Research Literature Review of Plant Flammability Testing, Fire-Resistant Plant Lists and Relevance of a Plant Flammability Key for Ornamental Landscape Plants in the Western States

Final Report

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Introduction

Many California residents live under a continual threat of wildfire. Ten of the State's top 20 most damaging fires occurred in the last 20 years with 11,115 structures and 38 lives lost. Of the top 20 largest California wildfires, 70 percent were in the last 20 years having burned a total of more than 2,600,000 acres (http://www.fire.ca.gov/, accessed December 2015). Moritz *et al.* (2014) report there has been over 60% expansion of the widland-urban interface (WUI; area in which communities intermix with or abut natural vegetation) in the western United States and "the WUI in this region also predominantly occurs where fire severities are high" (p. 61). Over the past 15 years, defensible space has been a recommended strategy to increase chance of the home surviving a wildfire (e.g. Bell *et al.* 2007, White & Zipperer 2010, http://www.firewise.org, accessed October 2015).

> Defensible space can be described as the area or space around homes and buildings where vegetation and other factors are managed for a specific distance to keep fire at a point where it cannot ignite the structure. This managed area or space literally provides a "defense" against the fire to reduce the structure's exposure to flame radiation (heat), flame impingement, and firebrands (burning embers), which are considered the three principal factors in igniting a fire. (Bell *et al.* 2007)

Although there are several considerations and strategies involved to create a proper defensible space (e.g. removing dead biomass, horizontal and vertical spacing, ignition resistant outdoor structures), incorporating plants with low flammable properties is often recommended (e.g. University of California Forest Products Lab [UCFPL], 1997; Nader, Nakamura, De Lasaux, Quarles, & Valachovic, 2007). To give property owners and landscape professionals guidance and for regulatory purposes, fire-resistant plant lists are frequently provided. However, these plant lists are often based on anecdotal information rather than scientific data or may only consider a few characteristics for ignition-resistant plants. (White & Zipperer, 2010; UCFPL, 1997).

Standardized methods for determining plant flammability and standardized criteria for landscaping plant recommendations would support greater consistency and accuracy of fire-resistant plant lists. Such standardization would be helpful when researching new plant varieties for fire-resistance, developing landscaping schemes for residents in the WUI and for expanding plant categorizations or list combinations (e.g. fire resistance and drought tolerance) (http://ucanr.edu/sites/WUCOLS/, accessed March 2014). Resources on horticulture species that provide clear and relevant fire-resistant classifications, will assist residents reduce their wildfire risks while achieving other

landscaping goals (e.g. water conservation, energy conservation, and wildlife habitat preservation) (Behm *et al.* 2004*a*).

In this paper we review research over the past 20 years on plant flammability, flammability testing and plant flammability ratings with special focus on those relevant to ornamental horticulture and home landscaping in California. We also discuss lists, which offer plant recommendations for defensible space objectives and provide findings from a review and compare exercise for existing plant lists in California. Finally, we discuss the lack of standardization in this arena and share concluding thoughts on the research and ornamental landscaping industry needs in California relating to plant flammability.

Plant Flammability and Testing

Plant flammability and testing protocols to support fire resistant landscaping recommendations has been ongoing in California since the 1950's (Weise, White, Beall, & Etlinger, 2005, Ching & Stewart, 1962). The literature on these topics was thoroughly examined and discussed by White and Zipperer (2010). Although there are numerous studies on vegetative fuels and flammability, most pertain to wildland vegetation, were conducted in regions other than California or the western United States and/or tested plant specimen not necessarily relevant to California ornamental landscaping (e.g. Bartoli, Simeoni, Biteau, Torero, & Santoni, 2011; Behm, Duryea, Long, & Zipperer, 2004b; Moritz, 2003; Zhang, Zhang, & Zhou, 2011). Within the last 20 years, only three scientific studies were found that examine flammability relating specifically to ornamental landscape plants in California. The University of California Forest Products Lab (UCFPL) (1997) prepared an internal report for the California Department of Forestry and Fire Protection that also addresses ornamental horticulture flammability and plant list issues. This report included a curated list of ornamental landscape plants for fire-resistant landscaping in California based on their review. In their study to develop a plant flammability testing protocol, Etlinger and Beall (2004) discuss prior research on plant flammability, plant rankings and plant lists for fire-resistant landscaping. Weise *et al.* (2005) provide a review of literature as an introduction to their research conducted on seasonal plant flammability of selected ornamental landscape specimen in California using a particular testing method, the cone calorimeter.

Plant Flammability

In their review, White and Zipperer (2010) addressed defining flammability of plant material, factors that effect flammability, flammability testing methods used and plant lists and criteria used for list development. Other reviews had similar discussions to a lesser degree of detail and/or in support of the specific research/project objectives (UCFPL 1997; Etlinger & Beall 2004; Weise *et al.* 2005). Regardless of detail, all recognize the complexity and controversy of plant flammability and lack of standardized methodologies to determine plant flammability.

Defining the term*, flammability*, is key (White & Zipperer 2010, p. 214) before addressing testing methodologies and ratings. White and Zipperer's (2010) review identified the components of flammability as ignition (heat source and time to ignition), combustibility (time of combustion after ignition), consumability (amount of plant material consumed by combustion) and sustainability (degree of combustion sustained once ignited, with and without continued heat source). They offered a variety of potential responses, which might be tested and measured for each of these four components and produced a table illustrating these suggestions [Table 2](White & Zipperer, p. 215). Suggested ideas relate to time, temperature, mass and elements. Determining plant flammability is complex due to the multiple perspectives that may be tested and the interdependence between the components (e.g. combustibility, consumability and sustainability are dependent on ignitability) (White & Zipperer, 2010, p. 215). Applying test results may be further challenging because they could be influenced by the type of test methods utilized (White & Zipperer, 2010, p. 215; Etlinger & Beall, 2004).

