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Post-Fire Restoration and Recovery Manual for Western Urban Forests

UNIVERSITY OF CALIFORNIA AGRICULTURE AND NATURAL RESOURCES & USDA FOREST SERVICE - PACIFIC SOUTHWEST RESEARCH STATION

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Glossary of Terms

Arborist- professionals who care for individual trees, or for groups of trees primarily intended for purposes other than timber harvest. There are generally two types of arborists:

- International Society of Arboriculture (ISA) "Certified Arborist": this certification is often held by owners of their own professional practice who charge for evaluation of a tree and then may also offer to perform work on the tree. This certification is also common associated with employees of a tree care company. Some of these may offer a free evaluation of a tree, but with an unstated expectation of future paid services.
- American Society of Consulting Arborists (ASCA) "Registered Consulting Arborist": professionals holding this certification are often principals of their own consulting practice who charge for evaluation of a tree. They primarily act as consultants and can provide recommendations as well as supervise demolition and construction activities but are seldom equipped to perform tree work.

CAL FIRE-California Department of Forestry and Fire Protection

Cal OES-California Office of Emergency Services

Defensible space-a buffer zone between a home and a wildfire that's been modified to reduce the risk of fire damage and to help firefighters protect the home

FEMA-Federal Emergency Management Agency. The government agency tasked with helping communities respond to and recover from disasters.

Fire-adapted community- a community that "collaborates to identify its wildfire risk and works collectively on actionable steps to reduce its risk of loss" according to the United States Fire Administration (https://www.usfa.fema.gov/wui/communities/)

Model Water Efficient Landscape Ordinance (MWELO)- California ordinances that govern efficient water use in new and retrofitted landscapes

Response- refers to home/landscape related actions that are needed immediately post-fire

Recovery – refers to individual trees.

Restoring – refers to canopy cover, tree stands, planting actions, etc.

Urban Tree- refers to a woody plant, with branches usually growing from a single trunk, that becomes over 2 meters tall at maturity and is "large enough to hurt you if it falls on you" (Dr. Matt Ritter of Cal Poly University, San Louis Obispo).

UC ANR – University of California Agriculture and Natural Resources is the State of California's extension service

Urban area- "urban place, as that term is defined by the United States Department of Commerce, of 2,500 or more persons" according to the 2009 California Public Resources Code - Section 4799.06-4799.12: Chapter 2. Urban Forestry

Urban fire- a fire event that occurs in urban land use-cover types and that is primarily driven by high winds, high housing density, flammable building construction practices, and close structural proximity to ignitable vegetation and other ornamental features.

Urban forest (private and public)' "native or introduced trees and related vegetation in the urban and near-urban areas including, but not limited to, urban watersheds, soils and related habitats, street trees, park trees, residential trees, natural riparian habitats, and trees on other private and public properties." according to the 2009 California Public Resources Code - Section 4799.06-4799.12: Chapter 2. Urban Forestry

Urban forester – a professional involved in the management and planning of trees and related vegetation in and near communities. An urban forester manages for tree population, stands and tree cover as opposed to an arborist who focuses on individual trees.

Urban tree cover or canopy – "Urban Tree Canopy is the leafy, green, overhead cover from trees that community groups, residents, and local governments maintain in the landscape for beauty, shade, fruit production, wildlife habitat, energy conservation, stormwater mitigation, and a host of public health and educational values". It is often measured using remote sensing methods and reported in a percent metric of unit area of urban tree canopy divided by area of interest (i.e.., square kilometers of a city or hectares of a neighborhood; USDA FS 2019).

USDA- United States Department of Agriculture

USFS- United States Department of Agriculture- Forest Service

Wildfire- unplanned fire events that occur outside urban areas in Wildland-Urban Interface and wildland land-cover vegetation types such as forests, shrublands, rangelands, and grasslands.

Wildland-Urban Interface (WUI)- the zone of transition between unoccupied land and human development. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels

Introduction

Francisco Escobedo, Alyssa Thomas, and Igor Lacan

Justification and current lack of information:

Urban forests have numerous social, economic, and ecological benefits, providing important ecosystem services. Trees in cities play an important role in providing cleaner air and water, and serve as a natural stormwater mitigation provider, decreasing runoff, flooding, and soil erosion. Wildlife and birds rely on trees for their habitat and a food source. Trees provide shade from the sun for people by blocking the sun from reaching the ground and heat-retaining surfaces such as sidewalks and roofs. This benefits residents by keeping homes cooler during the hot summer months thereby reducing energy needs and costs for cooling. Similarly, trees can also play an important role in air quality by filtering out air pollutants. Many studies have also documented how planting trees can increase the value of homes (Payton et al., 2008; Tyrväinen & Miettinen, 2000) and provide multiple physical and mental health benefits for residents (Lee et al., 2011; Wolf et al., 2020). They also have social benefits including increasing social cohesion, creating a sense of place and lowering crime rates (Nesbitt et al., 2017). Finally, trees play a vital role in slowing climate change as they absorb carbon dioxide (McPherson et al., 2017). However, trees can also have costs and often require maintenance and water and can attract nuisance wildlife and cause allergies. Tree, shrubs and grasses can also serve as fuels during wildfires.

Recently, there is an increasing trend in extreme fire events affecting more urban areas, socio-demographically diverse communities, and urban and community forests in places such as California, the Western US, and elsewhere (Thomas et al., 2022 and Yadav et al., 2023). These "urban fires" -- which are driven by burning structures, embers, and extreme weather events more than vegetation -- are leading to catastrophic impacts to communities and neighborhoods (Calkin et al., 2023). Chief among these impacts are the loss of urban forests and their benefits.

Resources are available to guide homeowners and public officials in the Wildland-Urban Interface (WUI) on topics such as wild and prescribed fire use and management, wildfire and fuel mitigation, restoration practices, and plant selection practices. Similarly, science-based information regarding defensible space, Firewise community practices, fuel treatments, structural hardening of homes, and post fire structure loss is readily available and actively being studied. This WUI-relevant information is currently being used to develop and improve community wildfire protection planning (CWPP) as well as Firewise and defensible space planning. However, these resources are more targeted and relevant to more rural and suburban neighborhoods than to those in denser urban areas (Figure 1).

Conversely, there is little information available on how to plan for, manage, and restore urban forests affected by fire (Escobedo et al., 2024). In fact, the concepts of “WUI” and “communities” as applied in most post-fire information resources are strictly defined based on the number of “structures” per unit area and the distance of these buildings relative to “natural or wildland” vegetation patches (Radeloff et al., 2005). These concepts also do not consider the complex physical, social, and ecological conditions of cities, or the structure, composition distribution, condition, and benefits of urban and community forests outside the WUI (Figure 1). So, there is

a pressing need to better understand urban fires and how to respond to, recover from, and plan for these events. Likewise, there is a need to share this information with residents, homeowners, and public officials to change both behavior and local policy. There is a need to develop a science-based online manual and guidelines.

Insert Box 1: Is it WUI or Urban?

Although these terms are regularly used in geography, land and resource management, and urban planning, knowing the difference between these two terms is important. Basically, if you are in the WUI, you may have additional requirements from CAL FIRE based on their fire severity zone maps. For example, living in one side of street may have requirements that other side of the street does not because they are outside a high fire severity zone. Nevertheless, several of the issues included in this guide will be applicable to WUI: for example, most arboricultural practices described herein are directly applicable to WUI, as are considerations regarding working with arborists, etc. On the other hand, WUI areas present a set of considerations that are explicitly not included in this guide. Foremost among them is the centrality of fuels management in WUI, which is both the crucial pre-fire management consideration, as well as an important post-fire management objective.

Thus, while important in urban areas as well, the specific issues associated with "urban fires" are fundamentally different from WUI. First urban fires are primarily wind driven and the primary "fuel" in urban areas comprises the structures themselves, not the vegetation. Another important difference is that of the relative importance of the different goals for post-fire tree management. Post-fire vegetation management goals in cities often prioritize restoring canopy cover near structures, to achieve the typically the paramount goal of shading and cooling effects that tree canopy offers to people and for the energy savings it affords to buildings. In contrast, vegetation management in WUI areas might be focused on such goals as watershed conservation or fuel mitigation treatments that remove vegetation, or on working lands management (optimizing forest products, grazing, etc.), or on land management for recreation, all of which might de-emphasize recovering tree canopy. In sum, a reader who is primarily interested in WUI issues is urged to consult the existing literature on WUI fires (Escobedo et al., 2024). Indeed extending WUI guidelines that call for removal of all vegetation near homes inside the urban matrix is not recommended as it can lead to undesirable quality of life and public health consequences. Accordingly, the area to the right of this Continuum of Wildland to Urban Densities in Figure 1.1 and the classes inside the Red Box are the areas that are most relevant to this manual.

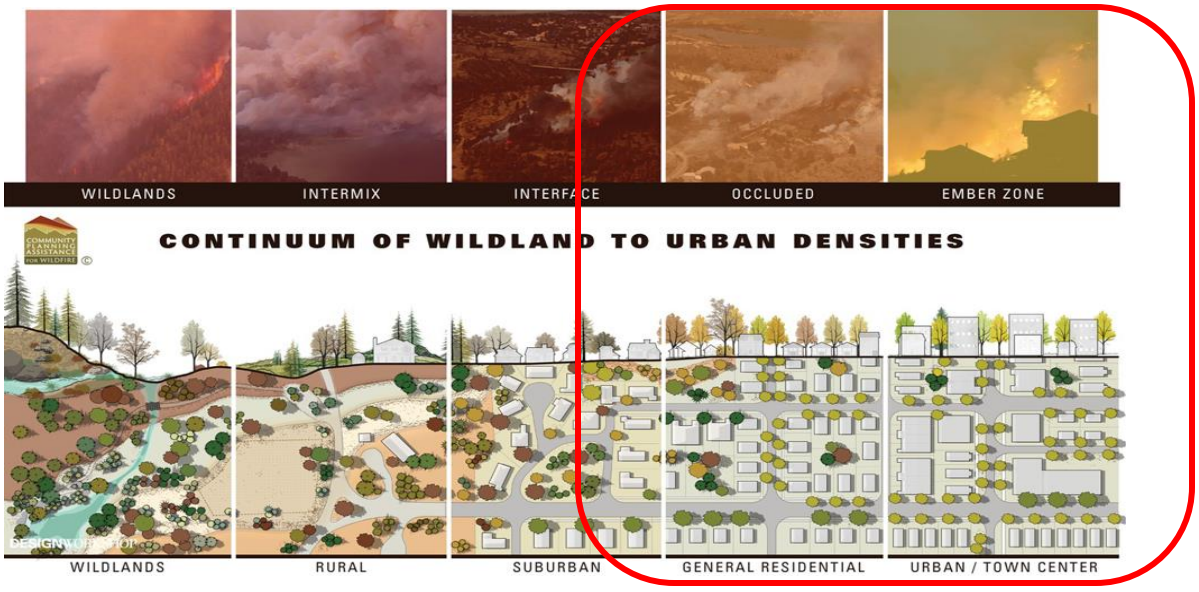

Figure 1.1. Wildlands-urban gradient. Copyright Headwaters Economics.

These new urban fire events are more frequently occurring in highly populated, residential and commercial areas with high building densities, typically composed of non-native urban forests, afforested areas, and often in areas well outside of "WUI" defined areas (Calkin et al, 2024; Escobedo et al, 2024). As a result, more information is needed on how to respond to these events, restore fire affected urban forests, and plan for future events. Likewise, local and state-level policy making guidelines for urban forest ecosystem restoration guidelines are few, anecdotal, and not easily accessible. Therefore, there is a need to develop a science-based online manual and guidelines for:

1) Assessing and restoring urban tree cover in fire affected urban and community forests for managers and homeowners,

2) Compiling best management practices for appropriate species selection and landscaping practices,

3) Developing regional tree planting, flammability, and design guidelines for restoring fire affected urban landscapes and

4) Presenting a suite of lessons-learned case studies of communities that have successfully (and not so successfully) restored fire affected urban forests.

This manual aims to develop state-of-the-art guidelines for urban forests and landscapes to not only provide social, economic and environmental benefits but also reduce or mitigate the risk of wildfire. This document will focus on suitability for mitigating wildfire risk characteristics that are appropriate for fire-prone Western cities, and for restoring urban landscape benefits (e.g., ecosystem services) in fire-affected neighborhoods in the Western United States. The best management practices (BMP's) and planning and policy guidelines included in this manual for post-fire restoration of urban forests are based on key findings from existing literature, and the expert opinions of urban forestry professionals.

Urban planners and tree professionals (e.g., urban foresters, arborists, tree workers) can also use this information to integrate this increasing reality of wildfire into urban forest management plans because techniques used in the WUI may not apply to the urban environment and vice-versa. Creating a wildfire plan within an urban forest management system ensures residents have access to proper preventative educational material, as well as clear guidelines for post-fire restoration processes.

This manual and its associated online components provide a guide to the management, planning and policies for restoring urban forests in fire-affected communities. Information will consist of a review of the relevant literature, case studies of urban wildfires in the western United States, including lessons learned, and listings of resources available for both public official and homeowners.

Audiences

This guide is intended for two distinct audiences:

1. Public officials, including professionals and elected individuals responsible for developing and implementing urban forest ecosystem management and restoration policies, plans, and resources for the local public.
2. Homeowners, including individuals, Homeowner Associations, and others who own, care for, and/or manage trees, shrubs, palms, woody plants, and other vegetation in urban settings around people's homes and properties.

Aims, scope and manual format

Aims: There is a need to develop a science-based online manual that provides information and guidelines for assessing and restoring urban and community forests affected by fire events. This guide has three principal goals:

1. To provide an **overview of information and guidelines** related to the practice of urban tree management – arboriculture and urban forestry – in post-fire affected communities in more urban and populated settings. Most of the material refers to the issues, actions, and considerations after a fire has occurred. The emphasis is on directing readers to existing sources of information when possible; not recreating that same information.
2. To provide an **overview and sequence of steps and processes** that can be used to assess, plan and manage for urban tree canopy before, during, and after a fire. Some of the processes/actions are sequential while others occur during different steps in the planning-management cycle or might be dependent on pre- fire planning as well as resources and existing information.
3. To provide **references, information sources, and links** that can provide background information on issues covered in this guide as well as on more general topics in arboriculture and urban forest management that are useful in a post-fire situation. It will also present a suite of tree planting, flammability, and design guidelines for restoring fire affected urban forests and landscapes.

This manual and the information presented is not exhaustive and is only intended as a guide to orient the reader to the wide variety of issues and considerations that relate to post-fire events and urban trees.

Scope: Although the topic of fire and trees is expansive, the scope of this manual is limited to:

(a) urban areas, including cities, towns, suburbs, and more densely developed areas in the Wildland Urban Interface,
(b) urban trees, especially those planted and actively managed in close proximity to homes and other buildings as well as parks and green areas in and near communities.

(c) the considerations specifically related to urban fire events, but we do borrow information from Wildland-Urban Interface fire resources as well as urban forest-hurricane response and other disaster management events.

We thus caution that the following information in this guide might not apply to:

(a) Rural or wildland settings.
(b) Plants other than trees and vegetation types, such as chaparral, where fire is a natural and potentially desirable element in ecosystem management.
(c) Arboricultural practices and considerations that are largely unrelated to fire (e.g., ornamental pruning practices).

A note on the distinction between the WUI and the "urban" settings, as used in this guide: The US Fire Administration defines the WUI as "the zone of transition between unoccupied land and human development. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels." In contrast, the focus of this guide is on populated areas where "undeveloped wildland" may be present but does not constitute a substantial portion of the fire-affected area. We use terms such as "urban trees," "urban forest," and "urban canopy" interchangeably, and intend them to refer to trees and other vegetation that are maintained in immediate proximity to human residences, businesses, and infrastructure in situations where, "there are more people than trees." Note also that we focus our discussion on woody plants. For a more technical discussion of the difference between "Wildland-Urban Interface forests" and "Urban forests" regarding fire, please see Escobedo et al. (2024).

Information in this guide is organized by theme and is generally presented according to both Homeowners and Public Officials. But it is important to recognize that the importance of each theme will vary in its relation to the events and action that occur before and after a fire event. Response to a disaster such as a fire best thought of us part of an adaptive "disaster management cycle as outlined in Figure 2. This manual was developed following this cycle and its content follows the process focusing on the response and recovery that takes place days, weeks, and months after an urban fire. But the manual emphasizes the mitigation and preparation that is required years after a fire; or the years before a fire event (Figure 2).

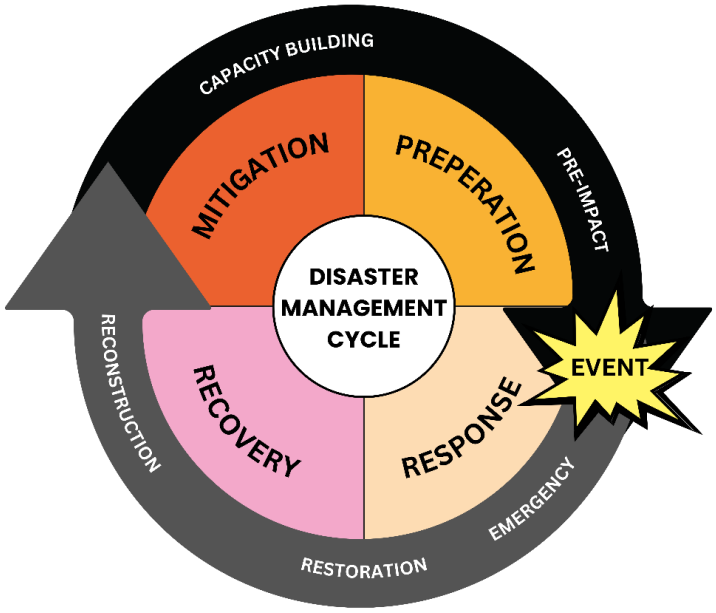

Figure 1.2. Response cycle to wildfire or urban fire events. Note how there is no start and no end, but a continual and adaptive process.

Limitations of this guide:

This publication is focused on discussing issues that relate to post-fire urban forest management and arboriculture related response and practices. The multiple "pre-fire" issues are covered to provide background information and to enable better understanding, preparation, and planning of urban forests with a view towards minimizing damage in future fires and facilitating post-fire recovery. We note that this guide is a complement to – and not a substitute for – Fire Safe, Fire Wise and other community planning guides. We include those guides in the References and direct the reader to them as needed. Finally, this guide does not cover any of the issues related to urban wood utilization, wildland forestry or other "working lands" management. Issues and practices such as reforestation, restoration, grazing management, timber production, watershed protection, and other topics central to managing wildland or commercial forests and rangelands are intentionally excluded from this document. This publication is also not a substitute for Burned Area Emergency Response (BAER) information and procedures. However, given the lack of available information on fire affected urban forests, we borrow some concepts and material from the areas of WUI fire management, BAER, urban forest-hurricane response, emergency management, as well as the conventional urban forestry and arboriculture literature and sources of information.

Chapter 1 Pre-fire Planning

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Introduction

This manual will be focused on discussing issues that relate to post-fire urban forestry. The multiple "pre-fire" issues are covered to provide background information and to enable better understanding, preparation, and planning of urban forests with a view towards minimizing damage in fire and facilitating recovery.

Before a wildfire occurs, communities and homeowners need to be prepared with guidelines on the best course of action. Proper pre-fire planning is important to minimize the potential damages and losses from wildfire. There are many simple actions that homeowners and cities can take to reduce their risk that require relatively minimal time and effort. Here we provide a selection of resources to help guide pre-fire planning. This planning occurs at multiple scales, from individual parcels to neighborhoods to the city itself. This chapter will provide (1) information for homeowners and residents for the pre-wildfire period to help communities and public officials more effectively prepare for wildfire; and (2) background material and definitions and resources on urban forestry concepts that relate to fire response considerations.

Homeowner-specific guidance focuses on two elements: fire-risk reduction for landscapes and structures, and evacuation preparedness. A brief overview of these issues is followed by links to reference materials. For public officials, we discuss the importance of preparing and updating the urban forest management plan (UFMP) and including specific considerations related to fire events in the plan. We also briefly discuss the need to evaluate municipal capacity to manage post-fire urban forest response and restoration, and to ensure effective communication and coordination across agencies at all levels of government.

Homeowners

This section provides links to and descriptions of resources for homeowners to help them mitigate the risk of wildfire. Generally, there are two main aspects to preparing to co-exist with wildfire-housing preparation (become fire-adapted) and personal preparation (become evacuation ready). Although homeowners have many demands on their time, the importance of pre-fire preparation cannot be overstated. For many actions, the first year requires the largest time investment, and subsequent years are less demanding in terms of time, and owners should ensure that they are up to date prior to the start of each wildfire season. It is also important to not underestimate the risk of wildfire and assume that preparation is not needed. The provided resources are not comprehensive, and homeowners should also ensure they are familiar with city-specific policies around vegetation management and evacuation procedures.

Become fire-adapted

An urban fire - like wildfires - can damage a home through three pathways: wind-blown embers (burning pieces of airborne wood and/or vegetation that can be carried more than a mile through the wind), radiant heat from the fire, and/or direct flame contact. Most homes (60-90%) destroyed by wildfire are first ignited by flying embers that land on flammable materials (on decks, roofs, litter in gutters, or poorly maintained vegetation that is in contact with the home), which can then ignite and produce enough heat to ignite the structure (https://ucanr.edu/sites/forestry/files/343690.pdf). These embers can come from either the approaching fire, nearby burning structures (home, storage shed, wood pile) or even vegetation or structures that are nearby or even from distances as great as 1.5 miles. This means that by reducing the flammability of the home *and* the area, or fuels, immediately around a home, the chance of your home surviving a fire are greatly increased (https://wildfirerisk.org/reduce-risk/ignition-resistant-homes/). "Home hardening" or structural modifications, is the most important thing you can do, but also includes proper maintenance and management of nearby vegetation, this can help lower the susceptibility of structures to being ignited by embers or flames. For homes, there are 11 vulnerable structural components:

- Chimneys
- Decks
- Fences
- Garages
- Rain gutters
- Roofs
- Roof edges
- Siding
- Skylights
- Vent
- Windows

Using WUI guidelines in urban areas: The Three Zones

The home ignition zone or "defensible space buffers" represent three areas from the house out 5 feet (Zone 0), 30 feet (Zone 1), and to 100-200 feet (Zone 2) and includes the home itself and other ignition sources such as nearby vegetation and other structures. It is however important to consider that these large clearance areas are based on typical situations encountered in rural or WUI areas, and that vegetation-clearing directions in Zone 1 and especially in Zone 2, are often impossible to meet in medium or high density residential-commercial urban areas. This is because other nearby properties, buildings, street trees, city parks, and other infrastructure will be located well within Zone 2, and frequently even within Zone 1. Nevertheless, it is important to understand the Zone concepts, especially for Zone 0, which is most relevant in urban areas and to a limited extent Zone 1 area.

Defensible space is the buffer between your structure and the surrounding area and permits firefighters to better *defend* your home and the first line of *defense* for reducing potential damage to, or loss of, your home by fire. In WUI guidelines and for fuel driven wildfires, plants are considered fuel for fire and homeowners are encouraged to manage the amount and type of plant biomass within a 200-foot perimeter surrounding a home or other structure. In these areas, vegetation that is "natural" and often composed of a few species, is managed more intensely and removed as you move closer to the house in a series of three zones (Figure 3). Again, we note that these conditions often apply to more suburban and WUI areas, since in more highly urbanized built areas you will generally find highly diverse vegetation composition and structure, as well as other homes and structures in Zones 1 and 2 as described in the following sections.

