California State Water Resources Control Board

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Summary of Environmental Effects
Evaluating effects of potential urban water use efficiency standards (AB 1668-SB 606) on urban retail water suppliers, wastewater management agencies, and urban landscapes (trees and urban parklands)

*** This file contains the evaluation of potential urban water use efficiency standards on urban landscapes (trees and urban parklands). The full report will be made public at a later date.**

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Office of Water Programs
California State University, Sacramento
6000 J St.
Sacramento, CA 95819
(916) 278-6142

Project Team

<u>Sacramento State</u>
Office of Water Programs, Department of Economics

Erik Porse, PhD
Jonathan Kaplan, PhD
John Johnston, PhD, PE
Harold Leverenz, PhD, PE
Khalil Lezzaik, PhD
Caitlyn Leo
Dakota Keene
David Babchanik
Patrick Maloney
Scott Meyer
Samira Moradi
Danielle Salt
Ramzi Mahmood, PhD, PE

<u>UCLA</u>
Institute of the Environment and Sustainability

Stephanie Pincetl, PhD
Lawren Sack, PhD
Felicia Federico, PhD
Robert Cudd
Julia Skrovan
Lauren Strug
Hannah Gustafson
Marvin Browne

<u>UC Davis</u>
Department of Plant Sciences

Mary Cadenasso, PhD
Joanna Solins, PhD
Bogumila Backiel

<u>Humboldt State</u>
Department of Economics

Erick Eschker, PhD
Jonathan Sander

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Through the implementation of AB 1668-SB 606, Suppliers that need to reduce water use to meet regulatory targets are likely to promote efficiency for residential outdoor uses. Consequent irrigation reductions on residential properties have the potential to impact urban trees in California, which often rely on landscape irrigation to meet their water requirements. Understanding the consequences of future water use efficiency efforts may have on urban trees requires an understanding of California's existing urban forests, the water needs of urban vegetation in residential neighborhoods across the state, and the reductions in residential outdoor water use likely to occur as a result of AB 1668-SB 606 rule-making.

1.1. Baseline Conditions

California's cities are planted with a wide variety of trees from around the world (Avolio et al. 2015; Muller and Bornstein 2010; Pincetl et al. 2013), and the composition of urban forests often reflects nursery offerings (Pincetl et al. 2013) and the preferences of residents and managers (Avolio et al. 2015) more than environmental conditions. Irrigation has made it possible to incorporate many tree species into California's urban forests that would otherwise not be suited to local climates (Pataki et al. 2011).

Recent work to characterize California's urban forests has provided some baseline information about their structure and composition. There are estimated to be more than 173 million urban trees statewide, with nearly 40% located in single-family residential areas (McPherson et al. 2017). Statewide, California's urban forests are also youthful—around half of the urban trees sampled in random plots across the state had diameters at breast height (DBH) less than 15 cm, and relatively few trees were recorded in the size classes with DBH above 46 cm (McPherson et al. 2017). While species diversity in California urban forests is typically high (McPherson et al. 2016, 2017; Muller and Bornstein 2010), the diversity of newer plantings may be far lower (Muller and Bornstein 2010), suggesting possible declines in overall urban forest diversity in the future.

Urban forest characteristics specific to residential neighborhoods across the state are not well understood. In addition, the water requirements of urban trees and other vegetation have not been assessed on a statewide scale. The analysis presented below helps to establish these baseline conditions.

1.2. Mitigation and Adaptation Strategies

There are many possible mitigation and adaptation actions that Suppliers, other institutions, and residents can take to reduce residential outdoor water use. In this context, mitigation responses are those that work within existing systems to reduce water use, while adaptation responses change systems so that they will be more resilient to reduced water use. These different mitigation and adaptation responses may increase or decrease the risk to urban trees, although in many cases the outcome is uncertain (Table 7-1).

While turning off irrigation systems entirely may reduce outdoor water use effectively, it also increases risks to trees from water stress. Other mitigation responses with existing irrigation systems, such as adjusting settings and changing sprinkler heads, have uncertain outcomes for trees depending on how they change the amount of available water. On the other hand, trees benefit from deep watering that can be facilitated with nonstructural interventions like soaker hoses (Sacramento Tree Foundation 2020), while appropriate mulching prevents water loss and improves soil health (Chalker-Scott 2007; Wang et al. 2021).

Institutional actions to reduce outdoor water use will create less risk for trees if they are planned in coordination with landscape managers and experts in horticulture and landscape design. An example of such an action would be a turf replacement rebate or incentive program, which encourages residents to convert spray-irrigated turf lawns to drought-tolerant vegetation with drip irrigation. This type of conversion can have uncertain outcomes for trees, and risks to trees are likely to be lower if the terms of the program are determined with input from experts and managers across institutions, and if regionally appropriate educational materials and guidance are made readily available.

While drip irrigation can be a very effective way to water trees, it must be set up and managed properly to meet the trees' needs. Mature trees typically require infrequent, deep watering at the edge of their canopies, although trees whose root systems developed in the context of frequent, shallow lawn watering may require a period of transitional irrigation (Sacramento Tree Foundation 2020). If the needs of existing trees are not fully considered in the design of water-wise yards, the process of landscape conversion can physically damage existing tree roots and create sudden changes in irrigation, potentially leading to tree water stress and decline (Robinson 2020). Even when drip irrigation is installed with trees' water needs in mind, it may not supply enough water to alleviate tree water stress under high-temperature conditions in arid climates (May et al. 2013), which could be a concern in arid southern or inland regions of the state. Additional irrigation might be necessary to supply adequate water to existing trees in such circumstances.