White and Zipperer (2010) classified plant flammability studies into two categories, "(1) physical structure and components (e.g. branch size, leaf size and shape and retention of dead material); and (2) physiological or cellular elements (e.g. volatile oils and resins, moisture content, mineral content, lignin and waxes)" (p. 215).

Moisture content was found to be a common and key influence to flammability by several researchers (e.g. White & Zipperer, 2010; Etlinger & Beall, 2004). This leads to questions regarding seasonal impacts, which have been addressed in a few studies (e.g. Alessio *et al.* 2008; Weise *et al.,* 2004) with results verifying that for most test samples, seasonality influences moisture content levels, thus influences plant physical and physiological characteristics and plant flammability. There are conflicting views regarding the influence of species' mineral content on flammability (e.g. Gill & Moore, 1996; Etlinger & Beall, 2004; Dimitrakopoulos & Panov, 2001; Ching & Stewart, 1962).

Plant species geometry has significant impact on flammability (White & Zipperer, 2010; Weise *et al.,* 2005; Doran, Randall, & Long, 2004). This includes the structure of the plant itself, as well as location and setting of the plant within the managed landscape. Surface mass of a plant is a key influence on its flammability. Plant features to consider include branching pattern, foliage size and density, litter production and retention and evergreen v. deciduous (White & Zipperer 2010, p. 215). Where a plant is situated in relation to other combustible objects within the landscape (wildland and landscape vegetation and home and garden structures) as well as plant condition (health and maintenance) also influences flammability. Just as there are multiple flammable component perspectives that may be tested, there are a vast amount of flammability influences to be considered. In addition, strategies used by residents and landscapers to alter influences to flammability (e.g. pruning and plant establishment methods) and the impacts to plant vigor v. flammability and other landscaping objectives need to be addressed. All these factors greatly add to the complexity of plant flammable testing for classifying plant desirability in fire resistant landscaping.

Flammability Testing Methods

The variety of possible scenarios and components to be considered for plant flammability testing influences the types of testing methods, equipment and measurement options. In their review, White and Zipperer (2010) discuss all three issues with a focus on six testing techniques: "thermal analysis, oxygen bomb calorimetry, ignition tests and three types of oxygen consumption calorimetry – microscale combustion calorimetry, cone calorimetry and the whole-plant calorimetry" (p. 217). However, they first raise the question about need for specific plant species testing.

> There are several issues to consider when it comes to measuring flammability of vegetation. First, does the species need to be tested? If heat yield is considered independent of species and flammability is considered largely a function of the density of the plant mass and other physical characteristics of the plant, then visual observations of the physical characteristic might be sufficient to evaluate the 'flammability' of a particular plant. (White & Zipperer, 2010, p. 216)

The plant flammability test techniques White and Zipperer (2010) discuss in detail are adaptations of flammability and/or ignition tests standardized for testing other products such as building materials, not vegetation. They analyze advantages and disadvantages of each but no single technique is proposed as being more favorable overall. Several scientists make note that when considering standardization of a flammability test protocol for vegetation, there also needs to be a method for relating test results to field studies (observations and correlations) (White & Zipperer, 2010; Weise *et al.,* 2005; Fernandes and Cruz, 2012). White and Zipperer (2010) also report that the ATSM International Committee is "working on the classification of vegetation for use in the wildland-urban interface" (p. 225). Current status of this work was not discovered for this review. Plant flammability is a multifaceted issue and there is considerable controversy over plant flammability testing (White & Zipperer, 2010; Fernandes & Cruz, 2012; Etlinger & Beall, 2004) making the prospect of standardizing testing protocols for ornamental landscaping plant flammability appear daunting.

Flammability of products other than plants that may be part of the home landscape environment should also be considered. Ignition resistant building materials and construction design for outdoor structures have been well defined and classified (Cal Fire, 2008). In recent years, varieties of mulch have been tested for flammability and rating (e.g. Quarles & Smith, 2008; Rogstad, DeGomez, Hayes, Schalau, & Kelly, 2007). Although recommendations are made based on research, mulch studies must contend with a similar lack of standardized flammability testing and classification issues as do plant flammability studies.

Plant Lists

Defensible space recommendations generally include several recommended practices relating to plant flammability. These include the use of fire-resistant plants, consideration of plant placement in relation to the house and other vegetation, modifying plant vegetation mass and geometry and maintaining healthy plant condition. Due to lack of standardized plant flammability testing or criteria for rating, there is no industry–wide flammability rating assignment for ornamental landscaping plants. However, plant lists have been developed to meet local residents requests for plant selection guidance and/or regulatory agencies' permitting and enforcement needs. Even though most fire resistant or plant flammability rating lists often include some type of warning statement that 'all plants can burn under extreme fire conditions', they can be misleading for a number of reasons. White and Zipperer (2010) address the functionality and accuracy of plant lists. Problems with plant lists may include lack of definitions, criteria or methods used, sources or options to request the use of non-listed plants (pp. 224-225). For those plant lists, which do provide criteria for species inclusion, varying methods are used v. a standardized system. Some are based on plant ignitability while others use plant characteristics as they relate to combustion and others are determined by the frequency a plant species is listed on other fire resistant plant lists (UCFPL, 1997; White & Zipperer, 2010). Lack of standardization also contributes to conflicting recommendations and inconsistent references to plant names between lists. Some use different groupings or common names while others use names of genus or species only and still others list sub-species and/or cultivar names. This is an important distinction. "Long *et al.* (2006) observed that species in the same genus do not always have the same flammability characteristics" (White & Zipperer, 2010, p. 224). There is also a risk of lists being misused if homeowners apply them in regions or climate areas other than intended location or by not considering other factors such as seasonal influences.