Figure 1.3. Defensible space/home ignition zone layouts for Wildland-Urban Interface areas. As you can see Zones 0 and 1 are most important and relevant in urban areas. Notice also that the layout depicted here – large lots, no adjoining structures visible, no street trees, etc. – is very different from parcels in urban areas. Copyright California Department of Forestry and Fire Protection.

Starting from your home and moving outwards, Zone 0 is the first five feet from your home and the most important zone. Zone 0 is defined as the ember-resistant or noncombustible zone and is focused on the home and its immediate surroundings. The goal of this zone is to reduce the risk to the home by creating a buffer around it that is ember-resistant. This zone is considered the most important zone when creating defensible space as it is the most vulnerable to embers. Simple actions such as cleaning gutters and roofs of any debris and not storing any combustible materials (e.g., wood chip mulch, wood piles) on or under decks/porches and any exterior surfaces are applicable to this zone and should be done regularly. Homeowners can also retrofit homes (i.e., home hardening) through projects such as installing ignition-resistant siding, roofs, decks, attic vents, eaves, and windows. Vents serve as openings for embers to get into the house, so installing metal screens can address this structural vulnerability. Regarding vegetation, WUI guidelines suggest there should be limited to no vegetation within Zone 0 and advise homeowners to keep this area clean of all dead and dying vegetation and vegetation debris (including pine needles and leaves). In urban areas, only low growing, well irrigated and maintained vegetation, that is not in contact with a retrofitted home is recommended.

Zone 1 ranges from 5 to 30 feet from structures and is defined as the intermediate zone. The goal of this zone is to use fire-smart landscaping to reduce the risk of fire spreading from surrounding vegetation to the house itself. Within this zone vegetation should be limited and well maintained (e.g., pruning dead, low growing branches to "lift the crown") and spaced so that trees and shrubs are separated from other plants or flammable materials (wood piles, patio furniture) by a minimum distance of 10 feet. Low flammability, well maintained tree and shrubs should be planted in small clusters of a few each to break up the continuity of the vegetation. Driveways, walkways/paths, patios and decks (if made of non-combustible materials) can also serve as fuel breaks. As with Zone 0, property owners should also keep this zone clear of all dead plants, leaves, pine needles, and other plant debris to avoid a fuel bed that allows fire to carry closer to the structure. Ideally trees should be planted and maintained so that the canopy is also at least 10 feet from the home (or other structure). While usually impractical in urban areas the WUI recommendation is that other structures in this zone, such as storage sheds, should not have adjacent vegetation and should have their own non-combustible zone. We note again that in urban areas, adjacent structures or homes will frequently be found in this zone, therefore this concept often is not applicable in many urban areas.

The third and final defensible space zone is Zone 2, 100 feet between surrounding vegetation or the property line and the structure. In urban areas adjacent structures, or homes, or infrastructure will likely be present in Zone 2. However, in homes with larger parcel sizes or those next to undeveloped areas of continuous vegetation, in this extended zone, the goal is to reduce the spread of fire and limit its movement from the ground into the tops of trees and shrubs and keep the flames smaller. In California, 100 feet of defensible space is actually required by law (Public Resources Code (PRC) 4291). Within this space, if a lawn is present, it should be maintained below four inches in height (although lower is recommended), create horizonal space between trees and shrubs, and create vertical space between grass, shrubs, and trees to keep future fire as close to the ground as possible. Ideally all plant debris should be removed from this zone, and small trees growing between mature ones should be removed. Remaining trees should be appropriately spaced (refer to the following resources for specifics) to maintain a distance between them and prevent fire and embers from easily spreading between them. Any structures in this zone, such as storage sheds, should not have adjacent vegetation and should have their own noncombustible zone.

Beyond the Zones approach: preparing for fire in medium- and high-density urban landscapes

Overall the key limitation tot eh Defensible Space Buffers is that, ultimately, the measures described above require sufficient physical space to be effective. In urban areas, managing vegetation in "Zone 2" will be nearly impossible for a single property owner, as the space in Zone 2 will include multiple other properties. Even Zone 1, considered from a perspective of one house, will often include another house within it, thus making the management recommendations moot. So, for dense urban environments, there are two key take home

messages. First, manage the structure itself and the area around it to provide firefighters the best opportunity to defend your home. And two, manage the entire neighborhood or community as a unit to ensure that community-wide measures are taken to both facilitate evacuation and lessen the risk of any one structure catching fire. So to summarize:

- Once a flaming ember has reached a structure, the structure's fate is tied with its ability to resist ignition. "Structure hardening" is a set of measures that aim to reduce the probability of ignition and includes installing appropriate shutters, screens, fire-resistant siding, fire-resistant roof materials among other practices.
- Be sure to provide firefighters the opportunity to defend you home by removing flammable items that are in contact with your home and might prohibit entry to firefighters such as: fences, gates, hedges.
- Limit the number of ways a flame can reach a structure by not placing combustible "pathways" adjacent to your house, such as wooden fences, decks, gates, or dry combustible materials stored next to the walls (e.g., a wood pile). Be sure to also regularly remove combustible dry material such as leaf litter from you gutters.

In sum, hardening your home is critical but it is also not sufficient. In dense urban environments, once a building catches on fire, there is simply not enough space between buildings to ensure that radiant heat and direct flame contact will not ignite the adjacent buildings. Thus, a community-wide approach is needed. For more information, Please refer to some of the webpages below.

"Ignition Resistant Homes"

- https://wildfirerisk.org/reduce-risk/ignition-resistant-homes/
- This online resource has a several helpful diagrams and videos about how to retrofit a house to better withstand ignition. But the main use of this website is the many provided links to other useful sources (including several included in this manual) that provide guidance on defensible space.

"Preparing homes for wildfire"

- https://www.nfpa.org/en/education-and-research/wildfire/preparing-homes-for-wildfire
- This is an excellent resource from the National Fire Protection Association. The website breaks down the three different parts of the home ignition zone, and details both home and landscape considerations for protecting your house. There is also a simple checklist for homeowners to go through before each fire season to improve home safety from wildfire.

"Reduce Risk"

- https://wildfirerisk.org/reduce-risk/

- A dashboard of resources provided by the USDA Forest Service for homeowners and communities to become better fire-adapted. This website is an easy-to-use tool for guidance on pre-fire planning, from ignition-resistant home building to evacuation readiness, as well as providing response and post-fire recovery resources.

"Wildfire Home Retrofit Guide"

- http://ucanr.edu/HomeRetrofitGuide
- This is a free 20-page downloadable guide from the University of California Agriculture and Natural Resources that focuses on how to harden homes against wildfire. Specifically, it includes best practices for 12 vulnerable components of homes in wildfire-prone areas including roofs, gutters, vents, siding, windows, decks, and fences. Other publications focus on defensible space with vegetation management, whereas this guidebook targets the exposed vulnerabilities of the structures themselves.

"Wildfire Prepared Home Free Online Home Assessment"

- https://wildfireprepared.org/wildfire-prepared-home-base-assessment/#:~:text=Ready%20to%20take%20the%20Wildfire,Ready?
- This website provides an online assessment to determine how prepared your home is for wildfire. It covers the different defensible space zones as well as structural modifications. The questions can serve as useful guidance for homeowners wishing to decrease the susceptibility of their home to wildfire.

Become evacuation-ready

In addition to working to make your home more resilient to fire, it is also important for households to invest time in personal preparation to make sure they are ready to promptly evacuate in the event of a nearby wildfire. In this section we offer some useful resources to help residents prepare for evacuation.

"Build a kit"

- https://www.ready.gov/kit
- Part of the larger "ready.gov" website of the US government, this portion focuses on creating a 'go bag' for you and your household. This site is probably the most comprehensive as it is for 'all' disasters, not wildfire specifically. An advantage is there is a downloadable checklist you can print out and take with you to the stores to ensure you don't miss anything. It is available in English and 11 other languages including Spanish, Japanese, and Chinese.

"Create your 'go bag"

- https://readyforwildfire.org/prepare-for-wildfire/emergency-supply-kit/
- Although much shorter than the US government's page (above), this short guide by CalFire is useful. It is focused specifically on wildfire and offers several practical suggestions.

"Make a go kit"

- https://firesafemarin.org/prepare-yourself/evacuation-guide/evacuation-go-kit/

- The important component of this website is a checklist and graphic on how to dress for evacuation. This information is crucial in the event of a last-minute evacuation when wildfire is already threatening your location.

"Ready for wildfire"

- https://www.readyforwildfire.org/
- A dashboard of resources provided by CAL FIRE for homeowners to improve their wildfire preparedness. Information is provided on the three aspects of wildfire preparation and response: "Prepare yourself", "Prepare your property", and "Prepare for evacuation". The first section focuses on pre-evacuation actions, including creating a customized evacuation plan for the household (including pets). The third section focuses on what to do in case your household is under an evacuation warning, as well as important advice for what to do in the event of a loss of power during a wildfire.

"Wildfire. Are you prepared?"

- https://plan.readyforwildfire.org/en
- This website helps you create a personalized evacuation checklist by answering some simple questions.

Public Officials

Step 1: Develop and/or update the Urban Forest Management Plan

Ideally, the first step in pre-fire planning in urban forestry is the development of an Urban Forest Management Plan (UFMP) or identify if an UFMP already exists for your community or other nearby regional or nearby entities. Key to most UFMPs is a tree inventory. More specific information on the kind of relevant information that is, or can be, included in an UFMP will be presented later in Chapter 7.

Step 2: Consider your community's capacity and create or strengthen the necessary inter-agency relationships

Just as important as Step 1, this critical step regards the institutional capacity for smaller municipalities, specifically restoring the urban canopy after a fire will involve many local agencies and experts, as well as require interfacing with regional bodies (if existent), as well as State and Federal government entities. Smaller cities and towns should evaluate their staffing and institutional capacity. For example, are the needed experts available within the city staff or are they contracted out? Remember that contract tree care companies, planners, and engineers will be extremely busy, tasked and over-subscribed with work immediately after a fire and will likely be unavailable for municipal work unless prior arrangements have been made.

In addition, local hiring, procurement, and contracting processes may impose substantial delays on the timeline for bringing in the needed help and thus delay the recovery – can contracts, or other agreements, be pre-approved to expedite such processes after a fire? Similarly, are there

any regional coordinating bodies whose approval will be required before work can proceed, or whose support will be instrumental to secure grant or relief funds? Two suggested worksheets on the following pages provide a starting point for evaluating local capacity and procurement as well as contracting processes. This information can be used to guide discussions across municipal departments, government agencies and the private sector, to better facilitate post-fire recovery.

TABLE 1.1: Agencies/expertise that will be involved in pre-fire planning.

City/Municipal Agency	Before (B) after (A) fire?	Contact Name / email / phone	Date last contacted?
County Agency			
Regional Entity			
State Agency			

Federal Agency			

Table 1.2. Contracting considerations for pre-fire planning.

	Precontract in place? Y/N or N/A	Contact Name / email / phone and any pre-agreement notes	Date last contacted and agreement exp.
Contract tree care company			
Contract consulting arborist			
Contract planning or engineering firm			
Contract waste disposal company			

Contract _____

"*Tree Emergency Plan Worksheet"*

- https://dnr.illinois.gov/content/dam/soi/en/web/dnr/conservation/forestry/urbanforestry/documents/treeemerplanwksheetjune2006.pdf
- Provides a comprehensive planning document for severe weather events. Includes sections to identify relevant staff positions, emergency call-out procedures, post-event clean-up procedures, and a place to list individuals and groups that are involved with urban forestry/city greening efforts.

"*Urban Forest Strike Teams*"

- https://southernforests.org/ufst/
- Provides information on urban forest strike teams, or groups of professional arborists and urban foresters that can assist communities with post-disaster tree damage assessments. There is also a button to "request assistance".

Chapter 2: Cleaning Up After a Fire: Safety Comes First!

Introduction

Alyssa Thomas, Igor Lacan, Francisco Escobedo

Figuring out where to start once the fire has passed and recovery begins can be overwhelming. Although post-fire cleanup is necessary as the first step in recovering the urban tree canopy, many considerations stand in the way of completing this process, and it may prove to be frustratingly slow and cumbersome under some circumstances. As will later be explained, environmental assessments are the first step to being able to rebuild post-fire. Wildfire ash and debris is often dangerous and can have long-term health risks if proper precautions are not taken. Regulations concerning hazardous waste disposal – which can apply to "dangerous debris" produced by the fire – as well as environmental review process(es) such as the national or state-level equivalents (e.g., California Environmental Quality Act in California) can delay the necessary work and add months to years to this very first step in recovering from a fire. It is also important to note that these regulations are often waived during emergency response and recovery operations. As it is impossible to provide detailed guidance on every issue for every community, we emphasize the need to reach out to city (for homeowners) or state/federal (for cities) officials for specific information, or with any questions.

Once hazardous material is removed and soil samples are within the environmental limits set by State and Federal laws, building permits may be issued. However, environmental assessments are also required for project and grant approvals, sometimes multiple assessments must be conducted as they may not transfer from one project or grant to the other. Keep this in mind with post-fire planning, as this process may take multiple years. Although it's understandable that residents are anxious to return home, it is important to wait until local law enforcement authorities have given the go ahead. Many potential threats remain even once the fire is out in an area. There are likely to be damaged power lines, structural damage to buildings, hazardous debris, and burned/damaged trees.

Cleanup after a wildfire generally consists of two phases: Phase 1) Household Hazardous Waste Removal and Phase 2) Debris Removal (Figure 2.1). In many localities, there is often an initial Hazard Assessment for hazardous trees and toxic substances that occurs prior to these 2 phases (https://www.mauirecovers.org/debrisremoval). It is important to note that in many fire-affected communities what to do with, and where to dispose of, this hazardous waste can be a very contentious issue.

Figure 2.1. Example of post-fire clean-up timeline and phases. Copyright County of Maui, 2024.

Phase or Stage 1 is done by staff from U.S. The Environmental Protection Agency, and/or the equivalent state agency (e.g., California Department of Toxic Substances Control). Hazardous waste removed during this stage is anything that represents a potential hazard to the environment and/or human health including pesticides, cleaning products, paint, pesticides, asbestos and batteries. During this stage arborists will also assess any fire damaged trees for an immediate threat to workers, and damaged buildings will be assessed for safe entry. This stage must be completed prior to debris removal and the public will not be allowed back to retrieve any items until it is completed. Phase 1 is completed as quickly as possible to minimize the risk of exposure to emergency workers and the public. However, some properties might be "deferred" because it of dangerous trees or terrain, unstable structures, or other unsafe conditions. Those properties will instead be done in Phase 2.

Phase or Stage 2 is overseen by the U.S. Army Corps of Engineers or the state recycling agency (e.g., Cal Recycle). However, these agencies will often contract the work out; and due to the scale of large fires multiple business are normally given contracts for the work (otherwise it would take too long). During phase 2, ash, debris and hazard trees will be removed. It's also useful to note that while stage 1 is always completed by the appropriate departments due to the specialized training required to handle hazardous substances, when it comes to phase 2 homeowners have a choice: They can opt-in to the government coordinated and sponsored program, or they can choose to opt-out and privately engage a company to carry out the debris removal at their own time and expensive (although insurance will often pay for at least a portion). The final stage of phase 2, and the cleanup process, is environmental testing (of the soil) to ensure there is no contamination and the land is safe for occupancy. A building permit cannot be issued until the entire process is complete.

Homeowners

Below is a selection of some helpful post-fire resources for homeowners:

"After the Disaster Guidebook: A toolkit for landowners impacted by wildfire"

- https://boulder.extension.colostate.edu/wp-content/uploads/sites/7/2024/08/Boulder-Ext-After-the-Disaster-Guidebook-8-2024.pdf
- This is a comprehensive guide to the post-fire period. It was published by the Colorado State University Extension in August 2024, after the highly destructive Marshall Fire. In addition to chapters around returning home, and cleanup, there is also a chapter on mental health & self-care.

"Dangerous Debris: Potential Health Risks Associated with Residential Wildfire Debris"

- https://www2.calrecycle.ca.gov/Publications/Details/1661
- This is a one-page fact sheet from CalRecycle that provides an overview of residential wildfire debris, why it can be harmful to your health, and how to reduce your exposure.

"State Recovery Resources"

- https://wildfirerecovery.caloes.ca.gov/
- This site has resource links for California wildfire survivors, hazardous waste removal, and news. Each of these categories contain information, and often additional links. The resources page contains information ranging from federal grants, general recovery resources, assistance centers, and the debris removal program (once again breaking down the two phases).

"Returning Home Checklist"

- https://readyforwildfire.org/post-wildfire/returning-home/
- This website details many of the safety concerns and precautions that could be encountered when returning home after a fire. At the bottom of the webpage there is also a downloadable checklist.

"Recovery Guide to Wildfire Debris Removal"

- https://cadresv.org/wp-content/uploads/2024Jan29DEBRIS_22-27_WILDFIRE_survivors_handb.pdf
- This is a comprehensive, downloadable guide published by the state agencies who manage fire cleanup. It provides a step-by-step guide to the different phases of the cleanup process. Each page also has a "Don't Forget!" sidebar to draw attention to key considerations.

"Wildfire Cleanup Information for Homeowners"

- https://calrecycle.ca.gov/disaster/wildfires/homeowners/
- https://www2.calrecycle.ca.gov/Docs/Web/127224
- A very informative website and guide by CalRecycle. The site and guide outline the two phases for post-wildfire debris removal and details the two different options homeowners have for debris removal (no out of pocket cost or homeowner expense). There are also links to other helpful sites, including a Spanish language guide to debris removal.

"Wildfire Recovery"

- https://ucanr.edu/sites/fire/Recovery/
- This website provides a number of useful tips, divided into categories such as: take care of yourself, assess home damage, assess resource damage, secure finances, and prepare for the future.

Public Officials

Information will be needed to identify where hazardous trees of greatest risk are located. This can be done as part of a rapid post-disaster needs assessment (PDNA) or a damage assessment as part of Phase 1. A PDNA is carried out in the weeks immediately after a disaster with the aim of identifying damage to community infrastructure, impact on service delivery, and recovery costs.

If an official disaster declaration - and the funds that come with it - will be needed, then a damage assessment will be needed. In this case, coordinate with your state to contact their FEMA Regional Office and request a joint preliminary damage assessment (PDA). The purpose of these assessments is to determine the magnitude of the damage and impact of the disaster. A joint PDA should include federal, state, and local government representatives. In both cases, work should be carried out with partners in different sectors. These partnerships can provide necessary skills including GIS, technical knowledge, equipment and technology for data collection, databases to store the information collected, and communication materials. Determining where to start hazardous waste (and thus debris removal) operations requires careful consideration of different criteria. For example, after the Marshall Fire in Louisville Colorado, Boulder County created a schedule (https://bouldercounty.gov/news/marshall-fire-coordinated-debris-cleanup-program-schedule-released/) based on multiple factors including:

- Imminent environmental hazards, including the distance of homes from waterways to protect the water supply.
- Input from the contractor on how to make the process the most efficient.

Resources

"Assess Impact and Damage Post-Emergency"

- https://www.ruralhealthinfo.org/toolkits/emergency-preparedness/5/assess-impact-and-damage
- This website outlines the different types of post-disaster assessments and provides several useful links.

"Damage Assessment"

- https://training.fema.gov/emiweb/downloads/is208sdmunit4.pdf
- Published by FEMA, this is a comprehensive guide to carrying out a PDNA.

"Preliminary Damage Assessments"

- https://www.fema.gov/disaster/how-declared/preliminary-damage-assessments
- This website from FEMA provides information on how to conduct a preliminary damage assessment. There are also links for a digital damage survey template and "street sheets" to assist in carrying out the assessment, as well as other templates. Although trees are not specifically included, they can be included as the "other category", or the templates can be used as a starting point to design a modified version.

Initial post-fire risk assessment:

Why: The goal of these initial tree risk assessments is to identify any hazard trees that pose a risk to public safety. For some trees such as western pines and other conifers, it's difficult to decide if the tree will survive, so tree survival assessments on fire-damaged trees should also be carried out later by certified arborist (See Glossary of Terms), especially if there was uncertainty regarding potential hazards during the initial assessment. Refer to chapter 4 for more detailed guidance and resources around post-fire tree assessments.

When: As part of phase 1 of cleanup. Should be done immediately around homes, roads and other areas where there is human traffic– while there's still smoke but the fire is under control. Assessments should be performed as soon as the fire is out to avoid unnecessary removal of trees that may survive. The city often waves tree removal permits due to low priority. The timeline for completion of the initial assessment is highly variable and depends on:

  - What infrastructure is present.
  - Utility involvement – they will begin tree work immediately.
  - Urban density.
  - FEMA involvement.

Also, funding constraints and the Tree Risk Assessment results will influence the timeline. For example, how detailed does the initial Tree Risk Assessment need to be? If there is no target

around fire-damaged hazard trees, then they are not of high concern (aside from identifying ones that present a public safety risk). However, most of the time this stage should be completed within the first six months post-fire.

Who: Certified arborists as defined in the Glossary of Terms, ideally with experience with fire - damaged trees, should conduct the Tree Risk and Hazard Assessments. The city might have sufficient experienced arborists on staff, or they will put the assessment out for bid and give the contract to a private company. Chapter 4 will provide more detailed information and resources around post-fire tree assessments.

"Wildfire Debris Removal and Recovery Operations"

- https://calrecycle.ca.gov/disaster/wildfires/
- To reduce and prevent harm, wildfire debris must be safely removed in the State or Federally approved order of operations. This website provides details on what is done under each of the two phases: Hazardous Waste Removal and Debris Removal, which includes hazardous trees.

Cleanup Resources for Public Officials:

"CA Dept of Public Health Wildfire Cleanup: considerations for public health officials"

- https://www.cdph.ca.gov/Programs/EPO/CDPH%20Document%20Library/Wildfire%20Cleanup%20Considerations%20for%20California's%20Public%20Health%20Officials%20(August%202019).pdf
- This is a downloadable guide that is broken into three sections: 1) Health hazards of debris; 2) Options for debris cleanup on private property; and 3) Public assistance program for private property debris cleanup. Two useful appendices cover commonly used acronyms and example ordinances and templates.

"Public Assistance Debris Management Guide"

- https://www.fema.gov/sites/default/files/2020-07/fema_325_public-assistance-debris-mgmt-plan_Guide_6-1-2007.pdf
- This a comprehensive guide to post-disaster debris management by FEMA. It includes 16 chapters on subjects including: eligibility, costs, debris removal, health and safety information, and other federal assistance. Of note is Chapter 3 which details eligibility requirements for hazardous trees, hazardous limbs, and hazardous tree stumps.

"The Phoenix Guide"

- https://co-co.org/wp-content/uploads/2018/07/CUSP_phoenix_guide.pdf
- A downloadable comprehensive guide to the post-wildfire period. The handbook is geared towards conservation districts, nonprofit groups and communities. Chapter 8 includes a section on hazardous trees including how to identify them.

