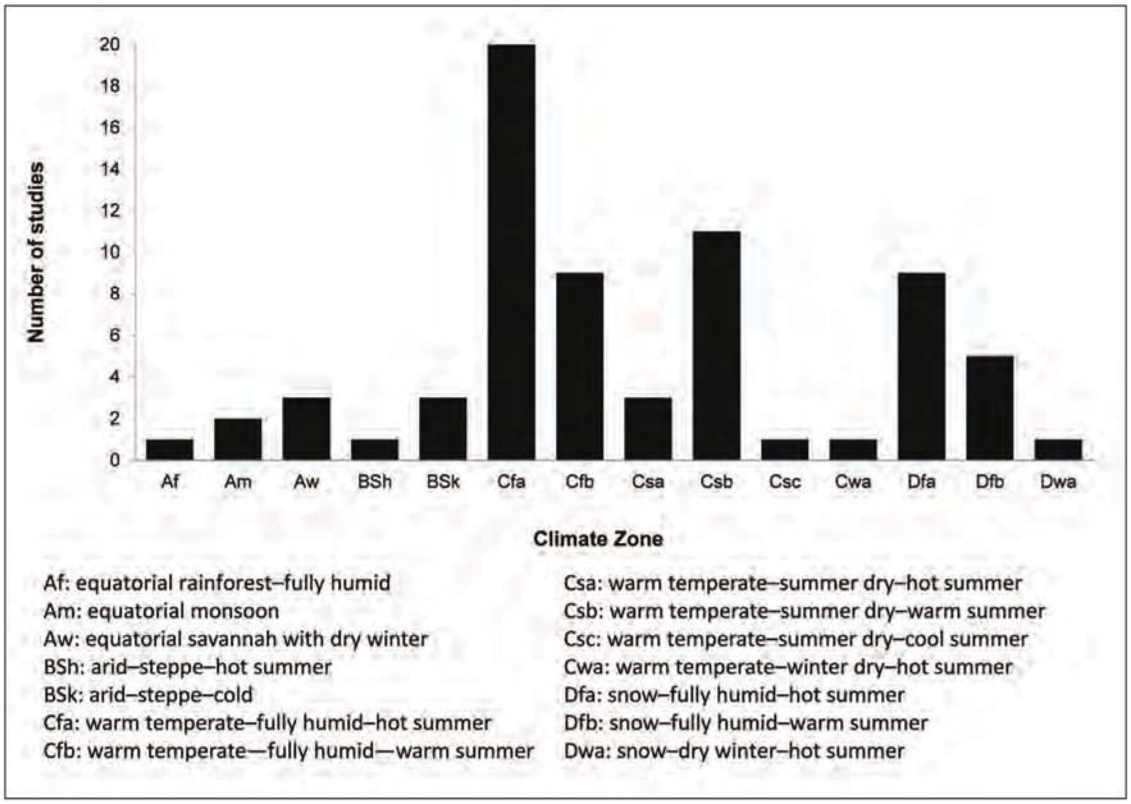

Figure 2. Climate zones where data was collected for the reviewed studies. Climate zones are based on the Köppen-Geiger climate classification system where the 3-letter abbreviations correspond to main climate, precipitation, and temperature (after Kottek et al. 2006).