One solution is to develop plant lists based on a decision key relating to plant characteristics and flammability influences. White and Zipperer (2010) share a listing of plant characteristics criteria for determining the degree of plant favorability relating to fire resistance [Table 3] (p. 216). Behm *et al.* (2004*a*) developed such a protocol, in which users are lead through a consideration of plant characteristics to determine whether a plant is of low, medium or high flammability. The advantage of this type of tool is the standardized basis it provides, which may then be used to develop flammability ratings for plants in specific growing zones, seasons or in consideration of other significant environmental factors. However, one would need to have plant biology expertise to assess each plant with best accuracy. Until there are standardized methods for measuring each plant characteristic in the key, results remain subjective. Additionally, White and Zipperer (2010) point out that the vast number of plant species and varieties to be assessed would be time consuming and costly (p. 225).

California Fire-Resistant Plant List Database and Source Analysis

As highlighted in the previous section a standardized test or decision key for determining levels of plant ignition and flammability is lacking in California as well as the western United States region. However, community wildfire educators (e.g. Fire Safe Councils), gardening organizations (e.g. Cooperative Extension Master Gardeners), fire authorities and land use and development agencies are frequently asked for information on recommended plants for landscaping around the home. For properties in fire hazard severity zones, as designated by State and County officials (http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones, accessed November 2015), maintaining adequate defensible space is mandatory (CA Public Resource Code 4291). Whether for personal interest or as a mandatory action, information for selecting the best plants to meet landscaping objectives is being sought out and found.

In researching preexisting fire resistant plant lists in California 53 plant lists based on 85 sources, with 50 plant trait codes were located. From the 53 lists identified, 2,572 plant records were placed into a cumulative database listing their scientific names and common names when provided (see Appendix I, California Fire-Resistant Plant Lists Database: accompanying Excel file).. The database also denotes key characteristics provided by the list the plants were retrieved from and we added a field to note if the plant is a native or non-native plant. Plant list sources have been assigned a code number and are listed in the database to indicate which source(s) a specific plant is featured. Plant trait codes, when provided from the source, are also noted in the database. The frequency in which individual plant species were recommended was not analyzed as part of this research as was done previously in the University of California Forest Products Lab review (UCFPL, 1997).

Plant lists are often developed for other landscaping objectives (e.g. drought tolerance, wildlife habitat). Expanding information on these other plant lists to include well-evaluated fire resistance recommendations might be helpful to identify potential conflicts between varying landscaping goals. (Behm *et al.,* 2004). Because California is under extreme drought conditions, plants on this cumulative fire-resistant list were compared to the Water Use Classification of Landscape Species list (WUCOLS IV) (http://ucanr.edu/sites/WUCOLS/, accessed November 2015) and the Arboretum All Stars plant list from the University of California, Davis (http://arboretum.ucdavis.edu /arboretum_all_stars.aspx, accessed December 2015). Both of these lists are widely promoted throughout the state as providing guidance regarding landscaping plants and water efficiency.

Portions of the 2572 plants in the cumulative database were cross-referenced to those appearing on the WUCOLS IV list. The majority of those examined were included on both the cumulative fire-resistant plant list and the WUCOLS IV list with ~14% of the test sample not featured on the WUCOLS IV list. Of the 100 species on the University of California Davis Arboretum All-Stars list, 55 of the species were represented in the

cumulative fire-resistant plant database while 45 were not. With moisture content a key plant characteristic in determining flammability, it is evident some of the plants currently being recommended for use as fire resistant landscaping plants in California have not been evaluated for their combustion characteristics. Common names were used for numerous plant species, without providing the scientific name. Because some unrelated plants have the same common name it was difficult to determine which exact plant species were being evaluated. Most fire resistant plant recommendation lists failed to provide adequate data on criteria used or source materials. Overall, the data from these 53 lists is unreliable, lacks scientific definitions, and lacks an overall consistency needed to adequately cross reference with other plant databases. More positively, it was noted that defensible space or fire safety information resources, which include plant lists also stress plant placement and maintenance as a key requirement (White & Zipperer, 2010).

Concluding Comments

As Californian residents become more aware of the benefits and/or requirements of defensible space and as long as defensible space strategies include planting and maintenance recommendations, lists for fire resistant plants will be needed. Our accumulation and review of identified fire resistant plant lists in California appear to support this. It's been nearly 20 years that defensible space strategies have been recommended to increase home survival from wildfire and nearly 20 years since the UCFPL review was conducted (UCFPL, 1997). In that timeframe, the number of readily found fire resistant plant lists in California have more than doubled. Regardless of how one is positively motivated to take action towards creating defensible space (e.g. news of ongoing wildfire events in the state, wildfire safety outreach and education or by enforcement), the science community, fire authorities and the home garden and landscaping industry should be ready to provide reliable and accurate ornamental horticulture and landscaping plant guidance for defensible space.