Table 7-1: Potential managerial responses (residents and/or institutions) to reduce residential outdoor water use and their expected effect on the risk to urban trees

	Mitigation responses	**Adaptation responses**
Increased Risk	• Ceasing or dramatically reducing landscape irrigation	• Unilateral/uncoordinated actions by management and regulatory institutions
Uncertain Outcomes	• Changing irrigation settings (timing, amount) • Changing sprinkler heads	• Planting low-water-use noncanopy vegetation • Changing landscape designs • Installing drip irrigation systems • Using shading alternatives (structures) • Municipalizing tree management to facilitate maintenance
Decreased Risk	• Using soaker hoses to irrigate trees • Mulching around trees and vegetation	• Coordinating institutional planning with landscape managers and plant/landscape experts • Planting drought-tolerant tree species • Boosting urban forestry operation and maintenance funding

		• Developing educational materials & regional guidance

Note: Compiled by authors.

One important adaptation strategy to prepare the urban forest for reduced water availability and a changing climate is to plant tree species with lower water needs. A current research initiative, entitled "Climate Ready Trees," is field-testing trees that have high potential to perform well under stressors associated with climate change in California's Central Valley, Inland Empire, and Southern California Coast climate zones (climatereadytrees.ucdavis.edu). This project ultimately aims to shift the palette of trees planted in urban areas such that high-water-use species will be replaced with trees that are more drought tolerant (McPherson and Berry 2015). However, it will take years for newly planted trees to mature and provide comparable benefits to existing shade trees. This type of adaptation strategy is likely to be more successful if urban forestry operations and maintenance budgets are well funded.

1.3. Results: Effects on Urban Trees

Given the diversity of urban forests and urban contexts across the state of California, reduced residential outdoor water use associated with AB 1688-SB 606 is expected to have varying impacts on urban trees. Many urban trees rely on residential irrigation, but some depend partially or entirely on other water sources such as subsurface groundwater (Bijoor et al. 2012b). Climate and tree species composition also influence the likelihood that changes in irrigation could impact existing urban forests. With these considerations in mind, it is possible to identify areas where existing trees are most at risk of negative consequences from reduced outdoor water use. However, identifying impacts of the legislation on individual trees is infeasible due to the influence of many site-specific factors, such as the irrigation history of the tree, groundwater access, and the ways in which overall outdoor water use is reduced—or not reduced—on a particular property.

1.3.1. Overall Approach

To identify potential risks to urban trees from the implementation of AB 1668-SB 606, a multistep procedure was followed. First, urban forests located in areas subject to the legislation were characterized, including tree canopy cover, species composition, and tree size. Using this information, the total water demand of trees in residential areas was estimated for all Suppliers with available data. Water demand is the amount of water vegetation would use if fully irrigated. The water demand of turf grass was also estimated because it is the other major component of vegetation in existing urban landscapes. Total residential vegetation water demand (trees and turf combined) was compared to recent residential outdoor water use, as well as to predicted changes in residential outdoor water use under different scenarios for the objectives specified by the legislation. Finally, to better understand risks to mature urban trees from changes in outdoor water use, effects of different types of residential irrigation on street trees were evaluated based on field observations.

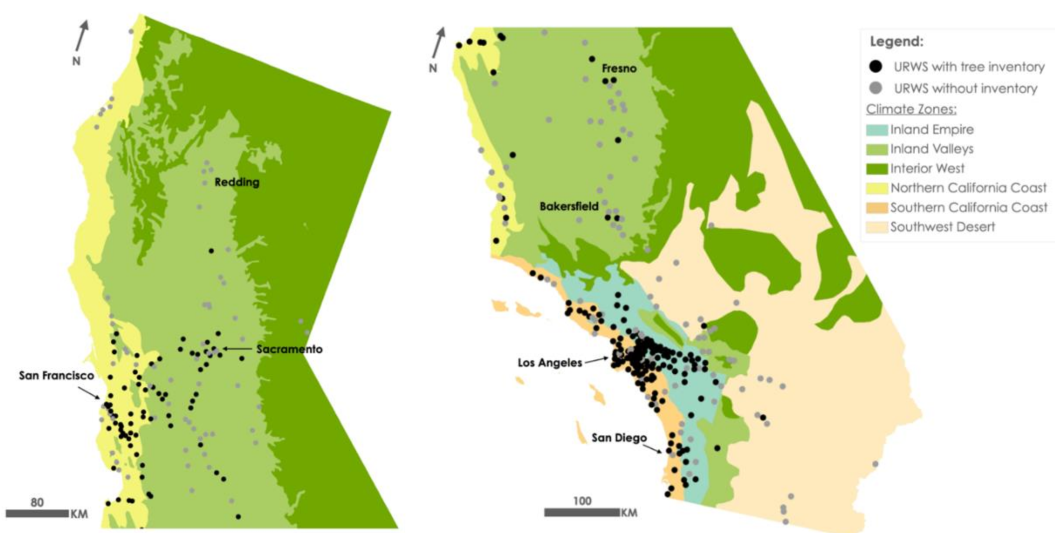
1.3.2. Evaluating Current Urban Forest Composition in Residential Areas

The process of identifying potential risks to urban trees from the implementation of AB 1668-SB 606 began with characterizing the urban forests currently found in the areas subject to the legislation. Tree inventories from California's urban forests were acquired from both public and private sources and evaluated for species composition and size distribution (for detailed methods, see Technical Appendix-2). In total, these inventories contained more than 6.5 million urban trees, and more than 3.5 million of those trees were within residential areas in Supplier boundaries. In total, the inventories included more than 1,100 tree species. This dataset is much larger than others used to evaluate California's urban forest composition in the past (McPherson et al. 2016, 2017; Muller and Bornstein 2010) and provides exceptionally rich information in many parts of the state.