"Worker Safety and Health in Wildfire Regions"

- https://www.dir.ca.gov/dosh/worker-health-and-safety-in-wildfire-regions.html
- This website provides official information from the State of California, Department of Industrial Relations. There are lots of links around Frequently Asked Questions, protecting both indoor and outdoor workers to wildfire smoke, and a whole section on worker safety and health during fire cleanup, as well as one on the safety and health of workers rebuilding after wildfires. Some of the links are also in Spanish

Immediate post-fire cleanup will include the removal of some fire-damaged urban trees, and this segment focuses on considerations related to this process. Here we only refer to the trees that have been assessed and designated for removal (i.e., trees that are dead, destroyed, or deemed hazardous). In the following Chapter 3, we will provide information on the role and importance of certified arborists in the post-fire assessment and recovery process. However, the immediate cleanup process will involve competing priorities, and an "order of operations" may need to be followed, such as is illustrated in the example below from California. When prioritizing debris removal, there is one important difference between fire-damaged trees and other types of fire-produced debris. Primarily, standing dead trees will become more hazardous over time, as their roots, stems, and branches degrade, increasing the likelihood of uprooting, breakage resulting in tree hazards to property and human life.

This issue with fire-caused tree hazards contrasts with most other types of debris which can become less of a hazard (e.g., ash, as it is gradually incorporated into soil or removed off site) or at least does not increase in the degree of hazard they pose. On the one hand, it may be appropriate to schedule tree removal after the hazardous debris has been removed, as in the example below. On the other hand, any hazard trees with limbs that extend over targets such as structures or high-traffic areas, as well as leaning or "widow maker trees (i.e., trees that are partially fallen but are caught up in other trees or leaning on structures) should receive immediate attention for removal (Figure 2.2). In Chapter 4, we will also discuss in more detail the process for evaluating individual trees for retention or removal. We note that in urban, wind-driven fire events, trees are very resilient to fire especially when they are monitored over the long-term, irrigated and maintained.

Figure 2.2. Tree that needs an immediate hazard-risk assessment (Left) and a tree that needs long-term monitoring (right).

FUNDING

Funding for recovery and restoration, including funding for tree removal, might come from somewhat various sources as outlined below. The process for securing funding and the funding requirements for specific tasks might be quite specific and/or somewhat complicated, so it may be appropriate to explore available funding streams before a fire, and to create connections with funding entities and agencies. At a minimum, consider becoming familiar with the potential sources of funding, their application requirements, and especially any deadlines that constrain fund availability.

FEMA Funding resources:

"FEMA Grants Portal"

- https://grantee.fema.gov/
- Homepage to logon, or to register your organization for public assistance

"FEMA Hazard Mitigation Grant Program Post Fire (HMGP)"

- https://www.fema.gov/grants/mitigation/learn/post-fire
- FEMA's HMGP provides postfire assistance for communities to implement hazard mitigation after wildfire disasters. This webpage provides guidance on applying for aid, pre-calculated benefits and a link to a fact sheet on how to apply for aid.

FEMA "Public Assistance Program and Policy Guide"

- https://www.fema.gov/sites/default/files/documents/fema_pappg-v4-updated-links_policy_6-1-2020.pdf
- Pages 99-116 contain information about debris removal requirements and checklists for potential grant applicants.

"*Summary of FEMA Hazard Mitigation Assistance (HMA) Programs"*

- https://www.fema.gov/fact-sheet/summary-fema-hazard-mitigation-assistance-hma-programs
- This webpage provides a broad overview of FEMA's activities regarding hazard mitigation. It also details subjects such as eligibility and cost share requirements and provides phone numbers of the different helplines.

Non-FEMA funding resources:

"Community Development Block Grant Disaster Recovery (CDBG-DR)"

- https://www.hud.gov/program_offices/comm_planning/cdbg-dr
- This program, administered by the U.S. Department of Housing and Urban Development, provides flexible funds to help cities, counties, and states recover from presidentially-declared disasters. Funds can be used for disaster relief, long-term recovery, restoration of infrastructure, housing, and economic revitalization. It is administered by the U.S. Department of Housing and Urban Development (HUD).

"Emergency Watershed Protection (EWP) Program"

- https://www.nrcs.usda.gov/programs-initiatives/ewp-emergency-watershed-protection
- The EWP "offers technical and financial assistance to help local communities relieve imminent threats to life and property caused by floods, fires, windstorms and other natural disasters that impair a watershed". These threats could include debris-clogged stream channels undermined and unstable stream banks, jeopardized water control structures and public infrastructure, and damaged upland sites stripped of protective vegetation.

Your state wildfire agency (e.g., CAL FIRE) and the USDA Forest Service often have grant opportunities for post-wildfire response. Finally, for an example of the importance of engaging with Environmental Health Services (EHS), please see the Santa Rosa case study in Chapter 9. In this case the priority was to coordinate with EHS the removal all hazardous material before issuing any building or landscaping permits. Note, engaging with these services may cover the cost of debris removal, but only if the site is not disturbed prior to their inspection; however this is often contrary to the wishes of residents, who want to "just get started". For another example of how an inappropriately extended timeline for removal prevents anything else from being done, please see the Paradise fire case study in Chapter 9.

Insert Box 2.1: "Constraints and Requirements" – the Tubbs Fire in Santa Rosa, California

An example of some of the considerations presented in this Chapter can be found in example of the Tubbs Fire in Santa Rosa, CA. The first notable aspect was a set of constraints that indirectly but inflexibly guided the process that the city was undertaking, not always to the benefit of the urban forest.

- Constrained timing: Santa Rosa had **60 days** after the fire to submit damage assessments to the FEMA grants portal – photos, document requirements, etc. The limited time window made focusing on trees challenging.
- Constrained eligibility: only city facilities and public infrastructure were considered for FEMA grants; not homeowners or private property. This is a potentially substantial constraint in situations where "street trees" are actually located in private front yards, as is the case in many low-density neighborhoods.
- Constrained decision-making: FEMA decided what were the highest priority projects and the emergency debris removal timeline to be done by the City.
- Need for rapid estimates of tree damage to be included in the assessment: the challenge with funding for tree assessment and removal on private property was that it was *optional*, yet the City needed an estimate of how many properties would enroll in the program (vs. the residents completing the work on their own).

Given these constraints, it makes sense for a city tree manager to consider, prior to a fire, the following two questions, and initiate community consultation if needed:

- Do we have a current and sufficiently detailed baseline information about our trees (i.e., a Geographic Information System-based inventory), so that we will be able to complete a post-fire assessment within the 60-day window
- What is the role of private trees in our city? If majority of our street-tree canopy is actually on private property, how will we fund the restoration of this canopy after a fire? Are those trees included in our GIS-based tree inventory? How will we ensure the replanting of these trees after a fire

Another interesting aspect of the Tubbs Fire experience was the City's experience of working with FEMA, specifically the "mechanics" of obtaining FEMA's assistance funding. FEMA requires a 3rd party arborist to be hired for any tree removal that is to be funded by FEMA; the arborist's report should prove that tree removal is necessary and demonstrate that any tree hazard is caused by damage from the fire (i.e., was not pre-existing).

- Phase 1 – In Santa Rosa, and arborist report was completed on all "street trees," with each tree assessed and coordinates recorded. Because private trees made up such a large fraction of the city's street tree canopy, the City of Santa Rosa intended to use this assessment process to provide tree information to homeowners, so each homeowner did not have to pay for arborist assessment.
- Phase 2 – Parks. The City found that trees in open spaces were not assessed in Phase 1 and had to be completed in a subsequent phase. This caused some delay.
- Phase 3 – Additional assessments were then completed on trees not included in the first two phases, but subject to the following requirements: trees must be over 4 feet tall and > 16 inches in diameter at breast height, and fire-damaged as verified by the arborist report.

Chapter 3 Cleaning Up After a Fire: Hiring and Working with Professional Arborists

Igor Lacan, Tara Kelly

Introduction

Arborists are professionals who care for individual trees, or for small groups of trees as opposed to foresters who manage wildland forests and stands of trees or urban foresters who plan and manage for community-level tree cover and tree populations. This distinction may be important in some settings, such as the State of California, where the development of management plans in the WUI or managing trees intended for timber harvest will generally be done by a professional forester ("California Registered Professional Forester"). Arborists on the other hand, typically work with individual or small groups of trees in urban or WUI areas.

Arborists typically hold a certification that attests to their professional competence and compliance with professional standards. However, only a few states require that an arborist obtain an actual "arborist license", so the certification should be considered evidence of (some) qualifications, rather than a permit to carry out work – depending on the work to be performed, additional licenses may be required, such as a contractors' license or pesticide applicator's license, etc. The two most common certifications are *ISA Certified Arborist* issued by the International Society of Arboriculture (ISA), and *Registered Consulting Arborist* issued by the American Society of Consulting Arborists (ASCA). Additional qualifications and certifications also exist, but only one is likely to be relevant to post-fire arboriculture and this is the Tree Risk Assessment Qualification (TRAQ) which is further discussed below in the context of tree hazards. We do note that in some states an arborist who is hired to perform tree maintenance should also hold a contractor license. However, this is typically not required for a consulting arborist (i.e., those who do not perform any physical work, but evaluate the tree and determine the future actions).

There are many reasons why you should hire an arborist versus a non-certified landscaping company. While hiring an arborist may be more costly in the short term, reasons for doing so may be either required by the city a funding source, or an insurance company, or even if not required, it may be advantageous in the long run. They are qualified and bonded experts with experience in maintaining the health of the tree and carrying out the dangerous work of pruning and/or removing large trees. Arborists can also help resolve neighbor disputes regarding tree preservation or removal, an oversee any demolition or construction activity that takes place near a tree. Post-fire they will also have the knowledge to assess the degree of injury and provide recommendations for continued tree care. The below websites provide further information:

"How to hire an arborist"

- https://www.ncufc.org/How-to-Hire-an.php
- Describes the difference between a certified arborist and a "tree guy", and potential consequences of hiring the later.

"Why hire an arborist"

- https://www.treesaregood.org/treeowner/whyhireanarborist
- This webpage provides an overview of services an arborist can provide and why you should hire a certified one.

In the sections below we discuss the issues associated with hiring a certified arborist, and detail some of the expectations from, and practices for working with, arborists. We note that it might be challenging to find an available arborist immediately after a fire, as they may be overwhelmed with service calls, and it thus may be advantageous for both residents and public officials to have an established relationship with one or more arborists or tree care companies before a fire occurs.

Many municipalities require a permit, issued by a city or county, before a tree can be removed, even if it is on private property under some circumstances. After a fire, a potentially large number of such permits may need to be issued quickly. This may place the need to balance tree preservation – which usually is the underlying objective of requiring the removal permit – in conflict with the need to enable removal of dead – and thus potentially hazardous – trees. Considering how these two needs can be aligned is best done before the fire; some considerations are outlined in Table 3.1.

Table 3.1. Post-fire tree removal considerations.

Tree removal permit requirement and challenges after a fire		**Potential approach in a post-fire situation**
Evidence of tree death and/or hazard; typically supplied by an arborist report; may be difficult to obtain after a fire, as arborists may be overwhelmed		~ reduce this requirement to only requesting clear photographic evidence in cases of obviously fire-killed trees (5 photographs, from varied angles, and distances, including close-ups of bark and branches)
Fee(s) paid to City; this may be both a financial hardship for the residents, and a procedural difficulty for the city administration that is busy in the aftermath of a disaster		~ set up a blanket fee-waiver for trees clearly dead (with a time limit after the fire) ~ create a "replant in lieu of fee" scheme where evidence of replanting in excess of any permit requirement is counted as a fee offset.
Replanting requirements. Important, but any timeline requirement may be difficult to meet after a fire and certain times of the year (e.g., hot dry summer) may make replanting less successful		~ consider extending the allowed term to replant but make clear that replanting is mandatory even if the timeline is temporarily extended. ~ provide a reminder of this requirement during the best time of year to replant (e.g., late fall in California)
Tracking removals.		~ if a georeferenced tree inventory of private trees was not completed before the fire (which is the

This critical function of the removal permits is sometimes de-emphasized in practice – yet this accounting of tree losses is even more critical after a fire! Note that this is an essential function performed by an "urban forester" or a "city arborist," and usually should not be left to individual tree care companies.		common situation), then it may be difficult to keep accurate track of removals. Consider printing large-sized paper map of the affected area and then using a simple numbering system to relate the removal records to individual addresses; such a map can then be used as a starting point for GIS inventory, once the cleanup and restoration work has been completed.

Homeowners

When an arborist may be required:

- Local regulations may require an arborist report. This is typically for the local authority to issue the tree removal permit for trees on private property. The requirement, typically, is for the report to come from either an ISA Certified Arborist, or an ASCA Registered Consulting Arborist – this varies by municipality.
- Situations where tree removal may be eligible for public funding: Street trees and those in the public right-of-way (PROW) that are the responsibility of the adjacent property owner, may, in some situations be eligible for state-funded removal. In such cases an arborist report may be required as condition of public funding. As always, the homeowner should check with the local officials for required forms and – especially – for the timeline for removal, including any deadlines.
- Insurance regulations that require an arborist appraisal of damages. In these situations, it is the homeowner's own insurance company that may require an arborist report, either to cover the costs of tree removal, or to cover the loss of value that the tree represented, or both. If the property includes one or more trees of special value, a pre-fire appraisal of the value of that tree or trees. This is a somewhat specialized activity, and requires an arborist qualified to perform "tree appraisals." The appraisal itself is a formal "opinion on the value" of the tree, and the arborist performing such a service should be using a standard protocol, as described in the most recent edition of the "Guide for Plant Appraisal" published by the Council of Tree and Landscape Appraisers (as of late 2024, the book was in its 10th revised edition; please check for the most current edition, as the mechanics of appraisal, and the resulting monetary values, can change substantially between editions).

When an arborist may be helpful:

- Assess the degree of injury and provide recommendations for continued tree care. Urban trees often are the most valuable and difficult-to-replace element in a landscape, but they also may pose a hazard (e.g., from falling branches) to people and infrastructure. Thus, getting an arborist to evaluate tree condition may be valuable, and would ideally be performed both before and after a fire to note any change in condition after a fire.

- Note that while most types of fire and heat injury to trees will be visible immediately after a fire (please see the next chapter), in some circumstance some damaging effects of fire may take time to manifest, so keeping a photographic log of the tree (by taking pictures of the tree from multiple angles before the fire, immediately afterwards, and subsequently every two months) will facilitate tree health monitoring and may provide useful information to both the arborist and the tree owner.
- Provide a formal evaluation of tree risks. "Tree risk assessment" is a formal, systematic process carried out by a specially qualified professional arborist, which results in a "risk rating" describing the risk posed by the tree (or a specific tree part, like a branch) to a specific "target" (like a part of the house, or a pathway, or a person walking down a path) during a specified time period. Arborists carrying out tree risk assessments should hold a TRAQ (Tree Risk Assessment Qualification) from the International Society of Arboriculture or be a Registered Consulting Arborist with ASCA (please see the next section). Note that tree risk assessment is NEVER a casual opinion or a passing remark but is a product of a systematic assessment process. It also may not be necessary to perform a tree risk assessment in many cases (for example, where a tree is obviously dead, or where consequences of tree failure would be insignificant because there are no "targets" for the failing tree), but it may be useful and even required in some cases (for example, where the municipal regulations require it before a removal permit can be issued). Thus, it is best to directly ask the arborist if a tree risk assessment would be appropriate, and why. It should be kept in mind that tree risk assessments are not typically part of a generic "arborist report" (which focuses on the tree health, structure, pests, etc.) and will incur an additional charge.
- Help resolve neighbor disputes regarding tree preservation or removal. This is an under-appreciated function of an arborist, but one that could be immensely helpful during a difficult time in the immediate aftermath of a fire. Hiring a third party – who also professionally understands trees and their health – to mediate the difficult issues surrounding the retention or removal of a large old tree can prevent years of conflict among neighbors and may stave off lawsuits. In cases where a tree is shared among two or more properties (i.e., a tree that is growing on the property boundary), it is sometimes mandatory – and always highly recommended – to hire an arborist whose professional opinion both neighbors pledge to respect and by whose recommendations both neighbors agree to be bound. Notably, however, not all arborists are comfortable with taking on a role of "tree dispute mediator," so it may be challenging to find an arborist to fill such a role, especially after a fire when work for arborists is likely to be plentiful. In larger cities, it may be worth contacting the city's planning department to find names of arborists who have acted as mediators in the past, as their names will likely have appeared in planning documents.
- Monitor any demolition or construction activity that takes place near a tree to prevent damage. This is a standard part of many arborists' jobs, but one with which the public

may be unfamiliar with. Anytime work is being done near a tree, there is potential for damage to tree branches, trunk, and – especially – the roots. As they are underground (not readily noticeable) and usually extend far beyond the edge of the tree's canopy, roots are frequently damaged during construction activities, with the damage only becoming noticeable months or even years later when the tree begins to decline. Especially concerning are grading of soil (and adding or removing soil), installation of pipes, sewers, or underground conduits; note that excavating even a single narrow trench, as is often made to install pipes, can result in large percentage of tree roots being cut, thus beginning a decline spiral which results in the death of the tree. *Thus, any construction or demolition activity that happens under the tree canopy or within the area bounded by a circle 1.5 times the width of the tree canopy should be overseen by an arborist.* The arborist should have the authority to stop any work that the arborist deems is damaging to the tree and require that the work procedure be changed to eliminate or reduce any such damage.

- Note on demolition activities: While much of the post-fire (re-)construction will occur well after the disaster, when arborists may be less busy and more available, the same is not the case with demolition activities that are often undertaken in days (sometimes hours) following a fire. While potentially less damaging to the tree roots than construction activities, demolition activities have the potential to compact the soil over tree roots (by heavy equipment being driven over bare soil), and to damage tree branches and trunk by direct strikes from equipment of the materials being demolished. It would be prudent to retain a consulting arborist whenever demolition activities are likely to impinge on the space under a tree's crown, or when large machinery will be driven (repeatedly) under a tree. In the absence of an arborist, it may be helpful to
    - install a temporary fence to enclose the area under the tree canopy and thus exclude both the demolition activities and the heavy machinery,
    - discuss the demolition process with the supervisor, agree on and mark out the path to be taken by any machinery or when dragging out the demolition debris,
    - deploy load-spreading plates and mandate that all machinery be driven and located only atop such plates.
    - treat the area under the canopy (and ideally the area 1.5 times the diameter of the canopy) as "tree protection zone" where heavy equipment is not allowed, and all demolition activities must be done with hand tools.

How to hire an arborist

- Look for ISA Certified Arborists or ASCA Registered Consulting Arborists. While either certification is acceptable, there are some differences between the practitioners and firms.

"How to find an arborist"

- https://www.treesaregood.org/findanarborist
- This webpage provides a good online starting point for finding a certified arborist near you.

Arborist-relevant steps before a fire

1. Hire an arborist to conduct a tree evaluation and provide a tree report, expect to pay for their time.
2. It is recommended to obtain more than one quote for the cost of evaluation.
3. Document the tree's condition before any work is done and continue documenting periodically after work is completed.
4. Based on the arborist's report, hire a tree care company to perform any recommended work.
    - It is best if the arborist conducting the evaluation is independent from the company performing the work, even if that means paying separately for the evaluation and for the work
    - Ideally, multiple cost estimates for the work should be obtaining, while ensuring that the company selected to perform tree work has a valid contractor license

Arborist-relevant steps after a fire (what to do with fire damaged trees)

1. Insurance and local regulations often require an arborist's formal evaluation and report of damage to trees.
2. Many fire insurance policies will cover the cost of hiring arborists to assess burned trees. However, insurance doesn't consider the total cost of removal and replacing trees.
3. Take photos and videos before anything is touched or moved.
4. Find out who is responsible for tree removals
    - First, check with your city to see which department(s) (e.g., Forestry, Transportation, Public Works) are in charge of tree removals Urban regarding tree removals.
    - Post-fire hazardous street trees and those in the public right-of-way (PROW) are often eligible for state-funded removal or reimbursement through Cal OES and/or Cal Recycle.
5. Check with your local officials for required forms and timeline for removal. Remember that there is likely to be a large number of trees needing removal so patience will be important.

Public Officials

1. Consider post-fire options for hazardous street trees and public right of way removal.
2. Identify who is responsible for tree removal. Depending on where that tree is located, it could be the homeowner's association, city, county, Department of Transportation, city/county parks or a utility company

i. If a government department (e.g., Public Works) is responsible for street trees:
    1. Connect prioritization of tree removal, re-planting, and recovery activities with the UFMP.
ii. If homeowners are responsible for street trees:
    1. Consider having emergency post-fire contracts in place with tree care companies for hazardous tree removal. For example, the timeline for creating a bid proposal and receiving bids from tree care companies may be a lengthy process, taking years to remove hazardous street trees.
    2. **FEMA may require a public bidding process in which they allocate funding to the lowest bidder and there cannot be an existing contract in place**It is important to require detailed bit specifications to avoid poor or unqualified contractors. It is advisable to require all assessments to be carried out by certified arborists (also TRAQ when appropriate) and removal work done by certified tree workers.
iii. Post-fire landscape recovery options need to align with city policies on street tree requirements. For example, building permits may require landscape design approval. If a city provides landscape templates for homeowners to meet requirements (e.g., water efficiency standards) they must also meet urban tree canopy goals. Additionally, landscape templates need to align with city laws if there are requirements for the numbers of street trees per parcel lot.

3. Connect tree removal with UFMP environmental policy actions.
    i. Ensure plans align with CalRecycle Urban Wood Waste.
        1. For example, wood that has been treated with chemicals (e.g., patios, siding) might need to be dealt with differently. In California refer to the Department of Toxic Substance Control for guidance.
        2. However, trees removed are not treated with chemicals so can likely still be utilized. The Urban Wood Network offers useful information around wood from urban trees.

"Wildfire and the Role of the Arborist"

- https://wwv.isa-arbor.com/quizbank/resources/1414/Wildfire%20and%20the%20Role%20of%20the%20Arborist.pdf
- This article, written for arborists, describes some post-fire considerations that arborists have to deal with regarding urban trees. It also provides background on the characteristics that make certain trees resistant, or prone, to fire. It also presents guidelines to

determine the likelihood of tree survival after fire as well as practices to make treed landscapes more resistant to fire.

Insert Box 3.1: Considerations for carrying out tree assessments

Not all cities will have an arborist on staff that is able to carry out pre- or post-fire tree assessments themselves. FEMA or utility companies can usually provide assessments in some cases, but make sure the selected company or consultant is qualified. There are some things to consider as far as what to look for when selecting an expert to conduct a tree assessment. For example, there are difference between a timber company and a company focusing more on fire-damaged tree risk assessment. If an outside company is providing the arborist(s), then you should ask about their qualifications and where they have experience working. Is their experience in a local area, or if not, in a similar ecosystem/climate? Arborists from out of state could be unfamiliar with local species and the ecosystem characteristics that need to be considered when assessing survival potential.

Ideally the arborist should have a good understanding of tree biology, tree species, ecology and for the ecosystem/climate. Is their background as an urban forester or a WUI forester? Otherwise, there is the risk of unqualified people carrying out the assessment. Conversely, in more rural or suburban areas that include wildlands or forests that are managed for timber and other forest products, then a Licensed Forester is often needed, however this is very uncommon in urban areas.

It is also advisable to have someone overseeing the contractors, especially if they are not local. A lack of oversight can lead to trees that could survive being cut down. Be especially careful in situations where contractors are paid per tree; this sets up a conflict of interest, and in such cases trees may, be marked for removal that would have recovered if they had been retained. CalFire has assisted with this oversight process in the past.