Consensus driven standardization needs to be determined for key plant flammability traits, testing protocols and criteria and/or methods for fire resistant plant list development. However, before this can be accomplished, the gaps in research relating to all facets of evaluating flammability of ornamental landscape plant species need to be addressed. We recognize that this report does not present an exhaustive list of all the literature available for these subjects or every fire resistant plant list currently available in California; however, from this review, we have concluded that horticultural plant flammability testing for California is lacking. Fire resistant plants are typically defined as having low ignition and flammability characteristics, such as drought-tolerance and low-resinous properties (UCFPL, 1997; White & Zipperer, 2010) but reviews of literature reveal there are other plant traits and influences to flammability that might be or should be considered as having more impact. With so many variables, subscribing to standardized test protocols and methods for delivering test results for public application is difficult.

California is a diverse and complex region from several perspectives (e.g. environmentally, geographically, economically, ecologically, socially), which contributes to the challenges of developing consensus between multi-disciplinary stakeholder groups. However, in regards to fire hazard reduction and environmental resource efforts in California, general agreement and collaboration have been proven to be attainable (e.g. community wildfire protection plans; building design and construction materials for fire hazard areas; watershed authorities' projects; development and adoption of the WUCOLS list). Until research is conducted and consensus for standardization is reached, lead stakeholder organizations should, at the very least, encourage the inclusion of more transparent and thorough information regarding plant list criteria and sources (White & Zipperer, p.. 225). Developing regional landscaping guides v. only lists might also be encouraged. Radtke's *Homeowner's Guide to Fire and Watershed Management in the Chaparral/Urban Interface* and the *Home Landscaping Guide for Lake Tahoe and Vicinity* published by the University of Nevada Cooperative Extension (UNCE) provide us examples of addressing multiple local environmental and safety issues, while delivering instruction on best management practices that meet critical landscaping objectives (Radtke, 2004; UNCE, 2009). Additionally, for fire safety educational materials containing a plant list, it should be clearly stated that any recommendations given for plant species to reduce fire hazards, are not "based on scientific trials" (UNCE, 2009, p. 84).

There are no 'fireproof' plants. Any plant will burn when exposed to an extreme wind-driven wildfire. However, it has been proven that actions taken by individual homeowners can potentially reduce the vulnerability of their home to wildfire, including creating an area of defensible space (Bell *et al.* 2007). To do so, many will require guidance on best management practices, plants and products. Lead stakeholders from multiple disciplines will need to work together to determine what those best management tactics are. Standardized plant flammability evaluation and translation are complex, challenging and, many times, controversial issues. However, when one considers the opportunities and benefits available to all – horticulture and landscape professionals, regulatory organizations, and residents – coupled with the potential for saving lives and property - is it not worth a concerted effort to find standardized solutions?

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Randall, C. (n.d.). Fire in the Wildland-Urban Interface: Understanding Fire Behavior. University of Florida, Institute of Food and Agricultural Services, Florida Cooperative Extension Service (Circular 1432). Gainesville, FL. 8p.

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Yassemi S, S. Dragicevic, and M. Schmidt. (2008). Design and implementation of an integrated GIS-based cellular automata model to characterize forest fire behaviour. Ecol Modell 210(1–2), pp. 71–84.

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Appendix I: California Fire-Resistant Plant Lists Database

See accompanying Excel file “Appx I_California Fire-Resistant Plant Lists Database.xxlsx”

Appendix II:
California Fire-Resistant Plant Lists Database Sources

Publication Citation
Beatty, R. (1991). Designing Gardens for Fire Safety. Berkeley, CA: Department of Landscape Architecture, University of California, Berkeley. Notes: Rates plants fire retardance based on the following: Broad-leafed plants tend to be more fire retardant than those with needle-like or very fine leaves; dense compact forms and low prostrate plants are more effective at retarding fire than more open or upright plants.
Berkeley Horticulture Nursery. (1991). Fire Resistant Plants. Berkeley, CA: Berkeley Horticulture Nursery. Notes: Defines fire resistant as being able to withstand high temperatures for prolonged periods without igniting and does not readily support open flames.
Bowker, M. (1995). High Danger this Year: Preventing the Firestorm. Motorland/CSAA. Notes: Considers that fire retardant plants share the following characteristics: grow close to the ground, have a low sap or resin content, grow without accumulating dead matter, are easily maintained and pruned, and are often drought tolerant.
Brende and Shapiro. (n.d.). Tree And Shrub Care List of More and Less Fire Prone Plants. Berkeley, CA: Brende and Shapiro Tree and Shrub Care. Notes: This reference suggests that any plant can be fire-prone if not properly maintained. Arrangement, spacing, density and dryness of the vegetation is probably more crucial than what species are planted.
Brenzel, K.N. (1995). Sunset Western Garden Book. Menlo Park, CA: Sunset Publishing Corporation. Notes: This reference was used to gather mature plant characterisitics and information on drought tolerance, climate zones and erosion control. Drought tolerance is defined as requiring little or no dry season water. Climate zones are defined for the western states, each species is listed with a list of zones that it will tolerate. The zone map for this publication was generated from Sunset Western Garden Book's climate zone information. Note is made if a plant is considered to be useful in erosion control, but further explanation is not offered.
Brush Fire Safety Committee. (n.d.). Make it Safe to Live in the Hills: Fire Resistant Plants. Los Angeles, CA: Brush Fire Safety Committte. Notes: This reference explains that some plants are relatively non-flammable because they are able to withstand high temperatures for prolonged periods without igniting and do not readily support open flames.