It is important to note, though, that tree inventories in residential areas primarily catalogue street trees, and this is a limitation of the available data. The species composition of an area's street trees is unlikely to be identical to that of the trees planted in other parts of its residential landscape, leading to uncertainty in the characterization of the overall urban forest composition. However, the general characteristics and size distribution of an area's street trees are likely to reflect those of its urban forest as a whole. In addition, street trees will be affected by changes in residential outdoor water use because they often rely on irrigation water from residential parcels (Bijoor et al. 2012b).

To describe trends in urban forests across California, differences in urban forest composition were examined among six climate zones defined by the U.S. Department of Agriculture Forest Service (USFS) (Figure 7-1). Available tree inventories were not evenly distributed across the state. Table 7-2 shows the total number of trees included in the analysis for each climate zone, and Figure 7-2 shows the Suppliers that had sufficient inventory data within residential areas for their urban forests to be characterized. For the Interior West and Southwest Desert climate zones, there were few trees within residential areas. All urban trees in the available inventories were considered.

Figure 7-1: Urban retail water suppliers (URWS) with and without tree inventories, shown with the California climate zones used for analysis (McPherson et al. 2016)



Notes: Figure created by authors based on mapping. A sufficient inventory was considered to be ≥ 2,000 trees and ≥ 2 trees/ha in residential areas. Suppliers with smaller areas that didn't make the 2,000-tree cutoff were included if they had ≥10 trees/ha, and Suppliers with larger areas that didn't meet the ≥2 trees/ha cutoff were included if they had ≥ 5,000 trees.

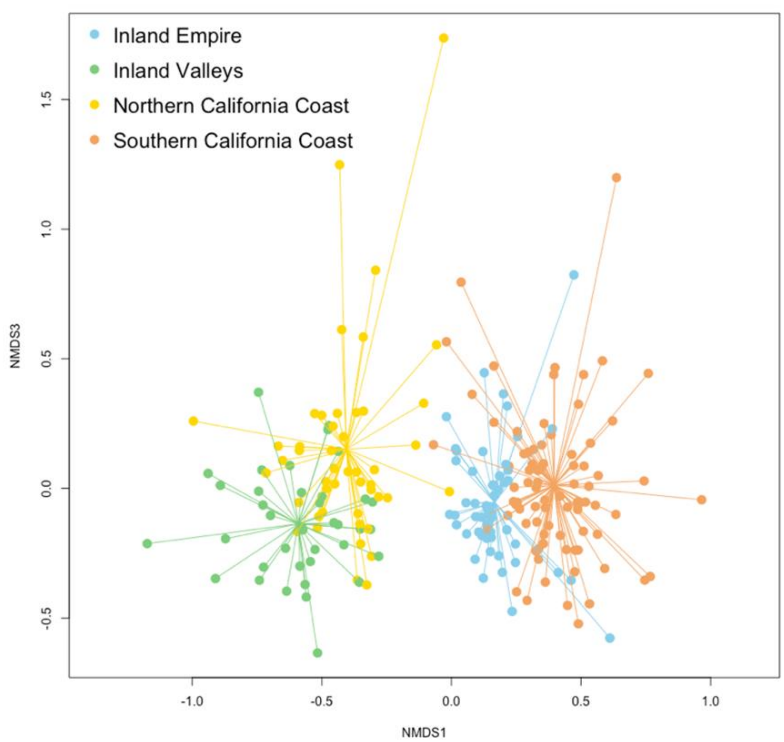
Table 7-2. The number of inventoried trees included in the analysis for each climate zone in California

Climate zone	Number of trees
Inland Empire	799,227
Inland Valleys	553,937
Interior West	9,321
Northern California Coast	938,346
Southern California Coast	1,440,104
Southwest Desert	54,088

Note: Author calculations based on compiled sources of tree inventory data.

Tree species composition of California's urban forests was relatively well differentiated by climate zone (Figure 7-2), suggesting that the existing urban forest has been planted with some consideration for climatic differences across the state.

Figure 7-2: A non-metric multidimensional scaling ordination based on urban tree inventories from four different climate zones in California



Notes: Each dot represents a different Supplier. Suppliers that are closer together have more similar species compositions. Suppliers are colored and grouped by climate zone. The Interior West and Southwest Desert climate zones lacked sufficient Suppliers with inventory data to include in this analysis.

However, some species are common across multiple climate zones. For instance, crapemyrtle (*Lagerstroemia* spp.) was among the five most common trees for all climate zones except the Southwest Desert (Table 7-3).