There is also the issue of stumps. In some cases, FEMA funding did not include stump removal and/or the utility did not remove the stumps of the trees that were cut down (which led to a lot of homeowner complaints). It is therefore important to consider this issue when applying for funding and drawing up contracts with companies. Finally, the city may choose to have their arborists also carry out the hazard tree assessments on private property as it can facilitate the re-building process.

Chapter 4: Assessing Fire-Damaged Trees and Deciding What to Do

Igor Lacan, Francisco Escobedo

Introduction

Once the fire is contained in an area, the *incident management team* in charge of the fire often mitigates hazards like fire-damaged trees prior to lifting evacuation orders and allowing residents to return to the area. Either way, assessing fire-damaged trees is best started at the beginning of the hazard site assessments or Phase 1 as outlined in Chapter 2. The aim of doing this assessment at the beginning of the process is to locate fire- or wind - affected hazard trees that are dead and severely injured, and/or damaged trees that need immediate removal to not endanger personnel involved with Phase 1 and Phase 2 cleanup activities.

In most typical fuel-driven fires, trees are usually killed outright by crown fires (when the fire reaches and consumes the top, leafy portion of a trees) during high severity fires. Conversely, damaged branches and/or partially fire damaged tree crowns are often the result of less severe fires. Often in urban fires, trees are damaged by radiant heat from burning structures, embers that land in the canopy, or ground fires that damage the lower stem. The recovery and subsequent growth of a fire-damaged tree depends not only on the severity of fire effects, but on its capacity to carry out its normal physiological processes, such as photosynthesis, growth and nutrient uptake. Subsequent assessments of surviving trees will also be needed to assess the longer-term impact of the fire on the tree's health since not all mortality will occur immediately after the fire but might take months or years.

However, post-fire recovery will necessarily start with an assessment of fire damaged trees, although winds and fire-fighting operations will also cause damage. The priority is to identify and mitigate immediate hazard trees, but other trees not posing a hazard or risk to people or objects, can be monitored to see if they recover. This is especially true for fast, wind driven urban fires. These tend to move fast, only scorch the canopy and not severely char the cambium of most species as badly and fire effects also tend to be closer to the ground in many cases.

Dead and dying trees will need to be removed, which then opens the space to implement a re-planting plan. This plan may be as simple as the process of replacing the dead tree with one of the same species in the case of a single property owner, to a sophisticated species-selection process and a multi-year program of planting and maintaining young trees across the public space in the city. But before any replanting can begin, all trees need to be examined for damage, and the decisions must be made regarding which trees to remove. These decisions will be made difficult by the relative dearth of research-based guidance on tree recovery after fire. This is especially relevant in cities, where numerous tree species are present; the species are likely to differ in their susceptibility to fire damage, and for many species no systematic assessment of fire tolerance exists. The "bottom line" is that it is difficult to accurately assess the degree of fire damage from the outwards appearance of a tree, and even more difficult to predict how well an individual tree will recover.

In this chapter we outline some considerations related to assessing burned trees, with some additional notes for municipal officials who must assess, or manage the assessment process on, a large number of trees. Specifically, this chapter: provides an overview of post-fire tree assessments, define what a "hazard tree" is and the different activities a forester or arborist conducts as part of a Tree Risk Assessment. Chapter 3 briefly discusses the assessment of fire damaged trees during post-fire clean up.

Hazard Trees

Key to chapter 3 and 4 are "hazard trees". Tree hazards are defined by the USDA Forest Service (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5332560.pdf) as trees that "have the potential to cause property damage, personal injury or fatality in the event of a failure". Tree hazards, on the other hand, are defined as condition that "include dead or dying trees, dead parts of live trees, or unstable live trees (due to structural defects or other factors) that are within striking distance of people or property (a target)." Another example, from Paradise, California, of how FEMA defines hazard trees in post-disaster situations, according to four categories:

- Category 1: Hazard trees on public property that are a threat to the public Right-of-Way (ROW) or public improved property.
- Category 2: Hazard trees on private property that are a threat to the Cal Recycle debris removal effort and/or the Cal Recycle crews and the public ROW.
- Category 3: Hazard trees on non PPDR (private property debris removal), private property that are a threat to the public ROW and/or improved property.
- Category 4 Trees are: Hazard trees on private property that constitute a threat to abutting or private property." These marked and identified Category 4 Trees do not qualify or fall into the scope of any of the previous categories of tree removal

Understanding Fire Damaged Trees

Fire can damage any part of the tree, from leaves and buds, to branches and stem, to roots. However, not all fire damage is equally impactful. In general, scorching or desiccation of the leaves, consumption or complete burning of leaves, on their own, is far less damaging than injury to the main stem – often referred to as charring - which damages the cambium, a thin layer of tissue located directly under the bark that is responsible for cell division and tree growth. If the cambium layer has been killed all the way around the stem, then the tree will most likely die. A tree whose cambium has been destroyed will show canopy dieback symptoms on twigs and branches even though the canopy itself was unharmed by flames or heat. With their cambium destroyed some species (esp. thin-barked trees not adapted to fire) will begin showing the crown dieback symptoms shortly after the fire, and other species (e.g., thick-barked fire-adapted evergreen species) may not show any obvious symptoms until the following growing season when new crop of leaves fails to emerge from what is a long-dead tree.

On the other hand, if fire damage was not evenly distributed around the trunk, and some part of the cambium remains uncharred and alive, then the tree might recover, although (1) recovery

may take as long as two or three years, (2) part of the canopy (crown), including some large branches, may die back permanently and thus require pruning, and (3) the tree's overall growth rate may be severely reduced for many years following the fire. Whether such partial/delayed recovery is acceptable will depend on the local management goals, but retaining some fire-damaged trees may be worthwhile both as a long-term management strategy, as it recognizes the unique value of mature trees, and as a short-term prioritization measure, as it focuses the removal resources on those trees that certainly will not recover.

Fig 4.1. Examples of green to slightly scorched (left), a scorched (middle), and completely consumed canopy (right) in 3 different magnolia trees.

Recognizing and Evaluating the Extent of Damage

Bark thickness and structure. Bark is the outermost layer of plant tissue covering the roots, trunk, and branches. The outermost layer of bark is the non-living "outer bark" or "cork" layer (which can be many inches thick in some species). It is not only biologically inert, but also has a low-moisture content, and serves as a good insulator protecting the tissues underneath. The next layer of bark is the living "inner bark," and it includes the critically-important cambium layer, and (further inward) the water-conducting tissues. Some fire-tolerant species (e.g., Mediterranean-climate oaks, some conifers, etc.) have thick outer bark that effectively protects the cambium from heat damage. Such species are likely to recover even if their leaves have been scorched. In contrast, thin-barked trees and species that seldom experience fire in their native habitat (e.g., Maples, willows, beeches) may suffer lethal cambium damage in fires that only resulted in leaf scorch for the thick-barked species.

Fig 4.2. Severe charring around the entire tree stem (left), light charring at the base and on one side of a coast live oak (middle) and moderate charring of roots and base of stem (right) on an elm tree.

Size. Larger trees often have thicker bark than juvenile trees of the same species, which may help to shield the cambium layer underneath. In addition, in urban fires much of the fire behavior occurs at ground level or at the height of the structure that is one fire. So, larger trees often have canopies above the active fire and may survive being charred or scorched on only one side (e.g., by flames and radiant heat from the burning building) whereas a small/young tree is likely to be fatally damaged in the same circumstance.

Fig 4.3. Tall trees that survived an urban fire, while lower growing trees and shrubs were completely consumed.

Canopy structure: trees whose limbs extend low, or even touch the ground, are likely to suffer greater damage than those whose lowest limbs are higher than the flames can reach. This is because the extent of damage is greater when canopy and trunk are both burned (vs. only the

trunk experiencing the heat) and because the burning canopy may contribute additional heat to the trunk, thus increasing the damage to the cambium. Tree canopies on the aspect closest to the burning building are consumed and scorched, while the side of the canopy opposite, or away, from the fire is often slightly scorched or green.

Fig 4.4. Different levels of the tree canopy that were consumed, scorched, or unaffected by fire.

Presence of dry plant parts (dry leaves, leaf litter, dry twigs, etc.) in the canopy. Dry plant matter is far more likely to ignite than the living tissues, so any dry leaves or twigs that remain in the canopy will serve as "hot spots" increasing the local heat load and exacerbating the damage.

Fig 4.5. Ash print of a home surrounded by dense, poorly maintained vegetation.

Unfavorable topography. Compared to one located on flat ground, a tree located on a slope – especially if other vegetation (e.g., shrubs) is present down-slope of the tree – may suffer additional heat and flame damage from a fire advancing up the slope from below.

Figure 4.6. Burned olive tree on a slope.

Fire behavior and weather at the time of fire. In general, a vigorous fire that moves quickly, such as driven by wind, will cause less damage to the trunk than fire of low intensity and long duration. In contrast, wind-driven fires often damage the canopy. In addition, it appears that trees are more sensitive to fire damage during their active growing season than they are in dormant season and suffer more damage in hot weather compared to cool or cold seasons.

Fig 4.7. Unaffected or slightly fire affected vegetation and trees surrounding the ash print of a burned-out home in the background.

Evaluating cambium damage: start with the bark. Determining the extent of cambium damage is difficult, and a systematic approach may be helpful, albeit still not foolproof. First, consider the bark condition: on young trees – those most susceptible to fire – the living bark is often somewhat soft, and can be scratched off to reveal another soft layer of green inner bark. In contrast, young trees that have been fatally injured will show a hard bark surface, with the underlying tissues similarly hard, dry, and brown or off-white. On older trees look for both the severity and the extent of bark damage: if bark has been entirely consumed by fire or is charred so thoroughly that it is visibly thinner (than undamaged bark) or has cracked or separated from the wood below – in all these cases, it is likely that the cambium layer is dead. The width (horizontal dimension) of the charred bark will likely well approximate the horizontal area of cambium damage, so if there is extensive bark damage all around the tree, then the cambium damage is probably similarly lethally girdling. Note however, that the vertical extent of cambium damage may exceed the height of the charred bark: i.e., damaged cambium may extend further upwards than is indicated by the charred bark. Next, cut away a small portion of the damaged bark and look at the tissue underneath: dark, yellow, and (especially) completely dry cambium is likely to be severely damaged or dead. In contrast, white or pink cambium that remains moist is a sign that the tissue may still be alive. However: in some species, heat-killed cambium may remain moist for weeks, although it has been noted that it gradually develops an odd "fermented" scent as tissues begin to decay. In any case, the distinction between dead and live cambium will become more prominent over time, so if risk considerations allow, consider repeating this assessment several weeks after the fire.

Classification of bark damage in oaks: A review of the English-language scientific literature found very few studies on the effects of fire on urban trees. Therefore, no universal system of classifying the degree of bark char and damage has been developed for urban trees, in part reflecting the vast variety of species and their associated bark.

However, one such system has been proposed for oaks in California and may be a useful starting point. Plumb and Gomez (1983) categorized bark damage into three "char classes" – light, medium, and heavy – based on the extent and severity of scorching or burning (see the flow-chart below). Light damage is described as "spotty char or scorch, with light pitting of the bark" and no obvious reduction in bark thickness. Medium damage is more serious, comprising "continuous charring, with areas of minor reduction in bark thickness". Finally, heavy damage is indicated by "continuous charring, pronounced reduction in bark thickness with the underlying wood sometimes exposed" – this is level of damage is likely to be lethal for nearly all trees. Large trees (> 12 in diameter) may survive medium levels of damage and are likely to survive light damage. In contrast, small trees (< 6 in diameter) exhibiting any level of char damage are unlikely to recover (this lethal outcome is near-certain with moderate or heavy damage), unless they are of a species that is tolerant of fire, some of which may survive light damage.

Figure 4.1. Proposed flowchart for decision-making for burned trees

Start here: Tree Size → / What you see on the tree ↓	Small tree: < 6 in diameter; or < 4 in dia. for fire-adapted species	Medium tree, not a species that is fire-adapted	Large tree, not a fire adapted sp., or a medium-tree of a fire-adapted species	Large tree, fire-adapted species
Leaves burned or scorched (NO trunk scorch)	Recovery possible, if no damage to bark	Recovery possible	Recovery likely	Recovery very likely.
AND:				
Bark with only spotty scorched areas	Recovery is unlikely → Remove the tree	Recovery is possible → if no risk, wait before deciding	Recovery is possible → if no risk, wait before deciding	Recovery is likely → if no risk, wait > 2 years before deciding
OR				
Bark scorched, with continuous charring around the base of the trunk	Recovery is unlikely → Remove the tree	Recovery is unlikely → probable tree removal	Recovery is possible, but unlikely → if no risk, wait before deciding	Recovery is possible → if no risk, wait > 1 year before deciding
OR				
Bark scorched, with continuous charring around the base of the trunk; bark separating from tree	Recovery is unlikely → remove the tree	Recovery is unlikely → remove the tree	Recovery is unlikely → possible tree removal	Recovery is possible in some cases → if no risk, wait before deciding

For an example of what some common California oaks look like before and after a fire, consult the well-illustrated work by Plumb and Gomez of the USDA Forest Service (https://www.fs.usda.gov/psw/publications/documents/psw_gtr071/psw_gtr071.pdf). The work also illustrates the difficulty of making generalized statements about bark damage.

Resources for Homeowners and Public Officials

Knowing what a tree risk assessment is and why you need one is crucial for not only preserving existing tree cover, but also to mitigate tree hazard and hazard trees. Homeowners should have a basic understanding of the process so that when contractors begin performing post-fire assessments, the homeowner will have an idea of what information is needed, and what to ask the professionals to better understand how decisions are made. It is also important for property owners to understand their rights: they can hire their own arborist or seek another opinion.

- **Tree risk assessment**: a certified Arborist uses systematic processes to identify, analyze, and evaluate the likelihood of tree failure and the severity of damage from it. It results in a risk rating, expressed in standardized terms ("low, moderate, high, extreme"), which refers to a risk of a specified tree or tree part impacting a specified target during an agreed-upon time period. This process requires consultation between the owner and the arborist to set the specified parameters at the outset (i.e., which tree part, which target(s), how long of a time period).
- Standard **arborist tree report**: a certified arborist assesses general condition of a tree: location, species, size, condition (usually in descriptive terms), maintenance needs, potential impacts of disturbance, recommended mitigation measure, tree appraisal value, etc.
- Note the difference: a tree risk assessment is a formalized process which follows a prescribed form and – importantly! – does not allow for a rating of "no risk" or "zero risk" to be assigned as a result. It also requires consultation with the tree owner. In contrast, the format and content of a "tree report" varies from one arborist to another, usually including details on the tree form, canopy structure, any defects, pests, or diseases that are noticed during the assessment, and any recommendations on pruning, irrigation, pest management etc. It usually does *not* address risk considerations!

"Basic Tree Risk Assessment Form"

- https://wwv.isa-arbor.com/education/onlineresources/basictreeriskassessmentform
- "The Basic Tree Risk Assessment Form is a tool for arborists to record and categorize information while performing a basic tree risk assessment."

"Trees Damaged by Fire: What Not to Do and What to Do"

- https://www.thebrittonfund.org/wp-content/uploads/2025/01/2025.1.16-Trees-Damaged-by-Fire-Guide.pdf?utm_source=emailoctopus&utm_medium=email&utm_campaign=News%20Update%20~%20February%202025
- This is a short, 2-page overview designed to answer common questions homeowners might have. The second page also includes a barcode to link to the how to find an arborist website.

"Tree Risk Assessment Qualification (ISA TRAQ)"

- https://www.isa-arbor.com/Credentials/ISA-Tree-Risk-Assessment-Qualification
- "The ISA Tree Risk Assessment Qualification (ISA TRAQ) is a voluntary qualification program designed to train and assess candidates in a specialized field of arboriculture. When a professional earns the ISA TRAQ credential, they should be recognized by their peers and the public as a tree care professional who has specialized knowledge in tree risk assessment."

Assessing fire damage versus assessing tree risk. Assessing fire damage on trees will most likely involve hiring a professional arborist who may also be asked to assess tree risk. The two processes differ although the same professional will usually be involved. Keep in mind that in assessing tree risk, an arborist will use a formal tiered protocol; in contrast no such protocol is universally accepted for assessing fire damaged urban trees. This lack of a standard protocol, in addition to the scientific uncertainties involved, makes the assessment of fire damaged trees somewhat more subjective than some other arboricultural assessments, e.g., tree risk assessment.

FEMA-eligibility criteria for "hazardous" trees: At the time of writing this manual, FEMA considers incident-damaged trees to be hazardous and eligible if the tree has a diameter of 6 inches or greater measured 4.5 feet above ground level, and the tree:

- Has a split trunk;
- Has a broken canopy; or
- Is leaning at an angle greater than 30 degrees.

For trees that have 50 percent or more of the root-ball exposed, removal of the tree and root-ball and filling the root-ball hole are eligible. For contracted removal of a tree with a root-ball, FEMA will not reimburse two separate unit costs to remove the tree and its root-ball. For trees that have less than 50 percent of the root-ball exposed, FEMA only provides PA funding to flush cut the item at ground level and dispose of the cut portion based on volume or weight. Grinding any residual stump after cutting the tree is ineligible (https://emilms.fema.gov/is_1000/groups/83.html).

It is important to remember that not all burned trees are hazardous and the aim of the initial tree assessment of fire-damaged trees is to identify those that represent a risk to public safety. For

example, damaged trees near buildings, roads and power lines are unsafe. A certified arborist can evaluate tree structure and identify trees posing an elevated risk to people and property. Burned trees that do not represent a safety threat should be left to serve as a seed source and habitat for biodiversity (such as birds). Additionally, the city should work with partners to ensure that any culturally significant or important trees are marked as protected during the process.

Follow-up assessments

What?

- These are not a risk assessment, which was completed immediately post-fire. Instead, these are a health assessment to examine the recovery progress and health of fire-damaged trees that were deemed non-hazardous and potentially able to recover. This assessment is needed because in the immediate post-fire timeframe it often cannot ultimately be determined if a tree will survive or not.

When?

- Most long-term studies have shown that fire-related mortality during the second growing season following fires is greater than that observed during the first. Approximately 90% of tree mortality occurs within three years (https://www.co.chelan.wa.us/files/public-works/documents/rp_fh_fire_injury_to_trees_2012.pdf). However, this is for wildland trees, not urban trees.
- A follow-up assessment the following spring can be used to reevaluate the likelihood of the tree surviving, based on if buds and shoots develop.

Potential resources for tree assessment.

Listed below are a selection of resources around assessing fire-damaged trees. However, it is important to note that most of them are for forest/wildland trees. There is little to no information on more urban species/the urban environment.

"Assessing post-fire survivability of trees"

- https://extension.oregonstate.edu/sites/default/files/documents/8341/assessing-post-fire-survivability-trees-summary.pdf
- A detailed downloadable guide for post-fire assessments of damaged conifer species found in Oregon and Washington.

"Fire damaged trees-What to look for"

- https://aplustree.com/fire-damaged-trees-what-to-look-for/
- Offers three simple questions that can be used by non-professionals to determine if a tree is an immediate hazard. Also offers tips on caring for surviving trees that are not an immediate hazard.

"Fire injury to trees"

- https://www.co.chelan.wa.us/files/public-works/documents/rp_fh_fire_injury_to_trees_2012.pdf
- A short downloadable guide to making an initial prediction if a tree will live or die, using two questions as guidelines.

"Mortality assessment"

- https://ucanr.edu/sites/fire/Recovery/ForestRecovery/TreeMortality/
- A website that briefly discusses the steps to determining if fire-damaged trees are alive or dead, separated by conifers and hardwoods. Several illustrations and photographs are provided.

"Post-fire assessment of tree status and marking guidelines for conifers in Oregon and Washington"

- https://www.firelab.org/sites/default/files/2022-01/Hood_508-compliant-Final_Post-fire_tree%20assessmentR6-FHP-RO-2020-02-revised2021.pdf
- A very detailed guide to assessing the health status of conifers damaged by fire. It is a pdf file so can be downloaded.

"Wildfire severity photo guide for assessing damage and aiding recovery of trees and forests across the northern Rockies"

- https://www.montana.edu/extension/forestry/publications/Fireseverity%20assessment%202020.pdf
- Another downloadable detailed guide to assessing the status of conifers damaged by fire. There are lots of color photographs to illustrate what to look for and differing degrees of damage.

Chapter 5: Design Solutions for a Healthy, Resilient Urban Forest

Igor Lacan, Alyssa Thomas

Recovering Trees After a Fire / Restoring Urban Tree Canopy After a Fire

An arborist and most urban foresters will be able to provide expert guidance on caring for fire-affected trees and urban forests, respectively. This chapter will focus on recovery, response and restoring (as defined in our Glossary of terms). However, as noted above in previous chapters, tree and urban forest professionals will likely be in high demand post-wildfire. Therefore, the below websites offer some general guidance on how to care for fire damaged trees. This information can be used until more detailed information is provided by an arborist.

"How to restore trees burned by wildfire"

- https://blog.davey.com/how-to-help-restore-trees-burned-by-wildfires/
- This website provides some practical guidance for how to care for trees that have been damaged by wildfire.

"Taking care of residential trees after wildfire"

- https://ucanr.edu/sites/fire/files/288333.pdf
- This is a short downloadable guide to post-fire tree care, complete with some color photographs. There is also some guidance on assessing if a damaged tree is likely to survive, although this is covered in the previous chapter.

Homeowners

- For some ideas on getting started with replanting – species selection, local nursery contacts, climate information, etc. – consider contacting your local Master Gardener Program. The participants in these programs are gardening enthusiasts trained and overseen by the local university, and they are usually well-informed on the local species suitability, potential problems, and where to source plants. This service is free, and the simplest way to find the local program is to search the web for "master gardener."
- For help with species selection, consult the Master Gardeners as suggested above, but also check with the city to see if an "approved tree list" exists that may guide you towards species that are known to perform well in your local area. Conversely, check with the city for any species that are discouraged or locally prohibited. If no local resources exist, consult i-Tree Species web-based tool as a starting point (https://species.itreetools.org/) and consult SelecTree to learn more about a species of interest or to select species based on their attributes like mature size, flowers, etc. (https://selectree.calpoly.edu/); note that it is best to confirm suitability of any species with locally-informed experts such as Master Gardeners.
- Note that recovery and restoration efforts also need to take into account future fire risk awareness/mitigation, thus it might be helpful to consult FireWise materials,

keeping in mind that some of the prescriptions will be inapplicable to urban areas (as contrasted with WUI).

- Make sure to check with the city about trees required for a building/occupancy permit. Requirements are often adjusted post-fire to help facilitate the rebuilding process, so no permit might be required, but it is good to check. A permit check can also be helpful in uncovering any local rules for tree planting (e.g., "plant no closer than 18 inches from a driveway" etc.) that might be in effect but are not well publicized.
- Regarding the optimal siting of tree relative to the building, especially if energy savings is a goal, consult i-Tree Design web-based tool (https://design.itreetools.org/) from the US Forest Service. The tool can help you determine the optimal position of a tree to maximize energy savings from shading and cooling.

Public Officials

The basic approach should be to connect the preservation and re-planting efforts with the local urban forest management plan (UFMP), ensuring as much as possible that post-fire activities on both private and public spaces are congruent with the UFMP. For example, urban tree canopy goals should have been specified in the UFMP during the pre-fire planning process; then, after the fire, both the tree preservation efforts and the replanting efforts can be evaluated for their contribution to the previously defined canopy goals. Below we outline several considerations.