Publication Citation
California Department of Forestry. (n.d.). Fire Safe, California! Sacramento, CA: California Department of Forestry and Fire Protection. Notes: Classifies fire retardant plants as those that are hardy succulents and flat ground covering plants that are kept groomed and free of dry leaves.
California Department of Forestry. (n.d.). Fire Safe: Inside and Out. California Department of Forestry Publication. Notes: Defines fire retardant plants as those easily maintained and pruned, drought tolerant in some cases, can be grown without accumulating dead branches, needles or leaves, have a low sap or resin content, and grow close to the ground.
California Department of Forestry and Fire Protection. (n.d.). Fire-Safe Demonstration Garden. Santa Clara Ranger Unit. Notes: A list of plants is offered without definition of fire retardance.
California State Fire Marshal Journal. (1989). Landscape for Home Fire Safety, CSFM Journal, No. 2. Notes: Defines flammable vegetation as plants containing volatile resins, oils, gums and terpenes, and plants that have accumulations of dead twigs and branches on mature live plants. This reference also defines fire retardant plants as those with a high moisture content, high in ash, well irrigated, free of dead matter, and low volume shrubs.
California's I-Zones. (1996). Sacramento, CA: CFESTES Book Store.
City of Los Angeles, Department of Arboreta & Botanic Gardens (n.d.). Green Belts for Brush Fire Protection and Soil Erosion Control in Hillside Residential Areas. Arcadia, CA: City of Los Angeles, Dept. of Arboreta & Botanic Gardens. Notes: The term fire retardant is used to describe plants inherently less flammable than others. Rates plants as HIGH(greatest fire retardance) low-growing succulent plants with thick, fleshy leaves and/or stems. MODERATE(moderate fire retardance) low-growing herbaceous perennials and sub-shrubs not distinctly succulent. LOW(low fire retardance) low-growing shrubs and sub-shrubs with rather dry, leathery or rigid leaves and branches.
City of San Carlos (1996). Fire Resistive Plants. The City of San Carlos, CA. Notes: Gives a list of herbaceous perennials, succulents, trees and groundcovers considered to be fire retardant. No definition offered.

Publication Citation
City of Santa Barbara Fire Department. (n.d.). City of Santa Barbara Firescapes Demonstration Garden. Santa Barbara, CA: City of Santa Barbara Fire Department. Notes: Defines fire resistant plants as those plants that can regenerate growth, despite burning and fire retardant plants as those which are less flammable than others.
Coate, B. (1990). Water-Conserving Plants and Landscapes for the Bay Area. East Bay Municipal Utility District. Only offers a list of plants considered to be more fire retardant than most plants. No criteria offered.
Costello, L.R. and K.A. Jones. (1994). Water Use Classification of Landscape Species: A Guide to the Water Needs of Landscape Plants. Half Moon Bay, CA: University of California Cooperative Extension, San Mateo/San Francisco Counties. Notes: Provides recommended watering for over 1200 landscapes plants based on 6 climate regions of California.
County of Los Angeles Arboreta & Botanical Gardens. (1970). Fire Retardant Plants for Hillside Areas. Los Angeles, CA: County of Los Angeles Arboreta and Botanical Gardens. Notes: Bases fire retardance on relatively high moisture content and prostrate or creeping growth characteristics. Rated as follows: HIGH - succulents (90-95% moisture content). MODERATE - non-succulents(80-95% MC) or 70-80% MC. LOW - 60-75% MC.
Crampton, B. (1974). Grasses in California California Natural History Guides. Berkeley Los Angeles London: University of California Press. 33p.
Curran, C. W. (1978). Wildfire Hazard Management in the Urban/Wildland Interface in Southern Oregon. Prepared for the Rogue River National Forest, USDA Forest Service. Southern Oregon State College. 55p.

Publication Citation
D'Alcamo, S. and C.L. Rice. (n.d.). Appropriate Landscaping Plants to Reduce Fire Hazard. East Bay Chapter, California Native Plant Society. Notes: Supplies a list of California native plants to be used to establish a more fire retardant environment because of one or more of the following characteristics: high mineral content, low fuel volume, high moisture content.
Deering, R.B. (1955). A Study of Drought Resistant Ornamental Plants. Davis, CA: University of California, Davis. Notes: Offers plant lists only with no definition of drought or drought tolerance.
Department of Water Resources and The Resources Agency. (1979). Bulletin 209-Plants for California Landscapes: A Catalog of Drought Tolerant Plants. State of California, The Resources Agency, Department of Water Resources. Notes: Offers a list of recommended plants without explanation or definition.
East Bay Municipal Utility District Water Conservation Division. (1995). Firescape: Landscaping to Reduce Fire Hazard. Community Services Department and EBMUD Board of Directors. Notes: Defines flammable or hazardous vegetation as any vegetation, including ornamental, that either by it's intrinsic characteristics, placement, or lack of care is easy to ignite, spreads fire rapidly, produces high heat, or creates fires that are difficult to suppress. Defines a fire resistant plant as less likely to burn, grows close to the ground and takes longer to ignite.
Edmuson, G.C. (1976). Plant Materials Study: A Search for Drought-Tolerant Plant Materials for Erosion Control, Revegetation and Landscaping along California Highways: Final Report. Davis, CA: U.S Dept. of Agriculture, Soil Conservation Service. Notes: Offers plant lists only with no definition of drought or drought tolerance.
Ellefson, C.L., T.L. Stephens, and D. Welsh, Ph.D. (1992). Xeriscape Gardening New York, NY: Macmillian Publishing Company. Notes: Offers plant lists only with no definition of drought or drought tolerance.
Flora & Forest Plants for Firescaping in Western Nevada County. (n.d.). Grass Valley, CA.