Table 7-3: The five most common species in urban tree inventories for each climate zone in California, with shading to indicate the water use rating of each species

Inland Empire	Inland Valley	Interior West	North Coast	South Coast	Southwest Desert
Crapemyrtle (*Lagerstroemia*)	Chinese pistache (*Pistacia chinensis*)	Mondell pine (*Pinus eldarica*)	London planetree (*Platanus acerifolia*)	Queen palm (*Syagrus romanzoffiana*)	Mexican fan palm (*Washingtonia robusta*)
Sweetgum (*Liquidambar styraciflua*)	Crapemyrtle (*Lagerstroemia*)	Arizona ash (*Fraxinus velutina*)	Sweetgum (*Liquidambar styraciflua*)	Crapemyrtle (*Lagerstroemia*)	California palm (*Washingtonia filifera*)
Mexican fan palm (*Washingtonia robusta*)	London planetree (*Platanus acerifolia*)	Jeffrey pine (*Pinus jeffreyi*)	Bradford pear (*Pyrus calleryana*)	Southern magnolia (*Magnolia grandiflora*)	Date palm (*Phoenix dactylifera*)
Southern magnolia (*Magnolia grandiflora*)	Bradford pear (*Pyrus calleryana*)	California incense-cedar (*Calocedrus decurrens*)	Crapemyrtle (*Lagerstroemia*)	Mexican fan palm (*Washingtonia robusta*)	Mondell pine (*Pinus eldarica*)
Camphor tree (*Cinnamomum camphora*)	Coast redwood (*Sequoia sempervirens*)	Crapemyrtle (*Lagerstroemia*)	Chinese pistache (*Pistacia chinensis*)	Jacaranda (*Jacaranda mimosifolia*)	Arizona ash (*Fraxinus velutina*)

Notes: Water use ratings from the SelecTree database: green = low, light blue = medium, and dark blue = high. Crapemyrtles (*Lagerstroemia* spp.) are not identified to species in most inventories, and water use ratings for different species and cultivars of crapemyrtle range from very low to medium.

The relative water needs for trees in each climate zone were characterized using water ratings from the SelecTree database, which were determined by expert judgment. Many of the most common tree species are rated as medium- or even high-water use (Table 7-3), suggesting that these species may require substantial irrigation inputs to remain healthy through the dry summer months in most parts of the state. Only the Southwest Desert climate zone had a majority of low-water-use trees among its five most common species (Table 7-3).

Water ratings by tree size (diameter at breast height, DBH) for all analyzed trees in each climate zone are shown in Table 7-4. For all climate zones except the Southwest Desert and Interior West, the majority of trees in all size classes were rated as medium water use. The Southwest Desert region had by far the greatest percentages of low-water-use trees in all size classes, suggesting a general trend of climate-appropriate species choices for this dry region. However, in all climate zones, the greatest percentage of low-water-use trees was found in the largest size class, suggesting that the planting of low-water-use trees may actually have decreased over time. While high-water-use species tended to be relatively uncommon in all climate zones, the percentage of high-water-use species was generally consistent across size classes, with the exception of the Inland Valleys and Southern California Coast regions. In these regions, the prevalence of high-water-use species decreased with tree size, suggesting that fewer high-water-use species have been planted recently.

Table 7-4: Mean percent of trees with different water use ratings for Suppliers in each climate zone, in three size classes

Climate zone	Tree size	High Water Use (%)	Medium Water Use (%)	Low Water Use (%)	Unknown Water Use (%)	Total % of trees
Inland Empire	small	5.8	58.2	8.7	27.65	23.7
	medium	6.9	63.1	16.8	13.2	52.3
	large	5.5	56.3	35.6	3.1	24.0
Inland Valleys	small	7.5	60.7	3.1	29.1	38.0
	medium	13.0	74.4	5.1	8.2	45.2
	large	18.8	64.3	14.9	7.9	16.8
Interior West	small	2.6	49.7	11.0	36.8	14.7
	medium	1.4	59.1	33.6	5.9	59.9
	large	1.6	38.7	51.6	8.2	25.4
N. CA Coast	small	7.4	64.8	5.7	22.3	32.6
	medium	13.6	66.3	8.6	11.4	49.0
	large	18.7	57.1	16.2	9.3	18.4
S. CA Coast	small	7.4	62.1	9.7	21.2	21.4
	medium	8.6	66.1	17.9	7.4	59.9
	large	6.9	59.1	32.4	2.3	18.8
Southwest Desert	small	0.2	36.8	40.5	22.4	15.7
	medium	0.5	28.1	61.7	9.7	60.3
	large	0.4	10.6	80.7	8.3	24.1

Notes: Author estimates. Tree sizes are based on diameter at breast height (DBH): small is < 6 inches DBH, medium is 6–18 inches DBH, and large is > 18 inches DBH. Water use ratings are from the SelecTree database, with the categories of "very low" and "low" combined, as very low water ratings were uncommon. The majority of trees with unknown ratings were crapemyrtles (*Lagerstroemia* spp.), which are not identified to species in most inventories.

Water use classifications for the most prevalent group of species, crapemyrtles (*Lagerstroemia* spp.), merit particular discussion. Crapemyrtles are small-statured trees and are often only identified to genus in inventories, leading to a large number of unknown water ratings in the small and medium size classes. Water use ratings for different species and cultivars of crapemyrtle that are commonly planted in California cities range from very low to medium. However, these trees will use a large amount of water for their size when fully irrigated (Wynne and Devitt 2020).

Overall, these findings suggest that low-water-use tree species have not been prioritized in California's urban forests, and that the planting of low-water-use trees has not increased substantially over time. The popularity of crapemyrtles and the uncertainty of their water use ratings makes it difficult to compare the percentages of low-water-use trees between the small and large size classes. However, it is clear that the majority of small trees would still be medium- or high-water-use species in all climate zones except the Southwest Desert. Even in this driest region of the state, more than one third of small trees are medium-water-use species. The high proportion of small and medium-sized trees with at least medium water needs across the state suggests that substantial water inputs would be required to maintain future urban forests as these trees grow and mature. In places where water use reductions are necessary, these trees with higher water needs will be at greater risk of negative impacts from reduced irrigation.