Water: Irrigation infrastructure is likely to be destroyed during the wildfire so maintenance of surviving trees can be challenging. For example, the city of Talent, Oregon had some large conifers that survived the fire, but the damaged watering infrastructure was not addressed, and the trees subsequently died due to lack of irrigation. The city therefore needs to invest in replacing damaged irrigation infrastructure concurrently with the replanting of trees on city property or streets. An understanding of temporary irrigation systems and irrigation methods that don't require permanent infrastructure can be critical during this period. Similarly, outreach to residents around irrigation needs post-fire and timelines for vegetation recovery is also important during this time because residents may be willing and able to provide water to newly-planted trees; we provide links to simple watering devices, and water application calculators, below.

Urban tree cover restoration: At a level of a street block, a neighborhood, or even the entire city, recovering tree canopy will involve preserving existing trees as well as planting many individual trees that are appropriate for specific planting sites. It is also important to ensure the urban forest is diverse. Different tree species have different roles (e.g., conifers stabilize soil in winter to reduce runoff, deciduous trees reduce transpiration in winter), so consideration needs to be given to diversifying an urban forest (even before the fire) to ensure that replanting efforts consider this.

Invasive plants, erosion and flooding: Other issues to consider include dealing with a possible influx of invasive species, especially once trees are removed. Some of these plants (especially shrubs, e.g., blackberry, or ivy) might need to be removed or controlled prior to replanting to maximize the success of newly planted trees. In some areas, for example in large urban parks or on steeper slopes, removal of all the trees and vegetation can lead to erosion problems and flooding concerns. Keeping some tree stumps could help to mitigate erosion, but communicating this with the public will be necessary. In addition, funding for infrastructure (e.g., straw wattles) to help mitigate flooding might also be necessary.

Wood re-use: Wood from the removed trees, often called "urban wood," may be used as lumber. This practice, although very beneficial, necessitates several special considerations that are probably best planned out before a fire. First, the time between tree death and removal and processing may be limited. For example, pine trees should be removed and processed within two years of tree death, and wood from other tree species may require milling and kiln-drying within months of removal for best results. Second, the removal technique will also be specific. For example, the tree should ideally be removed in sections that are much longer than is usually the case with standard arboricultural practices. This prioritizes speed and safety, thus often cutting the tree trunk into many shorter pieces; this may require special equipment and knowledgeable arborists. Finally, the costs of transporting the removed trees to processing facilities should be considered as well, as these are a major impediment to urban wood reuse. Because the transport costs are high, urban wood often only makes sense if a wood processing facility (a sawmill, a drying yard or kiln, etc.) nearby. Thus, if wood reuse is a goal in the UFMP or a city's sustainability plans, make connections with the members of the Urban Wood Network (https://urbanwoodnetwork.org/) and create and post a list of the nearby wood processing facilities that would be willing to process salvaged wood.

Insect and disease vulnerability: One of the most common goals in urban forestry is creating a tree population that is unlikely to be substantially damaged by a single pest insect or plant disease. Using a large number of different tree species – as long as they meet other goals – is the simplest way of achieving this goal, as a species-rich urban forest is unlikely to be wiped out by a single insect or pathogen, or even by a combination of multiple insects and pathogens. While several "rules of thumb" have been proposed (e.g., the "10-20-30 approach," arguing for the urban forest to contain no more than 10% of any single species, no more than 20% of any one genus of trees, and no more than 30% of trees from any one family), it is also perfectly appropriate to simply set an even simpler goal, e.g., "no more than x% of trees shall be from one species" where the target percentage is not more than 10. On the other hand, ready-made web tools exist that can display the vulnerability of a tree population to common insects and diseases. For an example, please consult the Pest Vulnerability Matrix that is available for California: https://ucanr.edu/sites/Igor/Test_PVM/index.cfm. Such tools can be modified for other regions, or can be made informally, simply by consulting with the local pest management experts.

Putting it all together: step-by-step approach to tree species selection: The most straightforward approach for tree selection at a city-scale will start with the goals for the city (e.g., canopy cover increase). Generate a large list of trees that could be used to meet those goals, then narrow down the list using a set of constraints. We offer an example below

1. *Define a short set of broad goals to be achieved*
   E.g. "Increase urban tree canopy to 22% in commercial areas, while focusing on low water use tree species"
2. Generate a large list of tree species that could be used to meet those goals
   E.g., a list contains 150 tree species common to California cities
3. *Remove from the list any trees* that
   a. do not meet the water-use goal (e.g., Coast redwood); and that
   b. do not thrive in the city (for climate reasons, usually);
   c. have undesirable arboricultural characteristics (poor structure; invasiveness; unacceptable litter; etc.)
   d. appear to be unsuited to warming climate
   e. and any other reasons that connect with the goals
4. *Stratify the list by*
   a. tree size at maturity (and indicate the minimum space required for that species)
   b. tree suitability for various sites in the city (e.g., "suitable for wetter site," or "suitable for pavement cutouts," etc.)
   c. tree performance thus far (e.g. "species is known to grow well in our city," vs. "species has not yet been widely used, but shows promise in our city" etc.)
   d. any other characteristic that is connected to the goals (e.g., if winter shade is desired, then can stratify by "deciduous" vs. "evergreen")
5. *Provide sufficient information for each species* so that a resident who is looking for a tree can use the list to make their decision (e.g., "I am looking for a tree for a large front yard, with limited irrigation, and want it to cast shade year-round"). Note that splitting the list into multiple lists may be helpful to make selection easier. Note also that linking to information sites like SelecTree can be very helpful.
6. *Ensure that there is a sufficient number of species* on the final list to meet the diversification goal to allay pest vulnerability. More is better, and fewer than 20 is unacceptable (unless severe climatic limitations prevail).
7. Seek feedback from experts and residents, and update the list as needed or at least once every decade.

Insert Box 5.1: Opportunities in Restoration-A Lesson from Lahaina, Hawaii

Lahaina was once known as the "Venice of the Pacific", because of its network of wetlands and canals and a lush lowland forest. It was an ecologically diverse landscape full of fishponds, a lush lowland forest and diverse vegetation. However, things started to change in the mid-1800s with the rise of the whaling industry when a stream was diverted into a canal to bring fresh water to sailors who docked in the harbor. And with the onset of colonization, settlers diverted water to irrigate their extensive sugar and pineapple plantations that required huge amounts of water. Wetlands were drained for development and deep-rooted trees (e.g., breadfruit) that helped retain soil moisture were cleared for plantations. The canal was filled and turned into what is now Canal Street and non-native plant species were introduced for livestock forage.

When the plantations were later abandoned (mainly in 1999 but the last one shut down in 2016), the introduced non-native grasses became widespread and took over the ecosystem. Now, tens of thousands of acres of former plantation lands are unused and overrun. These non-native species are highly flammable and have made the ecosystem much more fire prone. Additionally, streams and other water bodies that once served as natural firebreaks have all been diverted or dried up.

Reclaiming these abandoned lands and planting native species can help restore the wetlands and lower the fire risk. There are substantial costs associated with purchasing and restoring the abandoned lands, but the August 2023 wildfire has provided newfound momentum and offers opportunities. For example, the wildfire destroyed many water pumps, and in their absence water from underground springs is starting to come back into natural channels. As part of their restoration efforts, a local group is already planning on removing invasive fan palms from a city park and planting several native species such as coastal sandalwood. Finally, a derelict ballpark that was burned by the fire sits on top of a culturally significant site and water body, which many native residents have wanted restored for years.

These are several examples that illustrate how restoration after a wildfire presents an opportunity to assess the health of the land and its susceptibility to fire. Post-wildfire restoration can thus present an opportunity to address these issues and improve the land management to promote a healthier urban forest. Restoration efforts can mean creating long-term plans that improve land management to reduce wildfire risk. For more information on the Lahaina fire event, see Chapter 9.

Suitable Trees for Urban Sites: Site Evaluation and Species Selection

Part of a resilient urban forest is selecting the right tree for the right place and for the right purpose. This process is a basic consideration when choosing where to plant and what type of tree or shrub to select. In general, there are five things to consider:

1) Above and below ground site characteristics (e.g., soil quality and available planting space, overhead utilities),

2) Future site modifications, (e.g., root growth, sidewalk lifting, obstruction of human or vehicle traffic, fruit fall impacts),
3) Tree maintenance requirements (e.g. irrigation needs, pruning frequency)
4) Desirable tree traits and/or attributes (e.g., shading potential, flowers or fruit, natives, potential tree height and crown width), and
5) Site and purpose (e.g., flammable vs non-flammable, water use, litter generation, proximity to building).

Below are some online resources for selecting appropriate trees and plants. However, flammability considerations when selecting plants will be covered in the next chapter (Chapter 7).

"Landscape Plants"

- https://hort.ifas.ufl.edu/woody/site-evaluation.shtml
- The University of Florida offers suggests 27 questions to answer to provide a site evaluation for selecting the best trees. The website however does not offer any suggested species, but rather refers the reader to reference books or software programs (links included) for this second stage of the process.

"SelecTree: A Tree Selection Guide"

- https://selectree.calpoly.edu/
- This website provides recommendations based on a multitude of filters such as maximum tree height, deer resistant, native, zip code, water use and shade tolerance.

Suitable Trees for Urban Sites: Water Efficiency

Water use is a factor that is included in the above guides but is also important enough to have resources solely on this topic. When choosing what trees to plant, it is recommended to consider the relative water required by different species, especially in more arid locations.

"CA Water Use Classification of Landscape Species (WUCOLS)"

- https://ccuh.ucdavis.edu/wucols
- A searchable database that allows you to create a plant list by water needs (very low, low, moderate, high) for your climatic region.

"Planning a Water Efficient Landscape"

- https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=16894
- This website focuses on landscaping with plants that do not use a lot of water.

"Water Conservation & Efficiency"

- https://ccuh.ucdavis.edu/resources/irrigation-management-resources

- A resource from UC Davis that provides links to information on a lot of water-usage topics. This includes a downloadable worksheet to plan irrigation scheduling, water conservation & irrigation resources by city, and details on two useful irrigation tools: rotary system irrigation contraption (RSIC) and tree ring irrigation contraption (TRIC).

For public officials:

"Cal-Adapt: Data & Tools for Climate Adaptation Planning"

- https://cal-adapt.org/
- Essential data & tools for climate adaptation planning, building resiliency, and fostering community engagement. There are interactive maps and charts to help explore climate change data for California.

"Model Water Efficient Landscape Ordinance (MWELO)"

- https://water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance
- New development and retrofitted landscape water efficiency standards are governed by the MWELO, referenced by Title 24, Part 11, Chapters 4 and 5 CalGreen Building Code. All local agencies must adopt, implement, and enforce the MWELO or a local Water Efficient Landscape Ordinance (WELO) that is at least as effective as the MWELO.

Chapter 6: Plant Flammability: Choosing Less Flammable Plants

Stacy A. Drury and Natalie S. van Doorn

Most of the preceding chapters have outlined the benefits of having healthy plants in urban environments, particularly around homes. In this chapter, we discuss one of the negative aspects of vegetation around homes, i.e. plants – like buildings and structures - are fuels and will burn. Plants, along with burning buildings, can have the potential to carry fire from the into the urban environment which increases the likelihood of home ignition. Homeowners concerned with making their homes more fire resilient are increasingly faced with the tradeoffs of addressing fire risk reduction practices that call for vegetation removal versus installing and maintaining vegetation around their homes for the multiple benefits they provide such as: shade, noise and air pollution reduction, increased property values and wildlife. However, it is important to realize that: 1) all vegetation is vulnerable to burning under the right conditions and 2) urban vegetation is key for public well-being, biodiversity and the environment.

So, how can the homeowner make the decision over which plants to install on their property? Can less flammable plants provide the aesthetic and comfort benefits desired by homeowners? If so, where would a homeowner find the information on individual plant flammability and how reliable is it? The term “fire resistant plants” is often used and many recommend lists of low on on-flammable plants. However there is a science to plant flammability. So, in the next few pages, we provide some insights and information on what plant flammability is, where you can find information to select less flammable plants, and how much confidence the homeowner should have regarding the use of the available plant flammability lists.

What is plant flammability? In its most simple form plant flammability is the likelihood that a plant will burn given an ignition source, however, in essence plant flammability is a very complex phenomenon. About a decade ago, two USDA Forest Service researchers Robert White and Wayne Zipperer produced a scientific paper (White and Zipperer 2010) which reviewed plant flammability concepts and subsequent use of these concepts to develop tree lists. Here, we summarize the concepts described in White and Zipperer (2010) and others (Pausas et al. 2017; Alam et al. 2020, Toy-Otopazo et al. 2024) to provide information to potential users such as homeowners or public officials on how to use plant flammability lists and rankings.

Plant flammability is commonly characterized by four components, ignitability, combustibility, consumability, and sustainability (Anderson 1970, Martin et al. 1994, White and Zipperer 2010). Ignitability is measured as the time for a material to ignite, the critical temperature when the material is ignited, and the critical heat flux. Combustibility is commonly thought of as a measure of how rapidly the material is consumed. Consumability tends to be thought of as how much material is consumed during combustion. While sustainability brings in the concept of how likely a material is to sustain combustion and continue to consume once ignited.

Insert Box 6.1: The Science of Plant Flammability

How is plant flammability measured? Plant flammability can be measured qualitatively using simple visual observations (Fonda 2001) or more quantitatively using very technical laboratory equipment (Figure 6.1; White and Zipperer 2010). Visual testing may be sufficient if flammability is considered independent of species and more a function of the amount of biomass present, however for ranking species by how flammable they are, lab testing that includes measuring moisture content, are needed. The testing method used to create species flammability lists are also complicated by issues of scale, that is, laboratory methods such as calorimetric cone consumption testing evaluate flammability of small plant parts but flammability results for laboratory tests are not effectively spread across whole large plants or clumps of vegetation, while large scale visual flammability tests can provide useful qualified information across the whole plants but do not provide the specific metrics needed for creating scientifically based vegetation flammability rankings.

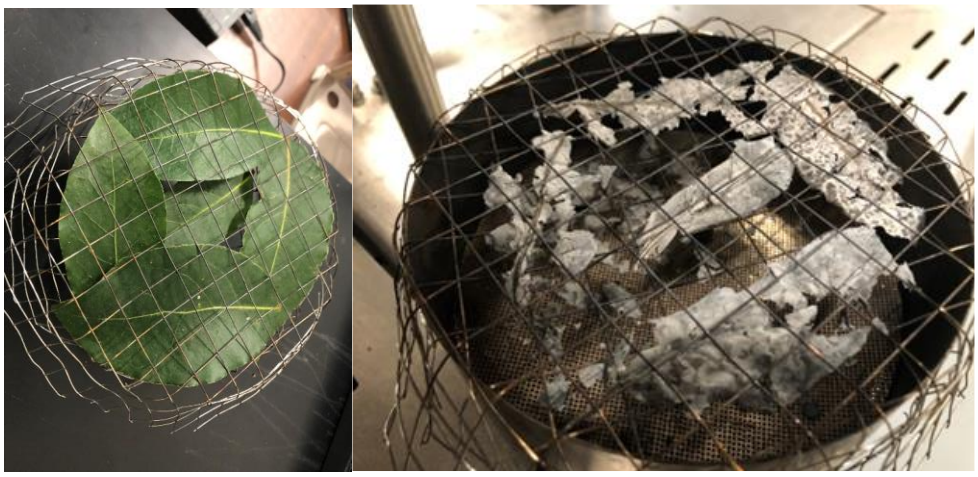


Figure 6.1. Photo 1, small plant sample prepared for burning in a cone calorimeter. Slide 2, same sample post-burn. Figure shows the burning process.

Figure X. Cone calorimeter test apparatus for measuring plant flammability. Photo 1 shows the small plant parts being preheated. Photo 2 shows ignition has occurred and the small plant parts consuming. Photo 3, small parts have been consumed that the plant parts are in the final, glowing stage of consumption

Many factors can influence plant flammability including vegetation: structure, condition, architecture, internal chemical components, and moisture content. Some flammability studies have emphasized that flammability is most often driven by moisture content and tend to define flammability solely in terms of percentage of moisture present when confronted by an ignition source (Curt et al. 2011; Murray et al. 2013; Bianchi and Defosse 2015; Popović et al. 2021). One clear need when identifying individual plant flammability characteristics is a set of standardized protocols for evaluating plant flammability (Toy-Otopazo et al. 2024). A standardized protocol would enable end users, including homeowners, to compare a wide range of plant species on the same flammability scale.

The difficulty in producing scientifically sound flammability metrics for comparing across plant species results in plant flammability rankings that are anecdotal in nature and have not been truly scientifically tested (Swain unpublished; 1998 plant flammability list). In this context and coupled with the fact that all plants will burn if exposed to enough heat, many fire wise or fire safe programs are currently focused on removing plant biomass near homes.

What plants to keep or plant once you have created defensible space? That is, how does one select less flammable plants to further mitigate the chance your landscaping carries fire to your home. Earlier we discussed plant flammability lists and the issues with creating scientifically based plant flammability lists and how many of the currently available plant flammability lists are based on anecdotal information. So, does the lack of a scientific basis for most plant flammability lists make then useless? We argue that current plant flammability lists can provide useful guidance for selecting plants that can make your property more fire resistant. Many FireWise or FireSafe organizations (listed at the end of this chapter) provide plant flammability lists. These lists are created using expert information from fire suppression specialists and in some cases, information gleaned from the scientific literature. In addition, some nurseries provide information to aid in selecting less flammable plant species.

Flammability lists from fire wise programs such as the Western Fire Chiefs association, FireSafe Marin, and San Diego Counties Fire Safe Council do provide useful lists for selecting more fire resilient plants for landscape use. Below we also provide links to multiple sources such as those mentioned above and others. As we discussed earlier these lists are often related to a plant's ability to maintain moisture even during dry or drought events; either because of irrigation or higher leaf water content (e.g., deciduous trees). This makes sense as before a live plant can be ignited the moisture within the plant's structure needs to be dried off, taking more energy to raise plant material to ignition temperature and may lengthen the time to ignition which lowers fire travel times and overall plant flammability and may save your home.

In closing, selecting less flammable plant species from regional plant flammability lists for landscaping around your home and surrounding structures can help mitigate the potential for fire to spread through your landscaping and carry fire to ignite your home. While plant flammability lists often are not based on scientific "peer-reviewed" information, many flammability lists do recommend species that are less flammable, relevant to a specific climate

and biome, and call for proper maintenance and irrigation of these plants, thus they do help in decision-making. However, all plants are composed of flammable materials and will burn when exposed to high energy heat sources. Therefore, water content, location of the plant relative to the home, maintenance (i.e., removing dead limbs and lifting of the crown) among other factors listed in this manual are often just as, if not more, important than a plant's taxonomy.

Sources for plant flammability lists

"Creating a Fire-Resilient Landscape"

- https://ucanr.edu/sites/fire/Preparedness/Landscaping/
- This website provides some questions to consider when selecting plants, and maintenance tips to lessen the flammability once planted.

"Fire-Smart Landscaping"

- https://readyforwildfire.org/prepare-for-wildfire/fire-smart-landscaping/
- This website provides information on making your landscape fire smart, including selecting fire-safe plants, and location & maintenance tips.

"Fire-Resistant Plants"

- https://wfca.com/wildfire-articles/fire-resistant-plants/
- Plants are split into categories of groundcover, shrubs and trees. The site also includes characteristics to look for when selecting "fire resistant" plants.

"Fire-Resistant Plants for Home Landscapes"

- https://extension.oregonstate.edu/sites/default/files/documents/lommena/pnw-590-fire-resistant-plants-compressed.pdf
- This is a downloadable guide that covers characteristics of fire-resistant plants, and then guides to different categories, including evergreens and trees. Has lots of color photographs.

"Fire-Resistant Plant Profiles: Trees"

- *https://extension.oregonstate.edu/gallery/fire-resistant-plant-profiles-trees*
- A good guide to fire-resistant trees often found in urban settings.

"Fuel Modification Zone Plant List"

- *https://ocfa.org/Uploads/SafetyPrograms/OCFA%20RSG%20-%20Planting%20Guide.pdf*
- A comprehensive list of different plants (including trees) and where they are allowed to be planted in Orange County.

Chapter 7: Urban Forest and Urban Tree Cover Management

Francisco Escobedo, Igor Lacan

Urban Forest Management

Urban forest management is generally defined as how a community uses its tree and vegetation resources to meet specific environmental, social, and economic goals and objectives in a sustainable and equitable manner. Accordingly, an Urban Forest Management Plan (UFMP) has been described as a roadmap to create a shared vision for a community's future urban forest and its urban tree cover (https://vibrantcitieslab.com/toolkit/). In most cases, an UFMP is a process and comprehensive document that often begins with an inventory and assessment of the existing urban trees and/or by articulating a vision and specific goals of what the community would like to achieve in managing its trees. Specifically, based on this vision, goals or objectives are defined or set by experts and the community. Then activities or practices needed to meet these goals or objective are developed and implemented accordingly. These goals are also monitored and evaluated as necessary until they are met, or they are adapted and revised to better address these new and changing realities (e.g., changing budgets, policies or a fire event; Figure 7.1).

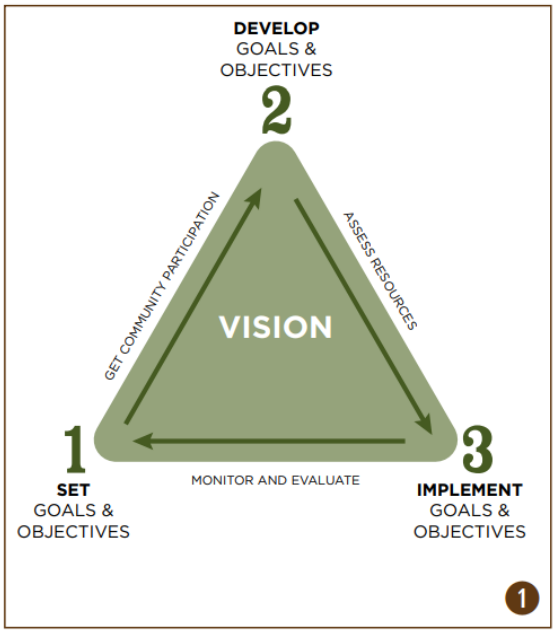


Figure 7.1. An adaptive management approach for setting, developing and implementing an urban forest management plan's vision, goals, and objectives. Source Escobedo et al., 2020.

Key to an effective and useful UFMP is the critical pre-fire planning differences between the WUI and urban environment (See insert box in Chapter 1 and Escobedo et al., 2024). An UFMP should therefore define the differences between the social-environmental goals, tree species, maintenance needs, and success metrics for urban trees in both WUI and urbanized areas. Forest management plans, Community Wildfire Protection Plans, and street tree management plans are usually different types of documents and processes, but an effective UFMP for a community in a

fire-prone environment, should borrow certain components from each of these different types of planning efforts. For example, adequate defensible space that is helpful in the WUI for fire prevention may not be attainable in urban settings due to the amount of private land tenure and densely packed housing on smaller parcels and lots. Conversely, recommending the planting of lush dense, flammable vegetation immediately adjacent to homes to maximize benefits in fire-prone environments should be avoided. Also, most UFMPs encompass multiple land tenures, administrate units and planning entities, so these differences, functions, goals, and purpose among different units and organizations need to be highlighted as part of a comprehensive UFMP.