Publication Citation
Gaidula, Peter. (1976). Wildland Fuel Management Guidelines for the CA State Park System. California Department of Parks and Recreation. Notes: This reference does not offer a definition of fire retardance with respect to plants, however it offers suggestions of certain plant characteristics to keep in mind when clearing brush to reduce fire hazard: plant vigor, poisonous plants, effects of plants on soils, value for wildlife food and cover, aesthetic values, and relative flammability.
Gilmer, Maureen. (1994). California Wildfire Landscaping. Dallas TX: Taylor Publishing Co.
Gilmer, Maureen. (1994). California Wildfire Landscaping. Dallas, TX: Taylor Publishing Company. Notes: Plants are grouped as the most fire retardant if they retain high levels of moisture in their leaves and stems; these plants are mostly succulents and have low-growth habits. Moderate fire retardance is given to plants that are non-succulent with leaves that retain a high moisture content. Plants with low fire retardance are those with leathery and dry leaves.
Greenlee, J. (1982). The Encyclopedia of Ornamental Grasses. Emmaus PA: Rodale Press.
Grounds Maintenance. (1988). Flirting With Fire. Notes: Erosion control was rated as : LOW - 30% or less. MODERATE - 60%. HIGH - 60% or steeper.
Hagen, Bruce W. (n.d.). Trees & Shrubs Generally Recognized To Be Fire Resistant. Santa Rosa, CA: CA Department of Forestry & Fire Protection Coast-Cascade Region.
Harlass, Sherry. (1993). How to Firescape to Reduce the Fire Hazard. Notes: Defines a fire retardant plant as one that burns slowly.

Publication Citation
Hickman, James C. (1993). The Jepson Manual: Higher Plants of California. Berkeley and Los Angeles, CA: University of California Press. Notes: Provides information on plant classification and mature plant characteristics.
International Erosion Control Association. (1977). Proceedings of International Erosion Control Association, 8th Conference. Seattle, WA: The Association. Notes: Offers species recommended for erosion control without providing a rating or a definition.
Landscape for Fire Protection. (n.d.). Calaveras County University of California Cooperative Extension. Retrieved from www.cecalaveras.ucdavis.edu/land.htm.
Landscapring Your Home in a Fire Area. (1993) Las Pilitas. Retrieved from www.laspilitas.com/fire.htm.
LeMay, David B and W.G. Mitchell.(1978). Recommended Low-Fuel Volume Species for San Luis Obispo County. San Luis Obispo, CA: Central Coast Fire Prevention Association. Notes: Rates species of plants as either having HIGH/MODERATE or LOW fire retardance; no explanation or definition of terms.
Lenz, Lee W. and J. Dourley. (1981). California Native Trees And Shrubs. Claremont, CA: Rancho Santa Ana Botanic Garden. Notes: Offers plant lists only with no definition of drought or drought tolerance.
Los Angeles County Fire Zones regulation approved plant list. (n.d.).
Maire, Richard G. (1962). Landscape to Prevent Fire. University of California Agricultural Extension Service. Notes: Fire retardance is not defined in this publication.
Maire, Richard G. and J.R. Goodin. (1969). Landscape for Fire Protection. University of California Agricultural Extension Service. Notes: Refers to Los Angeles Arboretum research. Makes clear the point that the term "fire resistant" is used, but that there is not a plant that exists that will not burn given the right conditions. Also suggests that well-maintained and well-watered plants will not burn as readily as those left dry and unmaintained.

Publication Citation
Martin-Richardson, B. (n.d.). San Luis Obispo County Fire Department: A Homeowner's Guide to Fire Resistant Plants for the San Luis Obispo Area. San Luis Obispo, CA: CA Dept. of Forestry & Fire Protection and The San Luis Obispo County Fire Dept. Notes: Lists fire retardant plants for the San Luis Obispo area; no criteria offered.
Miller, M. (1994). Fuels In: Fire Effects Guide. National Wildfire Coordinating Group. PMS 481. pp III: 1-27.
Moritz, R. (1995). Pyrophytic vs. Fire Resistant Plants. San Rafael Fire Department, FireSafe Marin. Notes: Defines fire resistant as: most broad leaf deciduous trees; leaves tend to be supple, moist and easily crushed; trees tend to be clean, not bushy, and have little deadwood; shrubs are low-growing (<2') with minimal dead material; tall shrubs are clean, not bushy; sap is water-like and typically does not have a strong odor; and plants that will not sustain a flame when ignition is attempted.
Moritz, R. and S. Pavel. (1996). Pyrophytic vs. Fire Resistant Plants University of California Cooperative Extension HortScript February No. 18. Notes: Defines fire resistant as: most broad leaf deciduous trees; leaves tend to be supple, moist and easily crushed; trees tend to be clean, not bushy, and have little deadwood; shrubs are low-growing (<2') with minimal dead material; tall shrubs are clean, not bushy; sap is water-like and typically does not have a strong odor; and plants that will not sustain a flame when ignition is attempted.
USDA Natural Resources Conservation Service. (1997). National Range and Pasture Handbook. USDA Natural Resources Conservation Service. p 411.
Needham, J. (1996). Tree Notes: Fire Safe Landscaping #17. Ukiah, CA: CA Department of Forestry & Fire Protection CDF Resource Management.
Nehrling, Arno and I. Nehrling. (1975). Easy Gardening with Drought-Resistant Plants. New York: Dover Publications, Inc. Notes: Defines drought as less than 1" of rainfall/week or </= 20" for growing season. Plants considered drought tolerant will survive under these conditions.