1.3.3. Estimating Tree and Turf Water Demand

While the SelecTree database and other vegetation water use rating systems can characterize *relative* water needs of trees and vegetation, they do not support the *quantitative* values of water demand necessary to evaluate effects of water use reductions. Statewide frameworks in California used to estimate demand of urban landscapes rely on a calculation related to the Model Water Efficient Landscape Ordinance (MWELO). MWELO is based on irrigated area, reference evapotranspiration, and a coefficient of efficiency associated with plant species and irrigation systems. These factors are typically known for the new landscapes MWELO was designed to characterize; however, with the exception of reference evapotranspiration, determining accurate MWELO inputs for existing landscapes at a statewide level is impractical. Furthermore, an MWELO-derived approach to estimate water demand is being used by state agencies as part of rule-making, and an independent strategy was required for the environmental impact assessment.

Therefore, this analysis uses a methodology developed in Los Angeles, which estimates municipal-scale water demand based on calculations of tree transpiration and turf evapotranspiration (Litvak et al. 2017b). These calculations are derived from field measurements of transpiration rates in numerous urban tree species (Litvak et al. 2017c), as well as evapotranspiration rates of turf grass under varied environmental conditions (Litvak and Pataki 2016). This method proved robust in pilot studies, but it requires substantial data inputs (Table 7-5). A brief description of strategies for acquiring and calculating the necessary data inputs follows, and more detailed methods can be found in Technical Appendix-2.

Table 7-5: Summary of data needs for estimating tree and turf water demand using the method described in Litvak et al. 2017a

Trees	Turf
Total number of trees Planting density of each species Mean sapwood area of each species Characteristics of each species: • Type (broadleaf, conifer, palm) • Evergreen vs. deciduous Monthly mean vapor pressure deficit Monthly mean solar radiation	Total turf area Proportion of turf area under tree canopy Monthly mean reference evapotranspiration

Note: Developed by authors.

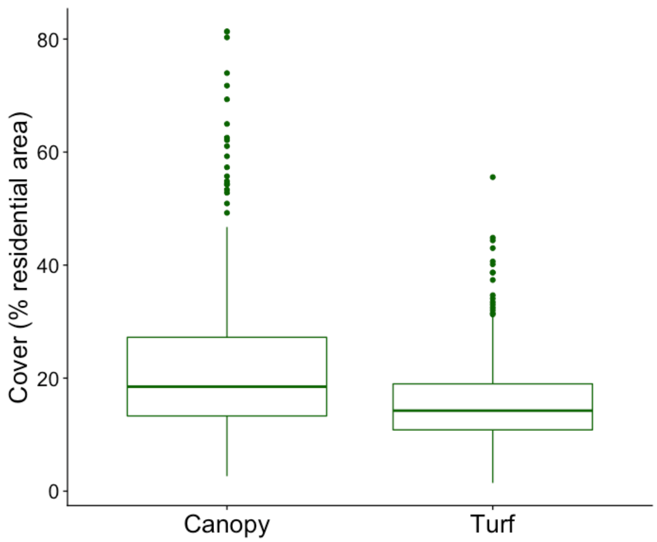
Determining the Total Area of Vegetation, Tree Canopy, and Turf

For each Supplier, the total number of residential trees and the area of residential turf are fundamental inputs for calculating water demand using this technique, but they are relatively challenging to determine. First, the total tree canopy area and total residential vegetated area for each Supplier needed to be calculated. To get these values, residential areas for each Supplier were defined based on parcel data. Parcels with residential use codes were aggregated, and then a 10-m buffer around the parcels was applied to capture the canopy area of trees that extended over the street. To ensure that the buffer did not include canopy area from trees planted in nonresidential parcels (e.g., schools), nonresidential parcels were clipped out of the buffer. In total, 384 retailers had sufficient parcel data to define residential areas.

Total tree canopy area within residential areas was determined using a shapefile of 2018 California urban tree canopy cover that was created by the company EarthDefine using artificial intelligence techniques. This file was made publicly available through the USFS and CAL FIRE. For Los Angeles County, tree canopy data available from the Los Angeles Region Imagery Acquisition Consortium (LARIAC) was used because it appeared to be slightly more accurate in that region. These canopy files were clipped to the residential areas of each Supplier to yield canopy cover within residential areas. However, some residential areas within Supplier boundaries were not included in either of these tree canopy layers. For those areas, the percent canopy cover was determined using point count estimates on 2018 aerial imagery from the National Agriculture Imagery Program (NAIP).

Total vegetated area within residential areas was determined using the normalized difference vegetation index (NDVI), a remote sensing technique that identifies living vegetation based on reflectance values. NDVI values were calculated using 2018 NAIP imagery, which has a resolution of 0.6 m. The difference between the total vegetated area and the total canopy area was assumed to be unshaded turf. To get a total turf area estimate, 50% of the area under the tree canopy was assumed to be turf, and this value was added to the unshaded turf value. The percentages of residential area covered by tree canopy and turf are shown for all 384 Suppliers in Figure 7-3.

Figure 7-3: Tree canopy and turf cover as a percent of residential area for 384 Suppliers



Note: Created by authors.

Because these remote sensing techniques cannot reveal what is under the tree canopy, the amount of turf under tree canopy is a source of uncertainty in this analysis. However, because shaded turf uses substantially less water than unshaded turf (Litvak and Pataki 2016), this potential source of error does not have an extremely large impact on overall turf water demand estimates (Litvak et al. 2017b). In addition, this method assumes that all noncanopy vegetation is turf, which is not strictly true in most places. However, making this assumption gives an estimate of the maximum water demand expected from noncanopy vegetation in a given area.