Several communities have developed urban and community forest management plans that incorporate the realities of wildfire, hurricanes, ice storms and other types of disturbance events. Therefore, the following chapter is only meant as a guide to better understand the components of an UFMP that incorporates wildfire-driven fire events that occur in more urbanized settings. The chapter will discuss a few key terms and concepts, as they relate to an UFMP in fire-prone environments (Table Z). It will also briefly explain and describe some key processes that have been found to be relevant to UFMPs in communities that frequently experience wildfire. For more detailed readings regarding the development of an UFMP for communities at risk of fire, here are a few specific examples of such documents and plans:

"Developing an urban forest management plan for hurricane-prone communities"

- https://edis.ifas.ufl.edu/publication/FR176?downloadOpen=true
- The publication presents and adaptive management approach to developing urban forest management plans for hurricane-prone communities and that is applicable to fire-prone areas.

"Room to Grow: A community forest management plan for Los Angeles County"

- https://lacountycfmp.org/wp-content/uploads/documents/LA_County_CFMP.pdf?version=20241203
- The community-based document provides UFMP-relevant information and guidance for unincorporated areas in the greater Los Angeles CA region. It also includes specific section and information on wildfire, urban tree canopy and equity goals.

"Sustainable Forestry Initiative Urban and Community Forest Sustainability Standard"

- *https://forests.org/sfi-urban-forestry-standard/*
- The website provides examples of indicators, performance metrics, goals and definition that are relevant to developing UFMPs

"Urban Forestry Toolkit"

- https://vibrantcitieslab.com/toolkit/
- This Toolkit guides public officials and community members through the UFMP planning process. It also provides examples of UFMPs for seral municipalities and institutions.

Urban Forestry Terms		Example connections with fire

Urban Forestry Management Plans

A comprehensive shared vision for the urban forest, articulating a community's goals, including plans, activities, objectives, monitoring, and evaluation. Common elements include:

~ how will a fire affect the over-arching goals of the UFMP?

~ will priorities stated in the UFMP need to be reconsidered after a fire (e.g., protection of veteran trees vs. greening of low-canopy areas)

Urban Tree Cover Assessment

A quantitative measure indicating the proportion of a city's surface shaded by the tree canopy. Often used as a goal in UFMP.

~ use the pre-fire canopy cover percentage as a starting point for evaluating fire damage

~ set area-specific canopy goals so that (e.g.) pedestrian zones receive priority for canopy restoration

Urban Tree Inventory

A catalog of a city's trees, usually GIS-based, comprising all street trees and occasionally including park trees, with data recorded for each tree (size, species, condition, location, etc.).

~ use the tree condition data in the inventory to proactively manage any dead or dying trees (to reduce dry fuel load)

~ use the tree species data to highlight any trees especially sensitive to heat or fire

Tree protection ordinance(s)

A local law restricting the residents' ability to remove trees on private property. Often based on size (protecting large trees), or on tree species (e.g., protecting oak trees), or tree location (protecting trees adjacent to sidewalks)

~ these ordinances are seldom considered in their relation to fire, but they may cause delay in removing dead trees that fall into one of the protected categories.

~ may need to balance the desired protection with a reasonably-fast process for removing fire-damaged trees.

Figure 7.2. Some common terms and how they relate to pre-fire planning

It is important to emphasize that municipalities with WUI fire policies, but no articulated urban fire-related policies, need to connect or account for pre-fire planning to the UFMP. Since the UFMP is a central document guiding the urban forest management, pre-fire planning needs to be included in the UFMP and to also account for environmental requirements and land use/zoning policies. These policies will influence the recovery trajectories and prioritization of recovery alternatives. Will also eventually link to/consider wildfire mitigation activities and policies. For example, a city's carbon policy may require that all suitable woody material be re-purposed into wood products (e.g., park benches) rather than be chipped or composted.

Additional information is also needed to account for other consideration. For example, tree protection policies need to be considered (e.g., heritage trees), and awareness of established urban tree cover goals and if they contradict other fire mitigation requirements or if they are environmentally sustainable. Formal consultation with fire officials is key during the UFMP process to assure that fire and urban forestry goals are incorporated and that different administrative units agree. Incorporating these 2 approaches will assure that we better understand best management practices or issues related to pre-fire planning in the urban forest such as the selection of appropriate tree species. Here are a few examples of such tools:

"Species selection tools"

- i-Tree Species: https://species.itreetools.org/
- According to the WebPage, "This tool helps you select the most appropriate tree species based on their potential tree benefits and your geographic area. "

"*SelecTree"*

- https://selectree.calpoly.edu/
- This is tool that guides users in selecting trees with certain characteristic as well as providing general information and tree characteristics for species commonly found in California.

Urban Tree Canopy or Urban Tree Cover

UTCs are a measure of the amount of tree or urban forest resource in a community and is used as a metric for establishing, achieving, implementing or assessing future or existing goals; often in an UFMP or other sustainability, greening or natural resources initiatives. When combined with other social, economic, environmental and urban planning information, this metric can enable communities to develop better informed plans and future policy decisions (USDA FS 2019). It is important to differentiate between "percentage point change" and "absolute percent change" when communicating urban tree cover change goals. To better explain this difference and guidance on these two concepts refer to this following tip sheet:

- https://journalistsresource.org/home/percent-change-math-for-journalists/#:~:text=Keep%20in%20mind%20the%20%E2%80%9Cpercent,relation%20to%20a%20previous%20number

It is also important to realize that most of a community's UTC is generally on private residential properties as well as other state and federal natural areas of parks; areas that are often not administered or managed by municipalities.

UTC assessment, like UFMPs are an adaptative management process that is a continuous cycle and not a process that ends with the creation of a document. But according to USDA FS (2019), there are 5 Key Steps of Implementing a UTC Project:

1. Project planning – set clear goals e.g., environmental justice, watershed protection, public health, etc.
2. Assessment – data collections e.g., LiDAR, GIS, etc.
3. Analysis – Align data with stakeholder goals
4. Implementation – Develop approach and timeline with clear communication to public and contractors.
5. Monitoring - evaluate progress and monitor with software.

Below are some specific resources to better understand and implement UTC assessments:

"Urban tree canopy assessments"

- Urban Tree Canopy Assessment: A Community's Path to Understanding and Managing the Urban Forest
- According to this synthesis report from the USDA Forest Service (2019), "This report provides an overview of the approaches, methods, and data sources used in UTC assessments, focusing on the initial steps of project planning, assessment, and analysis. The report also provides general guidelines for conducting UTC assessments and analysis."

"Examples of how the USFS provides information and resources for UFMP"

USFS Urban and Community Forestry Program

- The USFS works with state partners and community tree groups to invest in improving urban and community forests across the United States.

USFS Pacific Southwest Region 5

- Learn about previous projects and work being done with the Urban and Community Forestry (UCF) Program in California, Hawaii and U.S. affiliated Pacific Islands. Additional resources provide grant information, learning tools, and specific tree information for the Pacific Southwest.

Insert Box 7.1: More UFMP and UTC Considerations

Importantly, it might not make sense to have the same defensible space and vegetation requirements throughout the city. Instead, the city could break down requirements by fire hazard severity zones (available from the state fire department); reflecting the differential risk of neighborhoods based on their proximity to the wildlands. This section would also be the place to detail bush clearance protocols and defensible space where there is fuel reduction and weed abatement.

Local fire department should be consulted at an early stage of UFMP development so that any concerns can be discussed and addressed. The UFMP reflects a community's vision for the urban canopy, and it is important that the local fire department is aware of this vision and provides input on any issues early in the process. Similarly, the fire department should be informed of any specially designated protected trees (e.g., "heritage trees").

Cities should also seek to have a comprehensive tree inventory and know the canopy cover across the city. Without this information, it is impossible to know what was lost in the fire. This is the time to take stock of what existing plans and policies are in place around trees, and how wildfire fits in. For example, a heritage tree ordinance is useful, but unless it is known and included in the relevant documents, they might not be marked for protection.

With fires increasingly affecting more urban areas, cities should ideally include wildfire related information in their UFMP or update their existing plan with this information. Information that might be useful includes a summary of fire behavior and how the fire spreads, but in an urban context. For example, the role of embers in igniting nearby structures, rather than the direct flames, and the role of urban forests in fire spread and damages. It is also important to think about how the city will work with the local fire department, as well as regional level departments of the state fire agency (e.g., CalFire). The local fire department should also be consulted at an early stage of UFMP development so that any concerns can be discussed and addressed. The UFMP reflects a community's vision for the UTC, and it is important that the local fire department is aware of this vision and provides input on any issues early in the process. Similarly, the fire department should be informed of any specially protected trees (e.g., "heritage trees").

Overall an UFMP is a strategic document that established a vision and establishes the differences in urban forest management in both urban and WUI areas within the same city. As such, communities should establish close working relationships with fire organizations regarding urban-interface requirements related to high fire risk areas. Similarly, the city should also establish how they will work with utility companies, understand their requirements for vegetation maintenance and how they maintain clearance around power infrastructure. The UFMP should also clearly identify who is responsible for the removal of trees, and in different areas (street trees, parks, other open spaces, etc.).

Several community-specific realities need to be accounted for when developing UFMPs or UTC assessments. For example, sustainability goals are often included as part of strategy to improve green infrastructure. Similarly, there are policies that have been enacted to permanently fund city trees to be in care of public works. However, sometimes "trade-offs" or contradictory polices, and outcomes might occur (See Box I). As previously mentioned, lush green leafy vegetation and trees immediately next to homes are often recommended by tree advocacy groups. However, this can lead to increased fire risk in high fire hazard areas, so this type of landscape is prohibited by fire ordinances. The Case Studies in Chapter 9 provide further examples.

Insert Box 7.2: Home insurance, wildfire risk and tree ordinances

In places like the western and southern coastal US, wildfires and hurricanes, respectively; fire/hurricane risk mitigation practices and trees are often in conflict with each other. Insurance underwriters and fire managers often assign different levels of risk to trees located near homes than do arborists or urban foresters. For example, well maintained, irrigated, pruned, and properly selected and located trees near homes have been documented to be less influential in building loss than building construction type, materials, and characteristics in home loss during typical fire (or hurricane) events (Escobedo et al., 2024). However Insurance underwriters and other organizations identify such trees as posing risk and subsequently their removal or excessive pruning is required, which subsequently leads to increased tree risk and hazard. An example of this trade-off and contradicting policies is in Glendale CA, where a homeowner was told that they were being dropped by the home insurance provider because of an oak tree in the yard. When the homeowner inquired about removing the trees they were told that the oak tree species is protected by a city ordinance and as a result, such trees cannot be removed or damaged (https://ktla.com/video/woman-lost-home-insurance-over-a-tree-ca-city-says-she-cant-remove/10079862/). Unfortunately there is currently little scientific information on the role of urban vegetation in fire risk that can be used to better inform these types of situations. But information can be used from this manual's Introduction and Chapters 5-7, to make more informed decisions.

A similar process to the UFMP and UTC assessment that are relevant in fire prone areas in a community or region are Community Wildfire Protection Plans (CWPP). These CWPPs primarily focus on the WUI, however it may be used as a planning tool to plan, manage and mitigate wildfires in not only the WUI but also in urban areas.

"Best management practices for CWPPs"

- https://research.fs.usda.gov/treesearch/39838

- This BMP publication explains how CWPPs are, "a means of bringing local solutions to wildland fire management. In developing and implementing CWPPs, communities assume a leadership role in reducing wildfire risk"

"Creating a Community Wildfire Protection Plan"

- https://www.usfa.fema.gov/wui/communities/assess-risk.html
- This publication "will assist you in making a CWPP. The form-fillable templates in the guide allow you to create an action plan and document assets at risk, forest/landscape health issues, and key stakeholders". The guide is written in both English and Spanish.

"Community Wildfire Defense Program"

- https://www.fs.usda.gov/managing-land/fire/grants/cwdg
- The USDA Forest Service offers the Community Wildfire Defense grants annually through 2026. The purpose of these grants is to help communities "develop and revise or implement projects described in a CWPP that are less than ten years old."

"CWPP Quick Guides"

- https://jfsp.fortlewis.edu/QGMain.asp
- This Quick Guide series "offers a set of lessons learned from case studies of collaborative processes used to develop of Community Wildfire Protection Plans." There are 19 guides available in the categories of community context/readiness, CWPP development process, Outcomes, and Miscellaneous/Support.

We note that since about 2015, grant funding (Federal, and in some States) has been available to help municipalities develop UFMPs, with the result that many cities in the Western US have undertaken the steps necessary to develop these documents. If a community does not have an UFMP, pre-fire planning can be used as an impetus, and justification, to fund and develop an UFMP. Here we provide several resources for communities seeking funding related to urban forestry and tree canopy cover.

"California ReLeaf"

- https://californiareleaf.org/grants/
- California ReLeaf works with partners including CalFire and the Forest Service to distribute grants to "nonprofits, local agencies and community-based groups throughout the state for the planting and care of trees, education and outreach projects, green jobs training, and volunteer development." The website lists any current opportunities, and you can also sign up to receive alerts when new grants become available.

"Federal Emergency Management Agency"

- https://www.fema.gov/grants/mitigation
- FEMA offers hazard mitigation grants for projects that "reduce disaster losses". Specifically, "Building Resilient Communities and Infrastructure" potentially offers grants for hazard mitigation projects. The Hazard and Mitigation Grant Program provides

funding for communities to draw up hazard mitigation plans. Post-wildfire there may be new funding opportunities specific to the event, so make sure to check with state and federal officials for current opportunities.

"Grants"

- https://www.fire.ca.gov/what-we-do/grants
- CalFire has a dashboard showing the categories of potential grant opportunities, with two relevant categories. "Urban and community forestry" (https://www.fire.ca.gov/what-we-do/grants/urban-and-community-forestry-grants) gives with special consideration given to disadvantaged/underserved communities. "Wildfire prevention" (https://www.fire.ca.gov/what-we-do/grants/wildfire-prevention-grants) includes wildfire prevention education (e.g., defensible space training) and hazardous fuels reduction (e.g., community-led wildfire prevention programs). When funding is available, the deadline will show on the main page, and then clicking on the category of interest will take you to more detailed information about the current grant opportunity including topics, available funding, and eligibility.

"Urban and Community Forestry Program"

- https://www.fs.usda.gov/managing-land/urban-forests/ucf
- The USDA Forest Service Urban and Community Forestry Program is "dedicated to growing and maintaining urban trees, forests, and green spaces". The program often has funding available to work with partners around urban forests.

"Urban Forestry Grant Resources"

- https://planitgeo.com/library/urban-forestry-grant-resources/
- This dashboard by an urban forestry consulting firm provides an up-to-date listing of funding opportunities. Federal/regional are listed first, followed by grants specific to states.

While most UFMPs contain common elements, it is equally true that a specific UFMP can emphasize different elements of the urban forest (e.g., street tree canopy, or fire management) so that the plan reflects the values and preferences of the local residents. Pre-fire planning can – and should – be an element of the UFMP but is to our knowledge still somewhat uncommon. One interesting example is Appendix P in the City of Beverly Hills UFMP. This Appendix focuses on the WUI part of the City of Beverly Hills as a distinct area, which makes sense given that it (and not the rest of the City) has a "high wildfire hazard" rating from the California Department of Forestry and Fire Protection. This "distinct area" approach will not work for every city, but where appropriate it might be one way to separate out areas of the city in where fire concerns are disproportionally important (when compared to the rest of the city).

In this and previous chapters we have presented several types of urban forest management and planning approaches that are relevant to communities in wildfire-prone areas. Is it important to understand what they are and are intended to do (See Box K). In any case, we recommend that the UFMP and a "wildfire plan" (may be termed differently in a city's planning documents) be prepared concurrently because both the planning considerations and the prioritization of the best management practices (BMPs) in each document will be informed by the other document. This may help any clarify any questions or mitigate possible conflicts in management goal. For example, an UFMP might prioritize drought-tolerant trees, however this this choice of species (e.g., eucalyptus, some conifers) might also produce substantial dry fuels that will influence fire planning; conversely, if fire planning envisions a well-irrigated near-house landscape as part of preparedness, then the tree and plant selection could be adjusted to favor species that retain moisture year-round.

Insert Box 7.3: Differences among UFMP, Urban Tree Canopy Assessment, Tree Inventories, and a Community Wildfire Protection Plans

Urban Forest Management Plan is roadmap to create a shared vision for a community's future urban forest and/or urban tree cover and how to meet specific goals and objectives.

Street Tree Management Plan is a roadmap for creating a shared vision of trees in the public domain primarily along transportation rights of way but also parks, and other public institutional grounds.

Urban Tree Canopy Assessment is "a measure of a community's tree canopy cover as a percentage of the total land area and serves as a baseline for setting tree canopy goals and measuring progress" (USDA FS 2019)

Tree Inventory is a census or system that records the location, size, condition, taxa and other characteristics of trees in a specific area of interest.

Community Wildfire Protection Plan is a multi-organizational plan that identifies and addresses fire risk (likelihood of a fire occurring) and fire hazard (potential source of ignition of amount of flammable material causing a fire) for a given community.

Chapter 8: Restoring Urban Forests and Tree Cover: Selecting, Planting and Establishing Quality Trees from the Nursery

Igor Lacan

Selecting good nursery stock is an essential step in post-fire replanting. This is a different process from selecting site-appropriate species, which requires understanding the local growing environment – soil conditions, water availability, pest & disease threats – as well as defining the goals of the planting including any trade-offs that need to be considered. (e.g., shade in the summer vs. shade year-round; showy flowers vs. low pollen production; etc.). But once the species selection decisions have been made, the next step is to select in the nursery the individual plants (nursery stock) to be planted on-site – this is known as "nursery stock selection."

Although individual plants differ, good nursery stock should have some basic characteristics. First, a well-developed root system, with no roots circling or girdling the trunk or other roots, and most of the root mass composed of many small, short, branched absorbing roots (rather than having only a few long, un-branched, stringy roots that wind around). Second, a well-developed shoot system (canopy) that has a strong central leader, with other branches spaced about evenly along that central leader (rather than having all branches coming out of the same point, with all of them roughly the same length, giving a "lollipop-on-a-stick" appearance).

Note that the canopy of a young tree, such as those sold in the nursery, should not resemble in form the canopy of a mature landscape tree: avoid lollipop-shaped young trees! Note also that while canopy deficiencies can be remedied after planting, if the tree is still young, this work may involve extensive pruning that will not only make the tree look unsightly while the new branches grow but will also reduce growth for some years after such pruning.

On the other hand, correcting root defects must be done at planting, as once the tree is in the ground, any root defects will remain hidden and will eventually lead to reduced growth, shortened lifespan, and potential for root failure with possibly severe consequences (uprooting). Thus, it is best practice to select trees that have both a well-formed canopy and a defect-free root system. The canopy shape is easily observed, but evaluating the roots may be difficult where nursery stock is sold in containers, as it is in much of the Western US. One way to examine the roots is to lift the tree out of its container, but this may be difficult even with small-sized stock (e.g., trees in #5 nursery containers) and is completely impossible with larger-sized stock (15 gal. containers or larger). In such cases the buyer should brush off some soil at the top of the container and observe the roots that can be seen; again, avoid any stock with circled or girdled roots. Finally, a note about nursery stock size: as container-grown trees increase in size, so does the risk of them developing circling/girdling roots. Thus, it is best to select the smallest-size stock that will meet the planting objectives. In addition, if water is reliably provided, smaller stock tends to establish quicker in the landscape (compared to larger-sized stock), is easier to handle during planting.

As mentioned in our previous chapters, there is very little information on choosing tree species that are appropriate for fire prone urban landscapes. However, in the southeastern United States, where hurricane events have regularly affected urban forests and trees, The University of Florida-IFAS developed a series for hurricane-affected affected urban forests and trees that we will refer the reader to for Chapters 10-13 in this manual. Similarly, California ReLeaf/California Department of Forestry and Fire Protection have a series of "cue cards" relevant to this chapter (Figure 8.1). Many of them are also available in Spanish, although below we provide links to the English language versions.

Selecting high quality trees

"Selecting Quality Trees from the Nursery"

- https://edis.ifas.ufl.edu/publication/EP313
- This chapter is a comprehensive guide to choosing quality trees from a nursery with educational photographs and diagrams. After choosing the appropriate tree species, this fact sheet discusses site conditions and after-care planning. This publication also describes in detail the quality factors of nursery stock to evaluate before purchasing.

"Tree Quality Cue Cards"

- https://californiareleaf.org/wp-content/uploads/2016/02/treequality-card.pdf
- A simple printable guide from California ReLeaf for choosing quality nursery stock with educational graphics. This publication discusses desirable versus undesirable branch structure and root collar formation. Information on how to choose trees based on site-specific or after-care planning is not included.

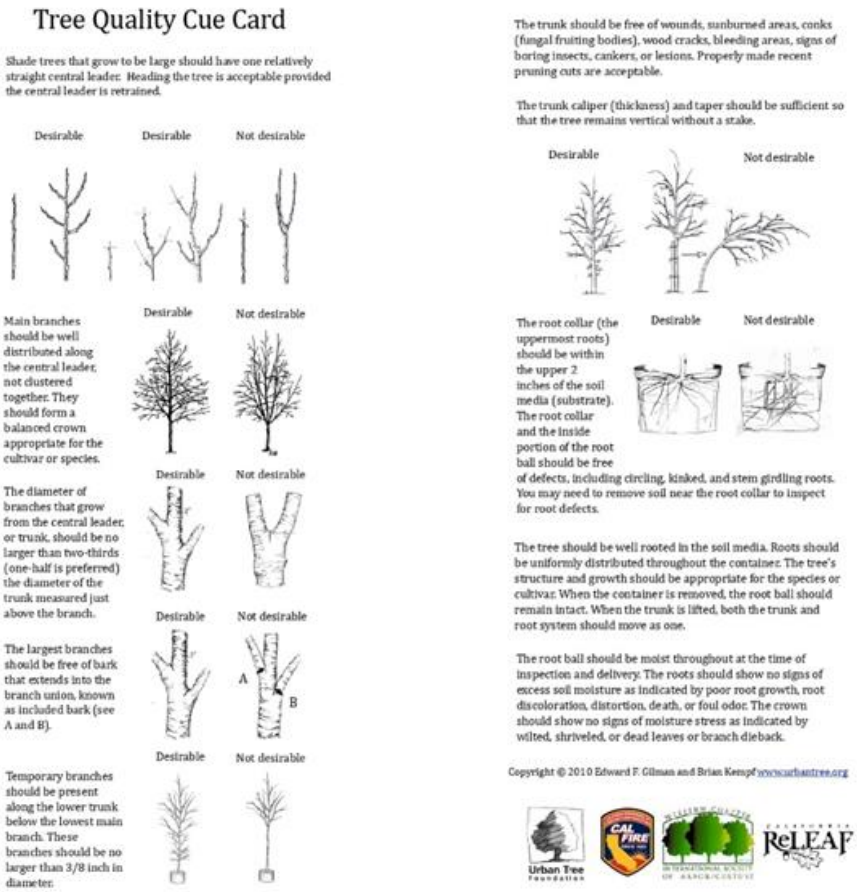


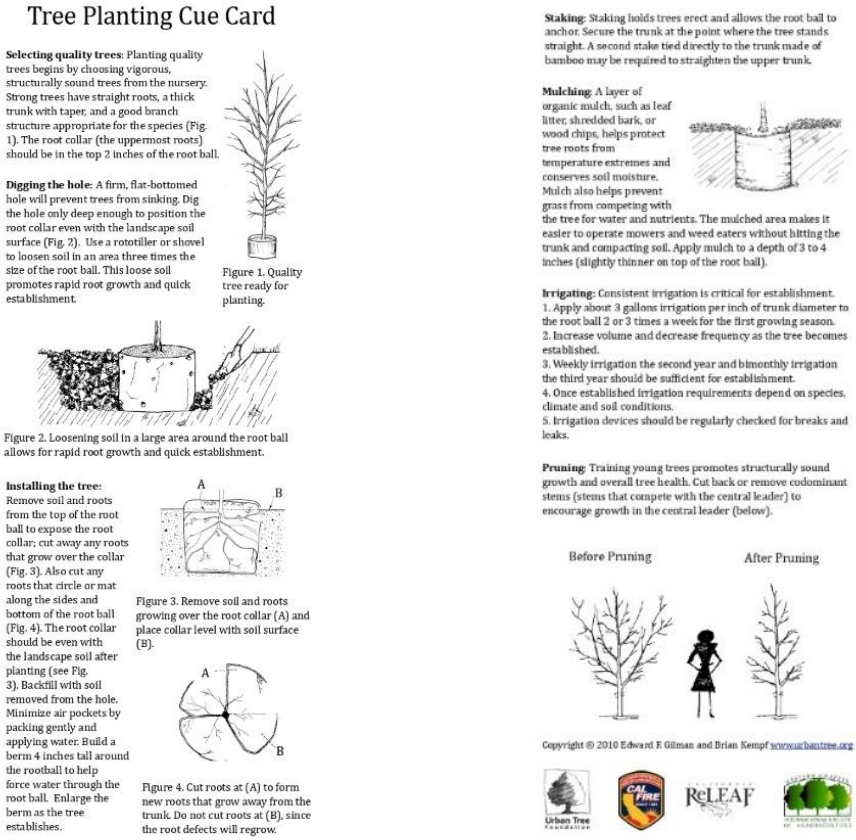
Figure 8.1. Tree Quality Cue Card. Copyright California ReLeaf.