Publication Citation
Nevada County UC Cooperative Extension Master Gardeners. (n.d.). Western Nevada County Gardening Guide. Grass Valley.
Nord, E. C. and C. M. Countryman. (1972). Fire Relations In: Wildland Shrubs-Their Biology and Utilization. USDA Forest Service General Technical Report INT-1. pp 88-97.
Northeast Ridge. (1990). Southwest Diversified Final Habitat Fire Buffer Program. Northeast Ridge, Brisbane, CA: Southwest Diversified, INC. Notes: This reference states that all plants will burn under the worst conditions, but some are more suitable for fire-prone areas because of one or more of the following characteristics: high mineral content, high moisture content, low volume of fuel.
Orange County Wildland/Urban Interface Task Force Subcommittee on Fuel Modification. (1994). Report of the Wildland/Urban Interface Task Force: Attachment C. Orange County Fire Department. Notes: Defines plants that are not suitable for fire prone areas as possessing some or all of the following characteristics: are known to be especially combustible; have dry or deciduous foliage during part of the year; develop deciduous or shaggy bark; develop dry or dead undergrowth.
Orinda Fire Protection District (n.d.). Protect Your Home: Landsape For Fire Protection. Orinda, CA: Orinda Fire Protection District. Notes: Offers a few fire retardant landscape plants with no criteria for classifying them as such.
Pavlik, B., P. Muick, *et al.* (1991). Oaks of California. Los Olivos, CA: Chronicle Books.
Perry, Bob. (1992). Landscape Plants for Western Regions: An Illustrated Guide to Plants for Water Conservation. Claremont, CA : Land Design Publishing. Notes: Categorizes landscape plants based on the water needs. Also provides information on the mature characteristics of plants.
Perry, Bob. (1989). Trees and Shrubs for Dry California Landscapes. Claremont, CA: Land Design Publishing. Notes: Fire retardance was rated as follows: LOW - high fire hazard species and undesirable domestic plant. MODERATE - acceptable domestic plant that requires ample amounts of water for best performance and valuable watershed species that should be thinned to reduce foliage mass, and be retained in limited numbers to prevent high intensity fires. HIGH - low-growing and high fire retarding plants and low fuel volume native and introduced species.

Publication Citation
Phoenix Team of the Environmental Action Committee of West Marin. (1996). After the Vision Fire. Notes: This reference provides a list of suggested fire retardant plants; fire retardant is not defined.
The California Chaparral Institute. (n.d.). Protecting Your Home from Fire. The California Chaparral Institute. Retrieved from www.californiachaparral.com/bprotectingyourhome.html.
University of California Cooperative Extension. (1996). Pyrophytic v. Fire Resistant Plants. HortScript No 18. University of California Cooperative Extension. 1996. 9p.
Radtke, Klaus W.H. (1993). A Homeowner's Guide to Fire and Watershed Management at the Chaparral/Urban Interface. Los Angeles, CA: County of Los Angeles, CA. Notes: Fire retardance was rated as follows: HIGH - very highly fire retardant. MODERATE - medium fire retardance. LOW - low very retardance.
Radtke, Klaus W.H. (n.d.). Living More Safely in the Chaparral/Urban Interface U.S. Dept. of Agriculture, Pacific Southwest Forest and Range Experimant Station, Gen.Technical Report PSW-67.
Red Shingle & Handsplit Shake Bureau. (1988). The Green Fireman Plan levue, WA: Red Cedar Shingle & Handsplit Shake Bureau. Notes: This references bases its recommendations of fire retardance on the following: plants with a high moisture content, low volume shrubs, and (up to a point) plants with a high ash content.
Resource Management International, Inc. (1988). Windbreaks Demonstration Project: Final Report. Sacramento, CA: The Office of Land Conservation, California Department of Conservation. Notes: Offers plant lists only with no definition of drought or drought tolerance.
Rice, Carol. (1991). Effects of Drought on Landscaping in the Paint Fire. Walnut Creek, CA: Wildland Resource Management. Notes: Lists species with the highest moisture content and therefore probably the most fire retardant. Also lists the driest plants -- these were classified as not being recommended for fire prone areas.
Santa Barbara City Fire Department. (n.d.). Firescape Demonstration Garden. Santa Barbara, CA: Santa Barbara City Fire Department. Notes: This reference offers only a list of suggested fire retardant plants, no criteria are given.

Publication Citation
Schmidt, M.G. (1980). Growing California Native Plants California Natural History Guide. Berkeley, Los Angeles, London: University of California Press. 45p.
Smith, E. and G. Adams. (1991). Incline Village/Crystal Bay Defensible Space Handbook. Reno, NV: University of Nevada Cooperative Extension. Special Publication SP-91-06. 57p.
Smith, E. and S. Sistare. (2005). A Compilation of Good Plant Choices for Nevada's High Fire Hazard Areas. Reno, NV: University of Nevada Cooperative Extension. Special Publication SP-05-16. 6p.
South County Fire. (n.d.). Protecting Your Home From a Brush Fire. South County Fire. Notes: Offers only a list of plants, without explanation or definition.
Southern California Chaparral Field Institute. (n.d.).
Sunset. (1992). Big Job #1: Landscape to Fight the Fire. Lane Magazine and Book Company. Notes: Defines highly flammable plants as those that are accumulators of fuel, not maintained or pruned periodically, and contain high oil, high resin or low moisture in leaves and branches.
Sunset. (1968). Brush Clearing for Fire Safety. Lane Magazine and Book Company. Notes: Describes fire retardant plants as those that are low-growing shrubs, non-native brush, and well maintained and watered brush.
Sunset. (1983). Protecting Your Home Against Brushfire. Lane Publishing Company. Notes: Lists succulents as having the greatest fire retardance. Herbaceous perennials if well-watered and woody groundcovers if well-watered are also highly recommended.
Sunset Western Garden Book. (1995). Menlo Park, CA: Sunset Publishing Corporation.
Tarbes, J.A. (1980). Physical Characteristics of Chamise in Relation to Flammability and Combustibility. San Francisco, CA: San Francisco State University. Notes: Defines fire performance characteristics of chamise species only.
The Staff of the Liberty Hyde Bailey Hortorium, Cornell University. (1976). Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada. New York, NY: MacMillan Publishing Company, Inc. Notes: Provides detailed information on mature plant characteristics.