Calculating Turf Water Demand

Given the above data, the calculation of turf water demand, or evapotranspiration (ET), is relatively straightforward using Equations 11 and 12 (Litvak et al. 2017b):

$$ET_{Turf} = k_{mc} ET_o \tag{11}$$

$$k_{mc} = a - b\frac{A_{shaded}}{A_{total}} \tag{12}$$

where k_{mc} is a microclimate coefficient, A_{shaded} is the area of turf under the tree canopy, A_{total} is the total area of turf, and parameters a and b are fixed at $a = 0.90 \pm 0.09$ and $b = 0.35 \pm 0.13$, based on empirical measurements (Litvak and Pataki 2016). Mean monthly reference evapotranspiration (ET_o) values were calculated from Spatial CIMIS data for each Supplier, for the years 2014–2019. The resulting ET measurement is in mm/day and can be multiplied by the total turf area to get a volume of water used per day.

Calculating Tree Water Demand

The calculation of tree water demand is more complex and requires additional data inputs (Equation 13). From Litvak et al. (2017a), the transpiration of trees (E_{Trees}) is calculated as:

$$E_{Trees} = \sum_{i=1}^{I} E_{bl(i)} + \sum_{i=1}^{I} E_{con(i)} + E_{palms} \tag{13}$$

where E_{bl} is the transpiration of flowering or broadleaf trees (Equation 14), E_{con} is the transpiration of conifers (Equation 15), and E_{palms} is the transpiration of palm trees (Equation 15). The transpiration of broadleaf trees and conifers can be estimated using equations based on field measurements:

$$E_{bl(i)} = 1.2 \times 10^{-6} d_i A_{s(i)}(5.5 + 2.3 lnVPD + 0.02R_s) \tag{14}$$

$$E_{con(i)} = 4.0 \times 10^{-7} d_i A_{s(i)}(5.5 + 2.3 lnVPD + 0.02R_s) \tag{15}$$

where d_i is the density of species i per hectare, $A_{S(i)}$ (cm^2) is the average sapwood area of each species i, VPD (kPa) is the vapor pressure deficit of the air, and R_S (W m^{-2}) is incoming solar radiation. As for ET_o, monthly mean VPD and R_S values for each Supplier from 2014–2019 Spatial CIMIS data. For deciduous trees, E was assumed to be zero for the winter months (Nov–Feb for most parts of the state).

Palm tree physiology is substantially different from that of broadleaf and coniferous trees. The transpiration of palms can be estimated as:

$$E_{palms} \approx 0.017 \frac{d_{palms}}{100} \tag{16}$$

where d_{palms} is the total density of palms.

The data used to determine the density of each species and the sapwood area of broadleaf and coniferous tree species are described briefly below; see Technical Appendix-2 for more details.

Tree Species Composition, Density, Sapwood Area, and Traits

As detailed in the previous section, tree inventories allowed the characterization of species composition and size distribution for residential trees within many Supplier service territories (see below for Suppliers lacking inventories). To calculate the density of each species in a Supplier's residential area, two pieces of information were necessary: the total number of trees in that area and the relative abundance of each species. Relative abundance was calculated from the inventory data as the number of trees of each species divided by the total number of trees in the inventory. Because inventoried trees represent a sample of unknown proportion for any given area, their numbers cannot be used directly to calculate the total number of trees. Instead, several steps had to be taken to calculate the total number of trees. First, allometric equations were developed to relate DBH values to tree crown area for different types of trees. These equations were then used to calculate the crown area of each tree, from which a mean tree crown area for each Supplier could be calculated. The mean tree crown area is the average canopy area occupied by one tree. Finally, the total tree canopy area was divided by the mean tree crown area to estimate the total number of trees. The density of each species is its relative abundance times the total number of trees, divided by the total area of tree canopy (to get density in trees per hectare).

Sapwood area is the part of a tree's trunk that can transport water, and thus is related to tree water use. The relationship between a tree's DBH and its sapwood area varies by species, so allometric equations relating DBH to sapwood area were developed using literature values for 37 common species representing 31% of all inventoried trees. For species lacking data for allometric equations, mean sapwood area values were used based on all available data. Sapwood area was calculated for each tree, and a mean value for each species for each Supplier was derived.

Each tree species was categorized as a broadleaf, conifer, or palm based on its family, and the SelecTree database was used to categorize each species as deciduous or evergreen (Table 7-6). The Inland Valleys region had the greatest percentage of deciduous trees, while the Interior West had the greatest percentage of conifers, and the Southwest Desert had the greatest percentage of palms. The Southern California Coast and Inland Empire regions both had relatively high percentages of evergreen broadleaf trees.

Table 7-6: The percent of different types of trees in each climate zone

Region	Broadleaf – deciduous (%)	Broadleaf – evergreen (%)	Conifer – evergreen (%)	Palm – evergreen (%)
Inland Empire	39.9	39.2	8.9	12.0
Inland Valleys	74.0	13.9	9.4	2.6
Interior West	50.6	5.0	44.1	0.3
N. CA Coast	57.9	29.6	9	3.5
S. CA Coast	31.0	42.8	9.8	16.4
Southwest Desert	34.8	23.6	5.2	36.4

Note: Author calculations.

With all of these pieces of data in place, E_{trees} was calculated for each Supplier. Again, the resulting value was in mm/day, and was multiplied by the total tree canopy area to get a volume of water used per day.