Planting Trees

As mentioned in the previous chapter and Introduction, there is very little information on choosing tree species that are appropriate for fire prone urban landscapes. However, after the 2005-2006 hurricane season that substantially impacted Florida's urban forests, the University of Florida-Institute of Food and Agricultural Sciences developed a series for hurricane-affected affected urban forests and trees. Given the lack of information regarding urban trees, forests and fire, here we provide some of the guidelines and criteria developed for Florida, but that is however applicable to restoring and planting trees in fire affected urban forests.

"Planting and Establishing Trees"

- https://edis.ifas.ufl.edu/publication/EP314
- Specifically, the Hurricane Recovery Series Chapter 11, presents a comprehensive guide on planting and establishing trees with educational photographs, diagrams, and tables. Successful establishment of trees is done by managing proper planting depth and irrigation. This fact sheet discusses in detail the ten steps to tree planting and factors that determine tree establishment rate.



Tree Planting Cue Card

Selecting quality trees: Planting quality trees begins by choosing vigorous, structurally sound trees from the nursery. Strong trees have straight roots, a thick trunk with taper, and a good branch structure appropriate for the species (Fig. 1). The root collar (the uppermost roots) should be in the top 2 inches of the root ball.

Digging the hole: A firm, flat-bottomed hole will prevent trees from sinking. Dig the hole only deep enough to position the root collar even with the landscape soil surface (Fig. 2). Use a rototiller or shovel to loosen soil in an area three times the size of the root ball. This loose soil promotes rapid root growth and quick establishment.

Figure 1. Quality tree ready for planting.

Figure 2. Loosening soil in a large area around the root ball allows for rapid root growth and quick establishment.

Installing the tree: Remove soil and roots from the top of the root ball to expose the root collar; cut away any roots that grow over the collar (Fig. 3). Also cut any roots that circle or mat along the sides and bottom of the root ball (Fig. 4). The root collar should be even with the landscape soil after planting (see Fig. 3). Backfill with soil removed from the hole. Minimize air pockets by packing gently and applying water. Build a berm 4 inches tall around the rootball to help force water through the root ball. Enlarge the berm as the tree establishes.

Figure 3. Remove soil and roots growing over the root collar (A) and place collar level with soil surface (B).

Figure 4. Cut roots at (A) to form new roots that grow away from the trunk. Do not cut roots at (B), since the root defects will regrow.

Staking: Staking holds trees erect and allows the root ball to anchor. Secure the trunk at the point where the tree stands straight. A second stake tied directly to the trunk made of bamboo may be required to straighten the upper trunk.

Mulching: A layer of organic mulch, such as leaf litter, shredded bark, or wood chips, helps protect tree roots from temperature extremes and conserves soil moisture. Mulch also helps prevent grass from competing with the tree for water and nutrients. The mulched area makes it easier to operate mowers and weed eaters without hitting the trunk and compacting soil. Apply mulch to a depth of 3 to 4 inches (slightly thinner on top of the root ball).

Irrigating: Consistent irrigation is critical for establishment.
1. Apply about 3 gallons irrigation per inch of trunk diameter to the root ball 2 or 3 times a week for the first growing season.
2. Increase volume and decrease frequency as the tree becomes established.
3. Weekly irrigation the second year and bimonthly irrigation the third year should be sufficient for establishment.
4. Once established irrigation requirements depend on species, climate and soil conditions.
5. Irrigation devices should be regularly checked for breaks and leaks.

Pruning: Training young trees promotes structurally sound growth and overall tree health. Cut back or remove codominant stems (stems that compete with the central leader) to encourage growth in the central leader (below).

Before Pruning

After Pruning

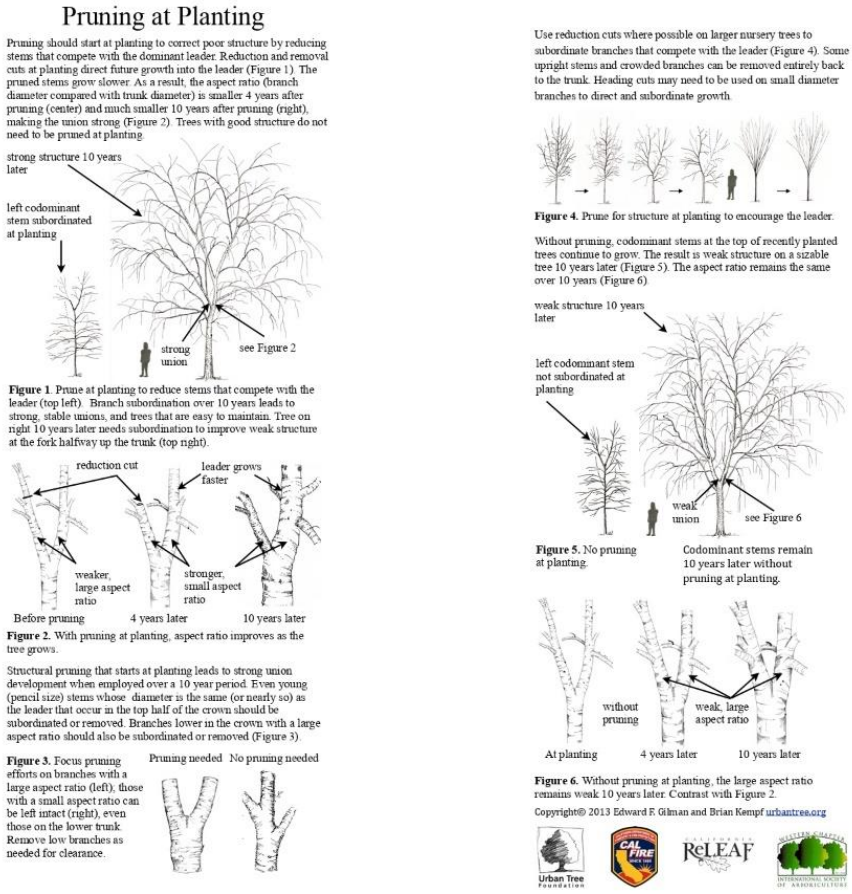
"Tree Planting"

- https://californiareleaf.org/wp-content/uploads/2016/02/planting-cue-card.pdf
- A simple printable guide to successful tree planting with educational diagrams. This publication includes brief descriptions of how to: select quality trees, dig proper holes, install the tree, stake, mulch, irrigate, and prune.

Preventative Pruning: Young Trees

"Developing a Preventative Pruning Program: Young Trees"

- https://edis.ifas.ufl.edu/publication/EP315
- A comprehensive guide to pruning urban and suburban trees with educational photographs, diagrams, and tables was also developed by the University of Florida. This specific publication describes how to create a preventive pruning program which helps to mitigate the risk of tree defects that cause failure. Included in this fact sheet are the components of preventive structural pruning, such as pruning objectives, pruning cycles, and implementation of a pruning plan for your community.



Pruning at Planting

Pruning should start at planting to correct poor structure by reducing stems that compete with the dominant leader. Reduction and removal cuts at planting direct future growth into the leader (Figure 1). The pruned stems grow slower. As a result, the aspect ratio (branch diameter compared with trunk diameter) is smaller 4 years after pruning (center) and much smaller 10 years after pruning (right), making the union strong (Figure 2). Trees with good structure do not need to be pruned at planting.

Figure 1. Prune at planting to reduce stems that compete with the leader (top left). Branch subordination over 10 years leads to strong, stable unions, and trees that are easy to maintain. Tree on right 10 years later needs subordination to improve weak structure at the fork halfway up the trunk (top right).

Figure 2. With pruning at planting, aspect ratio improves as the tree grows.

Structural pruning that starts at planting leads to strong union development when employed over a 10 year period. Even young (pencil size) stems whose diameter is the same (or nearly so) as the leader that occur in the top half of the crown should be subordinated or removed. Branches lower in the crown with a large aspect ratio should also be subordinated or removed (Figure 3).

Figure 3. Focus pruning efforts on branches with a large aspect ratio (left), those with a small aspect ratio can be left intact (right), even those on the lower trunk. Remove low branches as needed for clearance.

Use reduction cuts where possible on larger nursery trees to subordinate branches that compete with the leader (Figure 4). Some upright stems and crowded branches can be removed entirely back to the trunk. Heading cuts may need to be used on small diameter branches to direct and subordinate growth.

Figure 4. Prune for structure at planting to encourage the leader.

Without pruning, codominant stems at the top of recently planted trees continue to grow. The result is weak structure on a sizable tree 10 years later (Figure 5). The aspect ratio remains the same over 10 years (Figure 6).

Figure 5. No pruning at planting. Codominant stems remain 10 years later without pruning at planting.

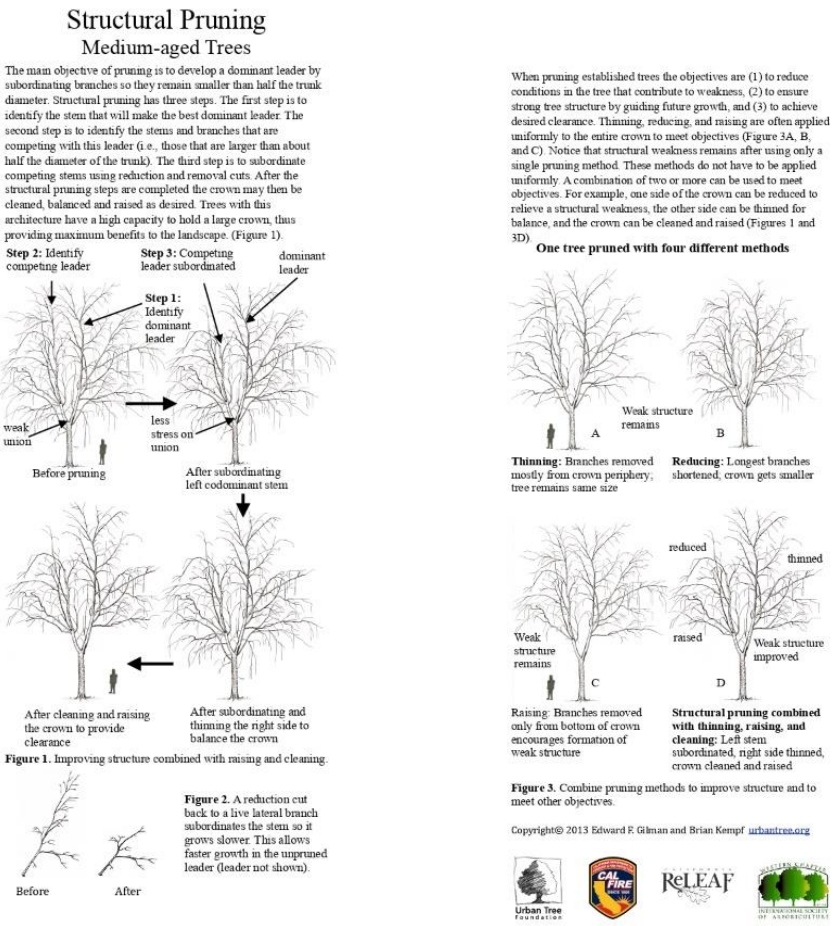
Figure 6. Without pruning at planting, the large aspect ratio remains weak 10 years later. Contrast with Figure 2.

"Pruning at Planting"

- https://californiareleaf.org/wp-content/uploads/2016/02/planting-cue-card.pdf
- A simple printable guide to proper pruning techniques of young trees with educational diagrams. This publication briefly describes how to establish correct tree structure of young trees at planting, which will help mitigate future structural defects.

"Developing a Preventative Pruning Program: Mature Trees"

- https://edis.ifas.ufl.edu/publication/EP316
- Finally, the University of Florida also presents a comprehensive guide to pruning methods of mature trees with educational photographs and diagrams. The goal of creating a preventive pruning program is to maintain proper tree structure and reduce the risk of tree failure. This fact sheet describes seven main objectives one should consider when formulating a preventive pruning program for their community.



Structural Pruning

Medium-aged Trees

The main objective of pruning is to develop a dominant leader by subordinating branches so they remain smaller than half the trunk diameter. Structural pruning has three steps. The first step is to identify the stem that will make the best dominant leader. The second step is to identify the stems and branches that are competing with this leader (i.e., those that are larger than about half the diameter of the trunk). The third step is to subordinate competing stems using reduction and removal cuts. After the structural pruning steps are completed the crown may then be cleaned, balanced and raised as desired. Trees with this architecture have a high capacity to hold a large crown, thus providing maximum benefits to the landscape. (Figure 1).

Figure 1. Improving structure combined with raising and cleaning.

Figure 2. A reduction cut back to a live lateral branch subordinates the stem so it grows slower. This allows faster growth in the unpruned leader (leader not shown).

When pruning established trees the objectives are (1) to reduce conditions in the tree that contribute to weakness, (2) to ensure strong tree structure by guiding future growth, and (3) to achieve desired clearance. Thinning, reducing, and raising are often applied uniformly to the entire crown to meet objectives (Figure 3A, B, and C). Notice that structural weakness remains after using only a single pruning method. These methods do not have to be applied uniformly. A combination of two or more can be used to meet objectives. For example, one side of the crown can be reduced to relieve a structural weakness, the other side can be thinned for balance, and the crown can be cleaned and raised (Figures 1 and 3D).

One tree pruned with four different methods

Thinning: Branches removed mostly from crown periphery, tree remains same size

Reducing: Longest branches shortened, crown gets smaller

Raising: Branches removed only from bottom of crown encourages formation of weak structure

Structural pruning combined with thinning, raising, and cleaning: Left stem subordinated, right side thinned, crown cleaned and raised

Figure 3. Combine pruning methods to improve structure and to meet other objectives.

"Structural Pruning: Medium-Aged Trees"

- https://californiareleaf.org/wp-content/uploads/2023/04/structural-pruning-medium-age-trees-mediamcue.pdf
- A simple printable guide for structural pruning of medium-aged trees with educational graphics. The publication briefly describes how to identify dominant leader branches and subordinating branches. By using proper structural pruning techniques, a mature tree will have a sound structure and minimal failure risks.

Chapter 9: Fire and Trees: Lessons Learned from Urban Fires

Alyssa Thomas and Tara Kelly

Introduction

These six case studies offer a closer examination at urban forest restoration post-wildfire. The selected wildfires represent a spectrum of conditions from a "city in a forest" (Paradise, California), to an arid high desert where no trees were present except those planted as urban ornamental landscape (Louisville, Colorado) to a former wetland ecosystem now home to many non-native species of vegetation (Lahaina, Hawai'i). Despite these differences, these fires share a common feature: they started as wildland fires that subsequently moved into nearby urban areas due to high winds and dry conditions. Taken together, the case studies offer valuable lessons. Public officials should be aware of this pattern: a wildland fire just outside the urban area, then spreading into the urban tree canopy and becoming an urban conflagration and consider it when planning for wildfire. They should seek to make connections with stakeholders such as regional fire agencies, large landowners located just outside the city boundaries, and any other non-city entities that would likely be involved in wildfire response.

Tubbs Fire 2017: Santa Rosa – Northern California city

Figure 9.1. Santa Rosa before (May 2015) and after (March 2019) the Tubbs Fire. Copyright Google Earth.

Background

Sonoma and Napa counties are inland regions north of the San Francisco Bay Area, with a Mediterranean climate that supports an array of ecosystems. Although Santa Rosa is surrounded by wildland and has many wildland-urban interface (WUI) neighborhoods, it is a well-established city of ~177,000 people. At 10pm on October 8th, 2017, a private electrical system adjacent to a residential structure in Napa County CA, about 3mi north of Calistoga, ignited the Tubbs Fire. Although the fire began in the wildlands (oak woodlands), by 1am strong winds had pushed it more than 12 miles to reach Highway 1. The 60mph winds then blew embers across the four-lane highway and began igniting structures in downtown Santa Rosa. Within the city limits, around 1,500 homes in the Coffey Park neighborhood were destroyed. By the time the fire was finally contained 38,807 acres across Sonoma and Napa counties had burned, destroying 5,642 structures, and killing 22 people.

Response and Restoration Timeline

- October 8, 2017: Tubbs Fire starts
- January 29, 2018: Debris removal completed in Coffey Park
- February 9, 2018: Fire is declared fully contained after 123 days.
- April 21, 2018: More than 100 volunteers gather to start reforestation efforts in the Fountaingrove neighborhood by planting ~350 native oak trees and other tree & shrub species. Trees and planting materials are supplied by Comcast and the Arbor Day Foundation.
- February 2019: American Tree Medics completed their report on the inventory of fire-damaged trees on public property.

- May 2019: The city releases an invitation for bids for removal of 702 hazardous street trees damaged by the fire and recommended for removal (as identified in the arborist report). Arborist Now was subsequently awarded the contract.
- June to October 2019: Phase 1 of tree removal, hazardous street trees. Removed approximately 450 fire-damaged hazardous street trees from burned areas in the Coffey Park, Fountaingrove and Hidden Valley areas of the city.
- September 2020: Phase 2 is completed with 130 hazardous trees removed from City parcels, Public Right of Way and Parks.
- May 2022: Restoration begins of several parks badly damaged by the fire.
- January 2023: Phase 3, the removal of all remaining fire-damaged trees not removed during phase 2, is still in the design process.
- January to March 2024 – Phase 3 is substantially" completed. All remaining fire damaged hazardous trees, mostly located within the city owned open space parcels, were removed.

Within two weeks of the fire, the Santa Rosa City Council adopted a Resilient City Urgency Ordinance to streamline and expedite review for housing permits. Santa Rosa landscape zoning requirements state there must be one street tree per 30ft of residential frontage. To acquire a building permit, owners had to submit landscape and irrigation plans. During post-fire rebuilding, Santa Rosa supplied public landscape template drawings that would meet the city's tree density requirements.

Lessons learned

Rebuilding for Public Officials

(Missed) Opportunity for urban forestry management. Santa Rosa had no Urban Forester / City Arborist or a working urban forest management plan to help with post-fire recovery. After the Tubbs Fire, the City informed residents that any tree removed on private property in post-fire cleanup did not need to be replaced if they utilized landscape template drawings provided by the City. However, not all the template drawings included trees, and those that did not mention species selection in relation to City approved street trees. The lack of an UFMP made it difficult to align post-fire restoration operations with urban canopy goals and made it challenging to provide relevant guidance to residents.

There were also some discrepancies between City pre-approved landscape designs and City zoning laws, as according to Santa Rosa zoning code 20-34.050 one tree pre 30ft of residential frontage is required by law. Additionally, Santa Rosa Recreation & Parks published a Planting and Irrigation Standards manual in 2014, which further states each residential lot is required to have at least one tree, and corner lots two trees, except where not possible.

Thomas Fire 2017: Ventura – Southern California coastal city

Figure 9.2. Ventura before (November 2017) and after (January 2018) the Thomas Fire. Copyright Google Earth.

Background

Ventura is a coastal city in southern California, home to 109,925 people, that borders a mountainous region of oak savannah and chaparral ecosystems. At 6:30PM, on December 4th, 2017, in a mountainous wildland region of Ventura County strong offshore winds caused two power lines to come into contact and ignited the Thomas Fire. The power lines created an electrical arc that deposited hot, burning material onto the ground and sparked the surrounding dry grass. By 11:30PM, the Thomas Fire had grown to an estimated 20,000 acres and had reached the city limits of Ventura. The strong winds pushed the Thomas Fire westward at 50-75mph and began igniting homes in eastern Ventura neighborhoods. The fire was contained after burning 281,893 acres and destroying 1,063 structures across Ventura and Santa Barbara Counties. Within the city of Ventura specifically, 504 homes were destroyed and 140 were damaged within the city limits.

Response and Restoration

December 4, 2017: Thomas Fire starts

December 12-22, 2017: Detailed safety assessments of ~1,800 sites

January 12, 2018: Thomas Fire declared 100% contained

January 19 – June 6, 2018: Cleanup operations at 672 destroyed properties for which owners chose to participate in the state-funded cleanup program. This includes both Phase 1 (household hazardous waste) and Phase 2 (fire debris and ash removal). For partially burned or damaged structures a local program was established.

September 2019: the City of Ventura has conducted a full tree inventory of street trees, including identified sites and vacant sites.

Lessons Learned

Potential for loss of institutional knowledge with staff turnover.

The City of Ventura has over 100,000 residents and is a full-service city. However, because of staff turnover at the local (city) level, there is no-one left in the city staff five years after the fire with first-hand understanding of the impacts, assessments, and restoration efforts. Thus, although the Public Works department was charged with both removing the damaged trees and replanting, it is now difficult, if not impossible, to evaluate the efficacy of those efforts or to learn about how to optimize this process (e.g. tree species selection; planting practices; in case of another fire). For cities where institutional knowledge is lacking around urban forests, they could consider the fire an opportunity to develop high-level strategic documents (e.g., UFMP) and

tracking procedures (urban tree inventory; urban tree canopy analysis) that remain useful into the future and allow an assessment of urban forest conditions over time.