Publication Citation
The Theodore Payne Foundation for Wildflowers and Native Plants, Inc., (n.d.). Sun Valley, CA. Retrieved from http://www.theodorepayne.org
U.S. Dept. of Agriculture, Soil Conservation Service. (1976). Plant Materials Study. Davis, CA: U.S Dept. of Agriculture, Soil Conservation Service. Notes: Offers information on plants suitable for erosion control.
University of California Forest Products Laboratory. (1997). Defensible Space Landscaping in the Urban/Wildland Interface: A Compilation of Fire Performance Ratings of Residential Landscape Plants. Berkeley, CA: University of California, Berkeley. 173p.
University of California Forest Products Laboratory. (n.d.). Vegetation Guide/Defensible Space Landscaping in the Urban/Wildland Interface: A compilation of fire performance ratings of residential landscape plants. Retrieved from www.prefire.ucfpl.ucop.edu/vegetati.htm
WaterWise Botanicals' Fire Safe List. (n.d.). Metropolitan Water District of Southern California. Notes: San Diego County recommended fire safe plants.

Appendix IV: California Fire-Resistant Plant Lists Trait Codes

Code / Abbreviation	Fire Resistant Trait	List Source
FS	Prefers full sun (6 or more hours)	List 4
FS-PS	Prefers full sun to part shade	List 4
FSh	Prefers full shade (6 or more hours). Avoid afternoon sun.	List 4
VLWU	Very low water-use plant; performs well in dry sites	List 4
LWU	Low water-use plant; performs well with minimal supplemental irrigation	List 4
MWU	Moderate water-use plant; performs well with supplemental irrigation	List 4
BF	Attracts butterflies	List 4
B	Attracts birds	List 4
DR	Deer-resistant	List 4
RG	Performs well in rock gardens	List 4
FS	Full Sun At least 8 hrs. of unobstructed sun daily	List 6
PS	Part Shade 3-5 hrs of sun daily	List 6
<2	Less than 2' tall - Grows 2 feet tall or less	List 6
M	Moderate Water twice a week	List 6
L	Low Water Once a week	List 6
VL	Very Low Water every 7-14 days	List 6
DW(7-10)	Deep water Water trees every 7-10 days	List 6
DW(10-14)	Deep water Water trees every 10-14 days	List 6
EM	Extra maintenance Require more than annual pruning, winter protection, sprayng for pests, etc.	List 6
TS	Temperature Sensitive Zones 5 & 6 require warmer climate; not conducive to outlying valleys and foothills	List 6
Bees	Indicates habitat or food source	List 6
Birds	Indicates habitat or food source	List 6
Butterflies	Indicates habitat or food source	List 6
CF	Cut Flowers Useful as a cut or dried flower in flower arranging	List 6
FC	Fall color eave turn color during the fall months	List 6
UT	Utility tree Height of tree at maturity will not interfere with overhead utility lines	List 6
N	Native Plant is native to Nevada	List 6
>30	Within 30 feet of house - Use only as specimen plant within 30 feet of house; use more extensively outside this area	List 6

Code / Abbreviation	Fire Resistant Trait	List Source
C	Coast	List 20 & 22
D	Desert	List 20 & 22
I	Inland	List 20 & 22
M	Mountain	List 20 & 22
(R)	Riparian- is often used to refer to the vegtation at the sides of a river or creek.	List 20 & 22
UNDERLINE	Underline indicates plants with low to modertate watering requirements	List 31
N	Indicates the plant is native to California	List 31
*	Shade tolerant or prefers shade	List 31
C	Coastal	List 20 & 22
I	Inland, Coastal	List 20 & 22
M	Mountain	List 20 & 22
D	Desert	List 20 & 22
R	Ripirian	List 20 & 22
R	Least drought tolerant plants on the list. These plants grow best in ripen areas. Riparian areas can be described as areas where the water table is very near the surface of the ground. Although the ground may be dry, the plants growing there will be green and lush all year around	List 29
Zone 1	The area directly adjacent to your home. These plants are highly fire resistant and are planted 0-30 feet from house	List 35
Zone 2	The "greenbelt", low growing, low fuel ground covers resistant to fire and are planted 30-70 feet from your house	List 35
Zone 3	Low fuel volume perennials and shrubs, less combustible than the native plants in zone 4. These are planted 70-100 feet from house	List 35
Zone 4	The outer most area, consisting of existing native vegetation which has been thinned to reduce fuel volume and create transitional area betweem the natives and plants around your home.	List 35
10	Drip line to Structure (ft)	List 54
30	Drip line to Structure (ft)	List 54
D	Deciduous	List 54
E	Evergreen	List 54