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,

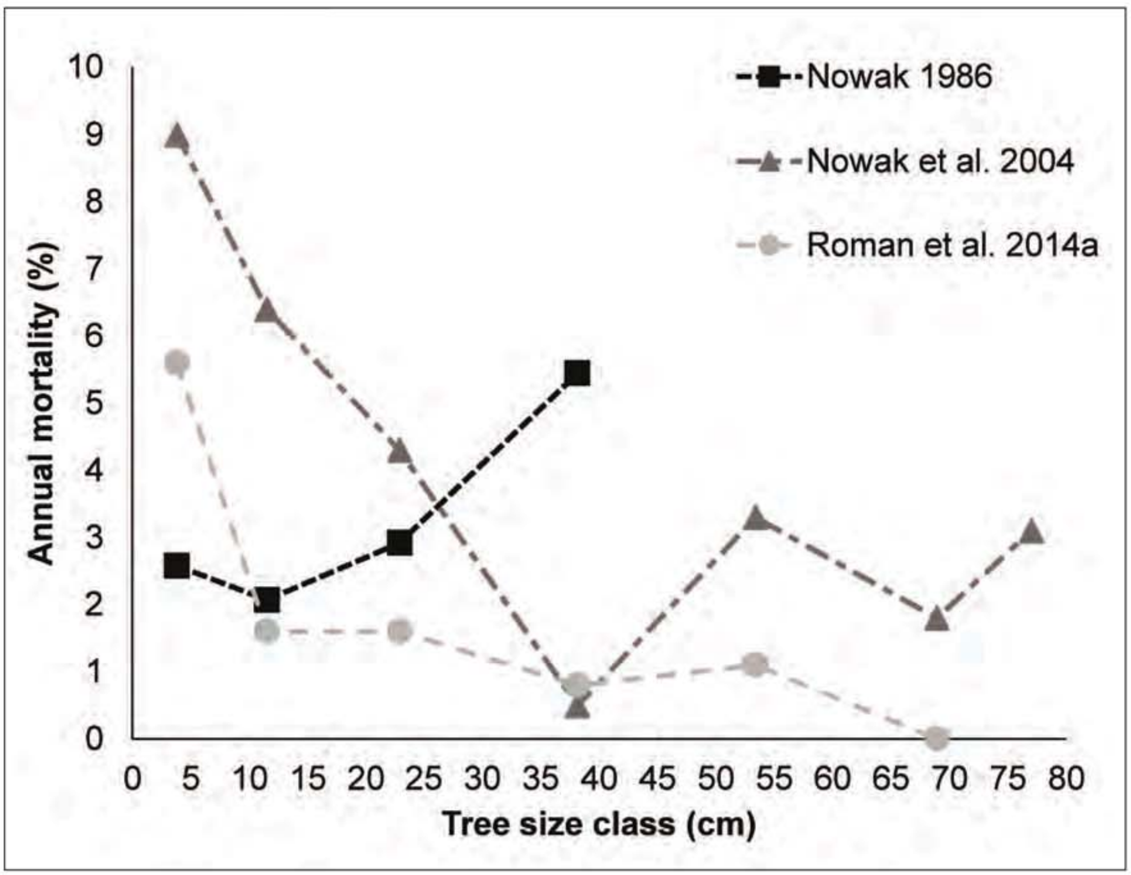

Figure 3. Mortality curves for studies that provide size-based mortality rates. Annual mortality rates are plotted at the mid-point of the size class interval.