Camp Fire 2018: Paradise, California – City in a forest

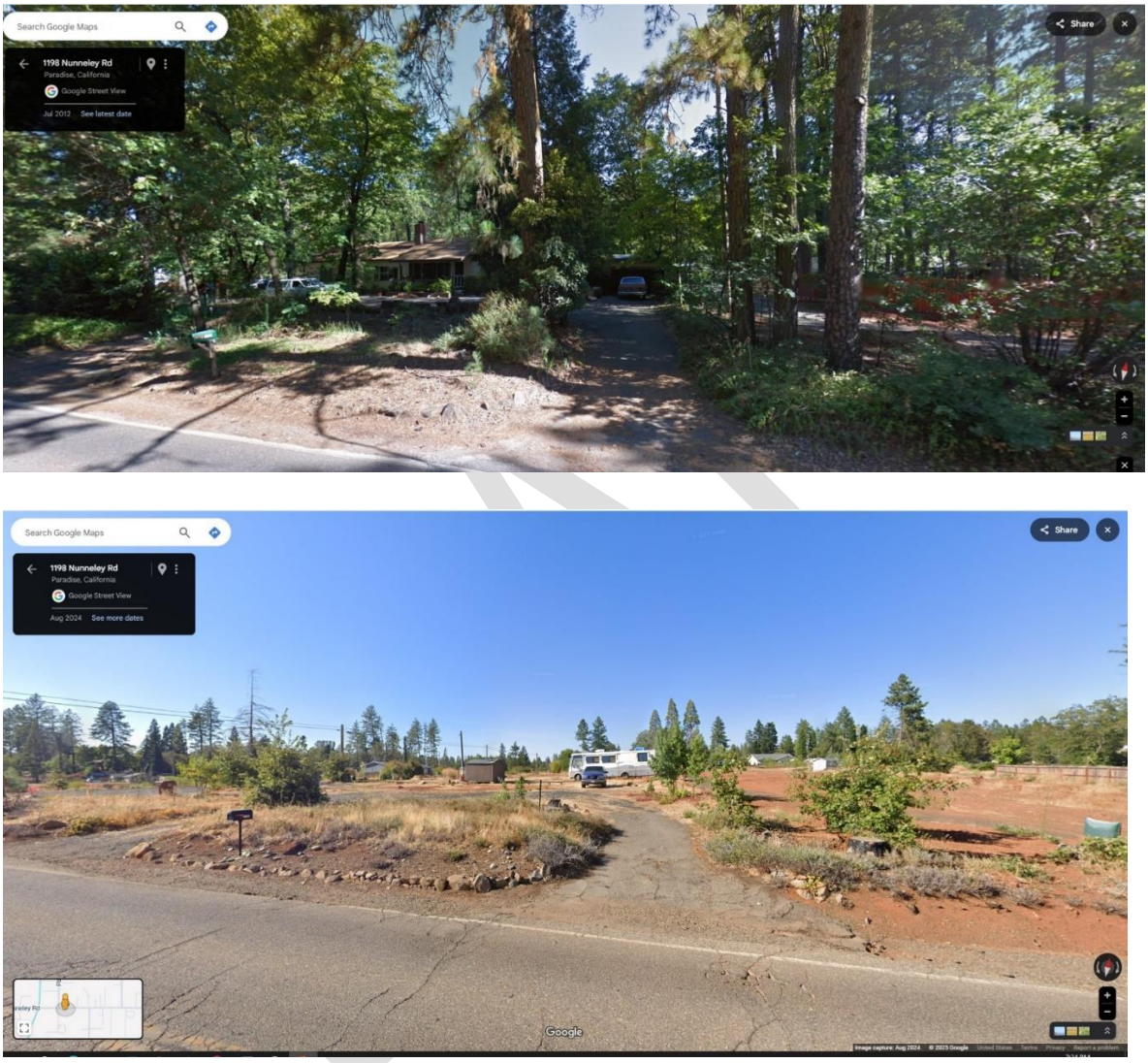


Figure 9.3. Paradise before (July 2012) and after (August 2024) the Camp Fire. Copyright Google Street View.

Background

Butte County is an inland region of northern California in the Sierra Nevada mountains' foothills, mainly consisting of mixed conifer forests. The Town of Paradise is situated on a wide ridge between canyons, with a pre-fire population of 26,532 people (2024 population is just 5,268). Although this region is not urban, as the entire town is within the WUI, some neighborhoods are

dense enough that Firewise techniques are largely ineffective. Around 6:30AM on November 8th, 2018, a faulty electric transmission line ignited the Camp Fire in the wildlands north of several communities. Due to excess dry fuel on the forest floor and high southwest winds up to 50mph, the fire rapidly spread, and by 8AM the entire town of Paradise was ordered to evacuate. When the fire was finally contained it had burned 153,335 acres, destroyed 18,800 structures, and killed 85 people. It was the deadliest wildfire in the modern United States until 2023. In the city of Paradise, an estimated 95% of homes and structures were destroyed. As opposed to many other *urban forests* affected by fire events (e.g. Ventura, Santa Rosa, Louisville) where trees were established in formerly agriculture, pastures and shrubland areas; Paradise is more of an *urbanized forest*, or a natural or wildland forest that was then urbanized.

Response and Restoration Timeline

- November 8, 2018: Camp Fire starts
- November 25, 2018: Camp Fire is declared 100% contained
- December 3, 2018- Phase 1 of cleanup, removal of hazardous waste, begins. This phase lasts two months.
- January 7, 2019-Phase 2 of cleanup (site assessment & documentation, debris removal, erosion control measures, and final inspections) begins.
- Early 2019-the City applies for funding for private property tree removal.
- November 19, 2019: CalRecycle and Cal OES announce the completion of debris removal.
- May 26, 2020: Cal Recycle announces they are looking for four separate contracting firms to carry out hazard tree removal: 1 firm for field management, 1 firm for administrative management, and 2 firms for tree removal. Federal funding provided by FEMA comprises 90% of the funding with State (under the California Disaster Assistance Act) covering the remaining 10%.
- August 2020: Contracted arborists begin assessment of fire-damaged trees to determine which ones could fall onto a public right-of-way.
- November 17, 2020: Hazard tree removal begins. Trees removed during this stage, and debris removal, are Category 1: Hazard trees on public property that are a threat to the public Right-of-Way (ROW) or public improved property. Category 2: Hazard trees on private property that are a threat to the Cal Recycle debris removal effort and/or the Cal Recycle crews and the public ROW. Category 3: Hazard trees on non PPDR (private property debris removal), private property that are a threat to the public ROW and/or improved property.
- July 25, 2022: Phase 1 (assessments) of private property tree removal begins. Applications open for homeowners to enroll in a program to have fire-damaged trees on their property assessed by city-contracted arborists. There was no cost to owners, with the City covering 25% of the cost, and FEMA/CALOES funding covering the rest. This program will remove

Category 4 trees, defined by FEMA as “Hazard trees on private property that constitute a threat to abutting or private property”.

- August 1, 2023: The City receives a $2.5 million grant from CAL FIRE to support phase 2 of private property tree removal. This grant covers the remaining 25% (FEMA covers 75%) and means homeowners will no longer have to pay anything.
- April 2024-Federal Environment Review is completed for Phase 2. Letters are sent to the property owners who participated in Phase 1 and had trees marked as eligible for removal. Phase 2 is expected to be completed by Fall 2025.

Lessons Learned

Tree removal for Public Officials

Consider consulting with environmental review professionals. Five years post-fire, Paradise is finally done with hazard tree removal on private property, despite having first applied for funds back in 2019. Although the request process was straightforward, the implementation was challenging leading to substantial delays. The required environmental assessments were the biggest barrier to recovery. This is due to each project and grant requiring environmental assessments that cannot be transferred from one project or grant to the next. So, the city essentially repeated the same assessment over and over. This process can be quite lengthy and add multiple years to the recovery process. Modifications to use an assessment multiple times over a set period would be highly beneficial and substantially speed up the recovery process.

Marshall Fire 2021: Louisville, Colorado – Front range grassland city

Figure 9.4. Louisville before (September 2021) and after (April 2022) the Marshall Fire. Copyright Google Street View.

Background

The City of Louisville, CO is situated in a semi-arid prairie climate in the southwest Boulder County region. Home to 20,975 people, Louisville is a small city with a mix of WUI neighborhoods and densely populated subdivisions. At 11AM on December 30th, 2021, two fires ignited near the city, less than half a mile apart and eventually merged into the Marshall Fire. The first fire started on a private property, where a controlled burn had taken place six days earlier but was re-ignited by high winds and other unknown factors. Roughly one hour later, a second fire 0.38 miles west at a park trailhead ignited from a downed communications power line. At 1pm, tens of thousands of people had been evacuated, including in Louisville. The Marshall Fire was contained by January 3rd, 2022, after burning 6,026 acres across the City of Louisville, Town of Superior, and unincorporated Boulder County, destroying 1,084 residential structures, and killing two people. Within the Louisville city limits, the Marshall Fire destroyed 550 homes and damaged another 43.

Response and Restoration

- December 30, 2021: Marshall Fire starts
- January 1, 2022: Fire is contained after a heavy snowfall the previous night
- January 10-29, 2022: Country removes cars, trees and materials blocking access to a public right-of-way
- January 31, 2022: Boulder County submits a funding request to FEMA for private property debris removal, including downed trees and other vegetation. FEMA ends up covering 90% of the costs, the State of Colorado 5% and Louisville/Superior/Boulder Counties the final 5%.
- January 11, 2022: Boulder County begins taking applications from homeowners who want to participate in the state-sponsored program for debris removal
- February 1, 2022: Deadline for contractor bids for debris removal
- February 11, 2022: Contractor for debris removal selected
- Week of April 20,2022: Debris removal program begins. The start was delayed several times due to lawsuits from companies unsuccessful in the contract bid.
- August 24, 2022: Debris removal is completed
- September 2023: Homeowners ready to plant in the fall can request free trees, organized by several local non-profits
- February 2024: Community organizations are still working on providing trees to homeowners affected by the fire.
- March 2024: The city is still evaluating and removing fire-damaged city trees. For example, some mature trees were marked for re-assessment rather than marked for immediate removal. An estimated 120 city trees within the fire perimeter have been removed, and over 1,000 private property trees have also been removed.

- November 25, 2024: To-date 40 building permits issued for rebuilding homes and 54 certificates of occupancy issued for rebuilt homes.

Lessons Learned

UFMP and land management

Outdated and irrelevant material within a UFMP will not help post-fire urban forest recovery. Without clear guidelines and goals for recovery, processes are made up and adapted as post-fire efforts are made. For example, street trees in Louisville were mature and well-established, but not being irrigated because the systems were 30+ years old and non-functioning. Now that some need to be removed and replanted, the city must first invest in new irrigation systems, watering agreements for right-of-way trees and a watering program for established trees to ensure successful growing. However, their UFMP does not address issues around planting trees in soil that has been scorched and has lost ground cover vegetation. Additionally, the semi-arid desert prairie ecosystem means that most tree species do not grow there naturally, limiting options if planting native trees is a priority for the city. Finally, the location where the fire started had many large areas of abandoned and overgrown hay fields that were known wildfire hazard. As these sites were not being properly managed, they provided a major fuel source upon ignition of the fire.

Lahaina Fire 2023: Lahaina, Maui, Hawai'i – Tropical island city

Figure 9.5. Lahaina before (March 2023) and after (November 2023) the wildfire. Copyright Google Earth.

Background

Located on the island of Maui in Hawai'i, Lahaina is a coastal plain region, east of the West Maui Mountains with a desert microclimate receiving 10-15in of annual precipitation. Lahaina was home to ~13,216 people prior to the wildfire, but thousands of residents have since been displaced. Shortly after sunrise on August 8th, 2023, extremely high winds caused downed power lines to ignite a field of dry grass in the eastern region of Lahaina, Hawai'i. Around 3:30pm the fire flared up and jumped containment lines, forcing Lahaina residents to begin frantic evacuations. The fire ultimately burned 2,170 acres, destroying 2,207 buildings, and killing 97 people. Response and recovery efforts would take longer than for most fires because of Maui's rich history & the number of associated important cultural sites, as well as the number of deaths (all fire-affected properties had to be searched by specially trained teams prior to any other work starting). Out of the roughly 25,000 trees in Lahaina pre-fire, only 700-1000 remain. Although much of the media attention around the city's urban forest was on the famous banyan tree, the fire burned all but two of the roughly dozen breadfruit trees (a culturally important tree that was widespread before colonization). Notably, several local businesses stepped up to help save important trees such as these, removing concrete to be able to access the tree roots, making compost, and/or providing water every day.

Response and Restoration

- August 8, 2023: Fire starts
- September 3, 3023: Fire is declared 100% contained.
- August 29-December 21, 2023-: Hazardous waste removal is carried out by the EPA. During this time initial tree assessments are also performed. Cultural assessments are done alongside these standard assessments, to determine if anything might have cultural significance, such as burial plots or markers and certain types of plants or trees. 202 trees end up being marked as culturally significant.
- October 8, 2023: West Maui re-opens for tourism.
- January 16, 2024: Debris removal on private properties begins by the U.S. Army Corps of Engineers.
- February 27, 2024: Commercial/public properties cleanup starts (phase 1-hazardous waste removal and site assessments).
- March 22, 2024: Phase 2, debris clearance, starts for commercial/public properties.
- September 11, 2024: Residential debris removal completed, well ahead of the initial planned completion of 2025.
- November 18, 2024: 91% of commercial/public properties cleared of debris, with anticipated completion in February 2025. 300 building permits submitted and 138 issued to-date.

The hazard tree removal will likely include many coconut trees that initially survived the fire but are too damaged to safely withstand winds once covered with coconuts. The Maui County Planting Plan states that lots must contain one shade street tree for each 100ft of frontage. For subdivisions of four or more lots, each street should be planted with trees belonging to three different genera. The genera selected are at the discretion of the landscape architect but should be chosen from the county's pre-approved list of species. Furthermore, palms are not considered shade trees and are only accepted as complementary landscape trees, unless shade trees are inappropriate for the site.

Lessons Learned

Partnerships

The Lahaina Restoration Foundation began tree restoration efforts immediately post-fire by transporting water with personal water trucks and volunteers. Another group, Treecovery, aims to "keep the trees in the fire zones alive and provide trees for no charge to the residents and businesses in Lahaina and Kula that lost their trees in the wildfire." The founder of this organization is the part-owner of a large landscaping company and has worked with over 20 volunteers to plant more than 200 trees and recover 150+ trees to date. However, it is important for volunteers to be aware of proper irrigation techniques and site-specific arboriculture knowledge. Public officials can reach out to volunteer groups and work together on restoration efforts. However, if volunteers do not understand basic principles of arboriculture, their efforts

may not produce desired results. Therefore, training and/or educational materials should be provided to volunteers prior to and/or during the first 'event'.

Another way Treecovery is helping to restore the urban forest is through the establishment of "micro-nurseries" across Maui. These hubs provide a place to grow trees (native species and fruit trees) until residents return to their homes or rebuild and are ready to replant. Since the first hub was established in April 2024, more than six resorts now participate in the program and around ~3,500 trees are being grown at hubs across the island.

Conclusions

Unlike wildland fires that occur in rural or WUI areas, fires in urban forests were rare but are now increasingly common, even though their importance has been somewhat under-stated when compared to other natural disasters such as pest outbreaks, prolonged droughts, or storms and hurricanes. The concepts outlined in this guide, and the resources listed, should serve as a starting point for discussion at the municipal level, as well as a reference for the individual homeowner and urban resident. At a minimum, municipal tree managers will want to:

- Create and regularly update their urban tree inventory so that they understand their urban tree resource. Effective post-fire recovery will largely depend on the manager knowing what was lost and where.
- Formulate, and build public support for, the urban forest management plan. In case of fire, the goals outlined in the plan will serve as a critical backstop when the goal of recovering trees inevitably falls behind other goals that might preclude such recovery (e.g., expanding building footprints).
- Find and establish connections with locally relevant resources that will be needed after a fire, from Federal and State agencies to consultants and tree care companies. It is better to do this during a quiet period, rather than in a chaotic post-fire environment.
- Ensure that all records, inventories, management plans, and resource contact lists are regularly updated, and readily available to all municipal agencies that work with trees. A recurring theme in interviews was the lack of communication across different municipal agencies and the loss of documents and knowledge after staff changes. This can be avoided this by designating a central repository for all tree-related documents, and by ensuring that it is both regularly updated and backed-up off-site.

Additional resources

General resources around disaster response and planning for urban forests

"Community Forest Storm Mitigation Planning"

- https://gicinc.org/wp-content/uploads/Forest-Storm-Mitigation_Book4.pd
- This is a short and easy to use guide focused on recovering the urban forest after a storm. It also contains links to other potentially useful publications.

"Hurricane Recovery Series"

- https://disaster.ifas.ufl.edu/trees--landscapes/
- A great resource from the University of Florida that is similar in aim to this manual, but for hurricanes. There are six sections, from overview to recovery, that provide links for further information and guidance.

"Resource Conservation District Post-Fire Playbook"

- https://cafiresafecouncil.org/resource/resource-conservation-district-post-fire-playbook/
- This is an excellent guide to post-fire recovery, although it is designed for Resource Conservation Districts so much of it will not be applicable to urban settings.

"Storms Over the Urban Forest"

- https://www.google.com/books/edition/Storms_Over_the_Urban_Forest/O-sTAAAAYAAJ?hl=en&gbpv=1&dq=Storms+over+the+urban+forest:+Planning,+responding,+and+regreening&pg=PA1&printsec=frontcover#v=onepage&q=Storms%20over%20the%20urban%20forest%3A%20Planning%2C%20responding%2C%20and%20regreening&f=false
- While not specific to fire and somewhat dated, this is a comprehensive guide to response to and recovery from disasters for urban forests, as well as pre-disaster planning. There are 11 chapters on subjects including preparing for disasters, regreening the community and two case studies. The USFS is in the process of update this publication in a Storymap format.

Regional FEMA Offices

Region 1: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Federal Emergency Management Agency
99 High Street, 6th Floor
Boston, MA 02110
(617) 956-7506

Region 2: New Jersey and New York
Federal Emergency Management Agency
Suite 1337, 26 Federal Plaza
New York, NY 10278- 0002
(212) 680-3600

Puerto Rico and Virgin Islands
Mailing address:
Federal Emergency Management Agency, Caribbean Division
PO Box 70105
San Juan, PR 00936-0105
Physical address:
Federal Emergency Management Agency
New San Juan Office Bldg, 159 Calle Chardon, 6th Floor
Hato Rey, PR 00918
(787) 296-3500

Region 3: Delaware, Maryland, Pennsylvania, Virgina, District of Columbia, West Virgina
Federal Emergency Management Agency
615 Chestnut Street, One Independence Mall, Sixth Floor
Philadelphia, PA 19106-4404
(215) 931-5608

Region 4: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee
Federal Emergency Management Agency
3003 Chamblee Tucker Road
Atlanta, GA 30341
(770) 220-5200

Region 5: Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin
Federal Emergency Management Agency
536 South Clark St., 6th Floor
Chicago, IL 60605
(312) 408-5500

Region 6: Arkansas, Louisiana, New Mexico, Oklahoma, Texas
Federal Emergency Management Agency
FRC 800 North Loop 288
Denton, TX 76209-3698
(940) 898-5399

Region 7: Iowa, Kansas, Missouri, Nebraska
Federal Emergency Management Agency, 9221 Ward Parkway, Suite 300
Kansas City, MO 64114-3372
(816) 283-7063

Region 8: Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming
Federal Emergency Management Agency
Denver Federal Center, Building 710
Box 25267
Denver, CO 80255-0267
(303) 235-4800

Region 9: Arizona, California, Hawaii, Nevada, Guam, American Samoa, Commonwealth of Northern Marinara Islands, Republic of Marshall Islands, Federated States of Micronesia
Federal Emergency Management Agency
1111 Broadway, Suite 1200
Oakland, CA 94607- 4052
(510) 627-7100

Region 10: Alaska, Idaho, Oregon, Washington
Federal Emergency Management Agency
Federal Regional Center
130 228th Street, Southwest
Bothell, WA 98021-8627
(425) 487-4600

State Fire/Urban Forestry Agencies

Alaska Divion of Forestry & Fire Protection
https://forestry.alaska.gov/
Phone: (907) 269-8400

Arizona Department of Forestry and Fire Management
https://dffm.az.gov/
Phone: (602) 771-1400

California Department of Forestry and Fire Protection
https://www.fire.ca.gov/
Phone: (916) 653-5123

Colorado Division of Fire Prevention and Control
https://dfpc.colorado.gov/
Phone: (303) 239-4600

Hawai'i Hawaii Division of Forestry and Wildlife
https://dlnr.hawaii.gov/dofaw/
Phone: (808) 587-0166

Hawai'i Fire Department
https://www.hawaiicounty.gov/departments/fire
Phone: (808) 932-2900

Idaho Department of Lands
https://www.idl.idaho.gov/fire-management/
Phone: (208) 334-0200

Montana Department of Natural Resources & Conservation
https://dnrc.mt.gov/forestry/Wildfire/
Phone: (406) 542-4300

Nevada Division of Forestry
https://forestry.nv.gov/wildland-fire-management
Phone: (775) 684-2500

New Mexico Forestry Division
https://www.emnrd.nm.gov/sfd/
Phone: (505) 476-9600

Oregon Department of Forestry
https://www.oregon.gov/odf/fire/pages/default.aspx

Phone: (503) 945-7200

Texas A&M Forest Service
https://tfsweb.tamu.edu/
Phone: (937) 839-8837 (text only)

Utah Division of Forestry, Fire, and State Lands
https://ffsl.utah.gov/fire/
Phone: (801) 538-5418

Washington Department of Natural Resources
https://www.dnr.wa.gov/programs-and-services/wildfire-resources
Phone: (360) 902-1300

Wyoming Forestry Division
https://wsfd.wyo.gov/fire-management
Phone: (307) 777-7586

State Offices Responsible for Disaster Operations

Alaska Division of Homeland Security and Emergency Management
https://ready.alaska.gov/
Phone: (907) 428-7000

Arizona Division of Emergency Management
https://dema.az.gov/emergency-management
Phone: (602) 267-2700

California Office of Emergency Services
https://www.caloes.ca.gov/
Phone: (916) 845-8510

Colorado Division of Homeland Security and Emergency Management
https://dhsem.colorado.gov/
Phone: (720) 852-6600

Hawai'i Emergency Management Agency
https://dod.hawaii.gov/hiema/
Phone: (808) 733-4300

Idaho Office of Emergency Management
https://ioem.idaho.gov/

Phone: (208) 258-6500

Montana Disaster & Emergency Services
https://des.mt.gov/
Phone: (406) 324-4777

Nevada Division of Emergency Management/Homeland Security
https://dem.nv.gov/
Phone: (775) 687-0301

New Mexico Department of Homeland Security & Emergency Management
https://www.dhsem.nm.gov/
Phone: (505) 476-9600

Oregon Department of Emergency Management
https://www.oregon.gov/oem/pages/default.aspx
Phone: (503) 378-2911

Texas Division of Emergency Management
https://www.tdem.texas.gov/
Phone: (512) 424-2208

Utah Division of Emergency Management
https://dem.utah.gov/
Phone: (801) 538-3400

Washington
https://mil.wa.gov/emergency-management-division
Phone: (208) 258-6500

Wyoming Office of Homeland Security
https://hls.wyo.gov/
(307) 777-4900

In Memoriam: Steven Swain

Our colleague, University of California Cooperative Extension Advisor Steven Swain passed suddenly during the preparation of this manuscript. Steven's extension program centered on landscaping in fire-prone areas. The early stages of this project benefited from discussions with Steven and from his help in setting up interviews with experts and his work that we cite in the References. We will dearly miss him, his expertise, and critical eye.

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- Nancy Sappington, Inland Representative, California Urban Forests Council
- Chris Litchy, City Forester - Louisville, Colorado
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Introduction

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