Estimating Tree Water Demand for Retailers without Inventories

A substantial number of Suppliers lacked sufficient tree inventory data to characterize their urban forests (Table 7-7). To obtain estimates of tree water demand for these Suppliers, their species composition was predicted from areas with existing inventories, using both climatic and sociodemographic characteristics to find areas whose urban forests were likely to be most similar. First, given that suppliers within the same climate zone tend to have relatively similar urban forest composition (Figure 7-2), Suppliers were separated by climate zone. Within each of the four climate zones with adequate data, a joint species distribution modeling technique known as the hierarchical modeling of species communities (HMSC) framework was employed (Ovaskainen and Abrego 2020). This technique allows the use of site characteristics and tree species traits as predictors to model urban tree inventory composition and also considers the spatial relationships among different sites.

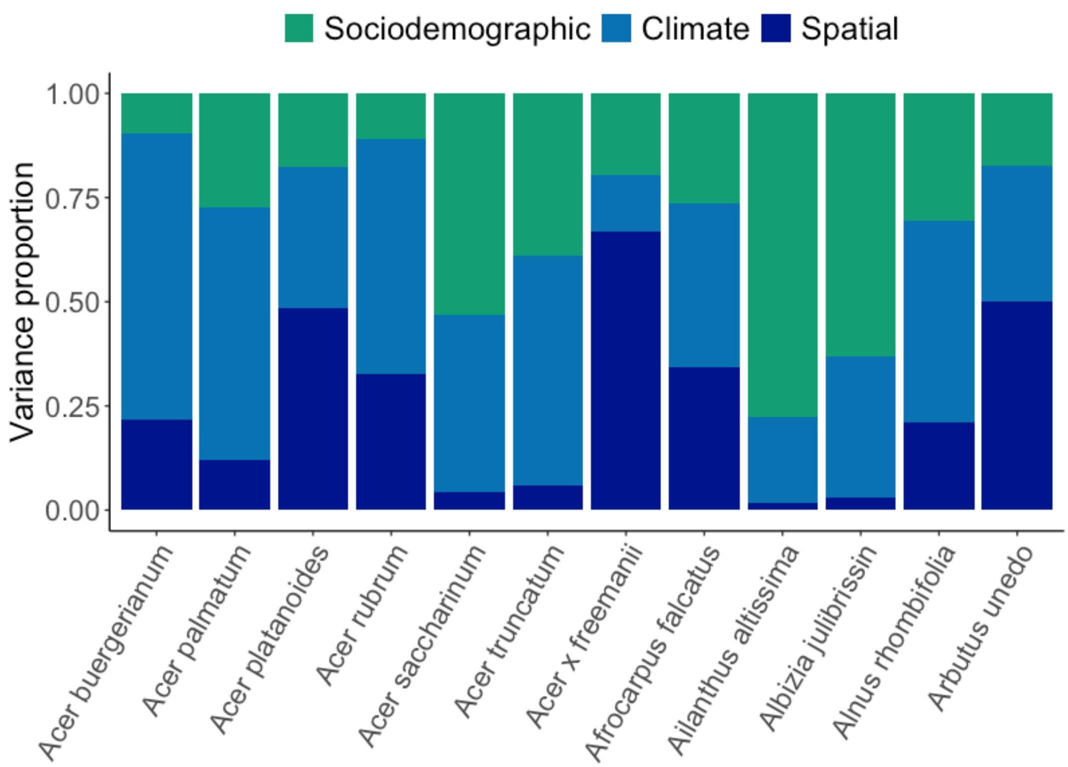
Table 7-7: The number of Suppliers with and without sufficient tree inventory data in each climate zone

	Suppliers with data	Suppliers without data
Inland Empire	54	17
Inland Valleys	38	75
Interior West	0	5
N. CA Coast	47	28
S. CA Coast	82	17
Southwest Desert	2	19
Total	**223**	**161**

Note: Author calculations.

To allow the inclusion of sociodemographic variables as predictors of urban tree species distribution, these models were run by zip code instead of by Supplier. For model fitting, only zip codes with at least 2,000 residential trees and at least 2 trees per hectare were included. Models were fit using the most common species in each climate zone that made up at least 95% of total trees. Although models were run separately for each climate zone, a buffer of adjoining zip codes from other climate zones was included for model fitting. Sociodemographic predictors from the American Community Survey included median household income, the Blau index of racial diversity, percent home ownership, and development age. Climate predictors included precipitation, minimum temperature, and maximum vapor pressure deficit derived from 30-year normal values from the PRISM Climate Group. Every variable included in each model was important for predicting the distribution of some species, and species varied widely in terms of which variables were most important in predicting their distributions (Figure 7-4).

Figure 7-4: An example of results from the Inland Valleys HMSC model for the first twelve species alphabetically, showing the proportion of the variance in each species' distribution explained by different types of predictors in the model