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

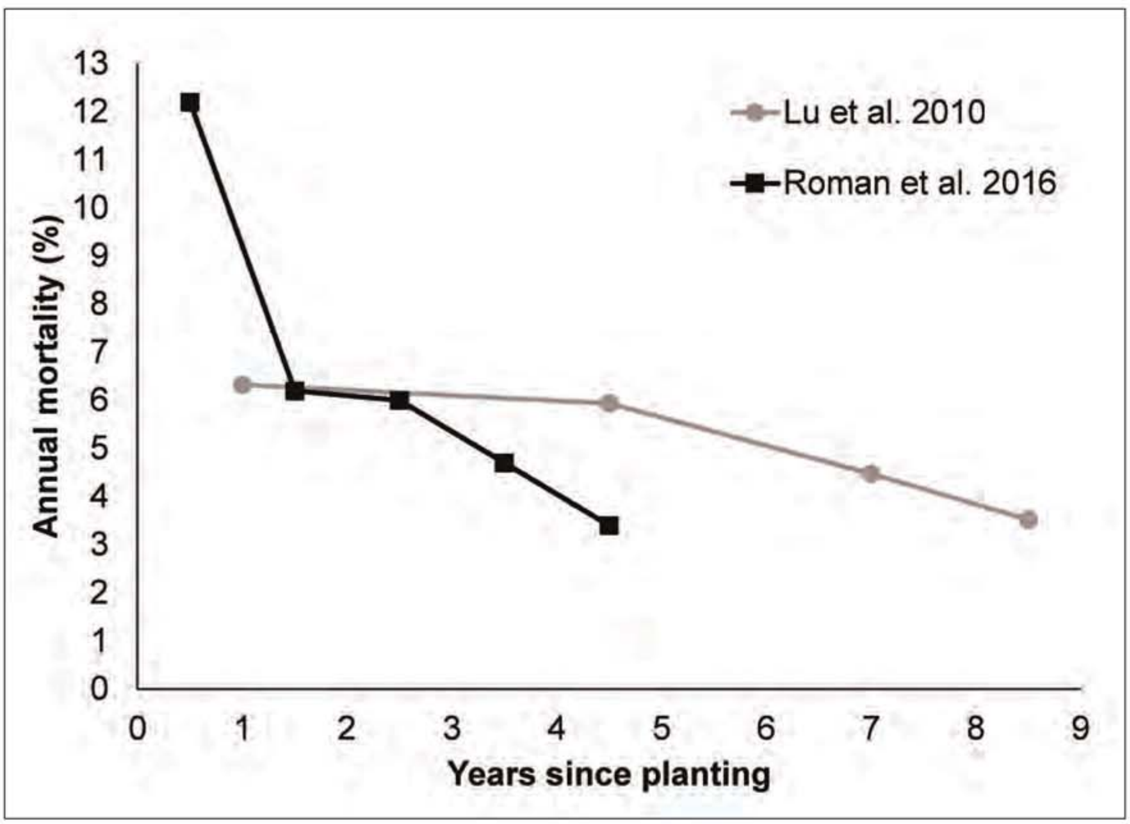

Figure 4. Mortality curves for studies that provide age-based mortality rates. Annual mortality rates are plotted at the mid-point of the age (i.e., time since planting) interval.

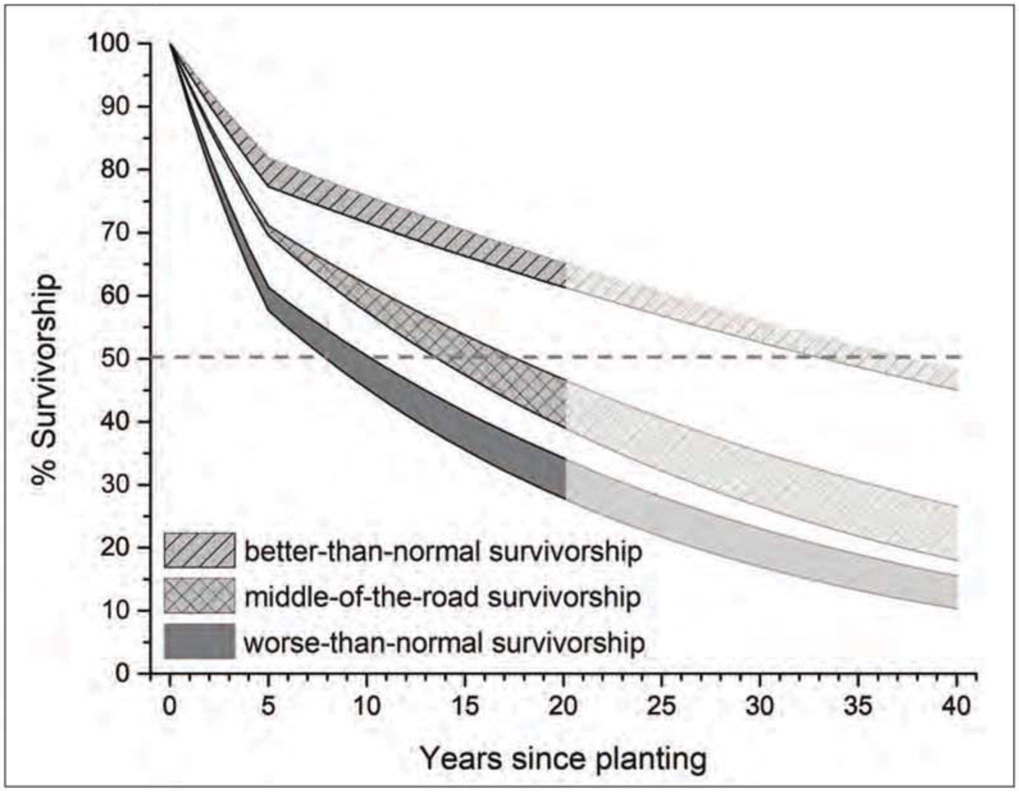

Figure 5. Survivorship curves based on quartiles of mortality rates in planting cohort studies (Table A1). Better-than-normal survivorship reflects 1st quartile, middle-of-the-road reflects median, and worse-than-normal reflects 3rd quartile. The first five years used establishment mortality rates, while 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