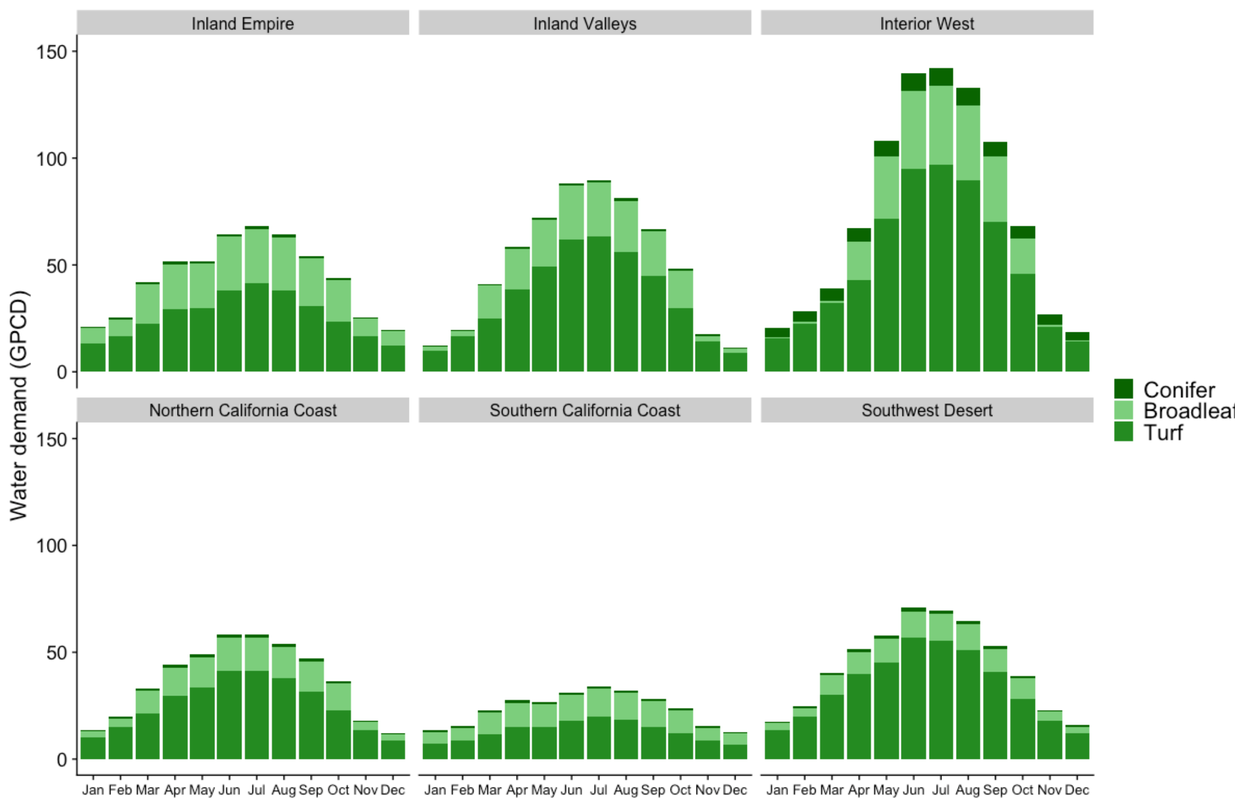


The models provided predictions of species composition for each zip code; however, it was not possible to model size distributions simultaneously, and size information is crucial for transpiration calculations. Therefore, the predicted urban forest composition of each zip code without inventory data was used to find similar zip codes with inventory data, based on the Bray-Curtis dissimilarity metric. For each zip code within each Supplier in need of a prediction, E_{trees} was calculated for all similar zip codes using the Supplier's climate data. This strategy yielded a range of predictions for each zip code, as well as a mean prediction. A weighted mean E_{trees} value for each Supplier was derived from these mean predictions, based on the proportion of the Supplier's area occupied by each zip code. For the Southwest Desert and Interior West climate zones, which did not have enough zip codes with data to run these models, all zip codes with available data were used as predictors for Suppliers without inventory data.

Monthly and Annual Water Demand Estimates

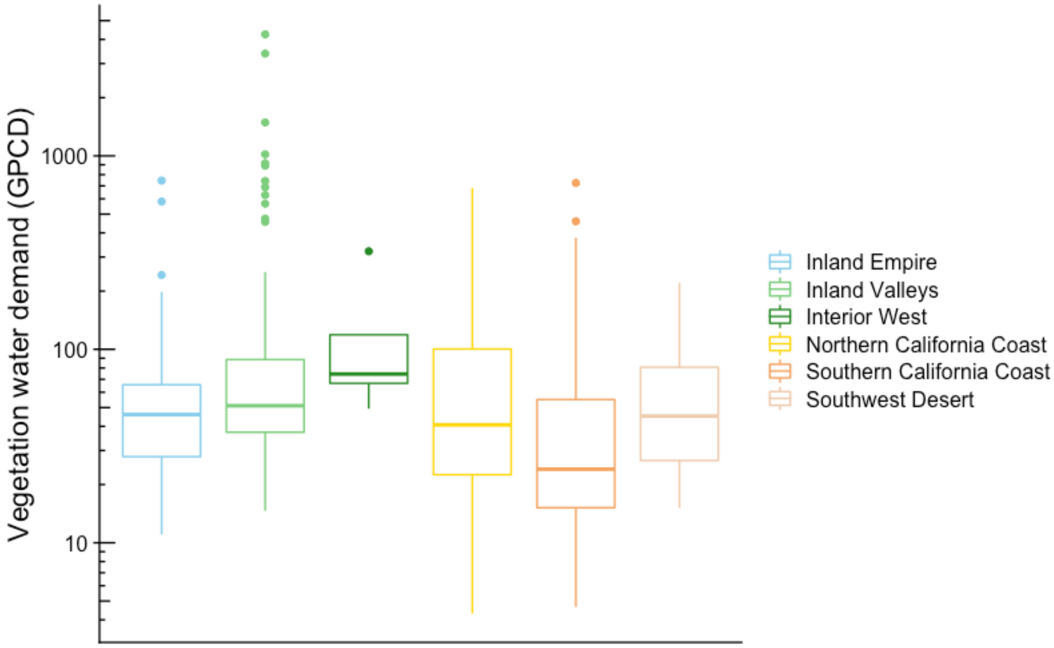
Once water demand estimates were calculated for each Supplier, they were converted to gallons per capita per day (gpcd) using population values from 2020, which were available for all but one Supplier. Median monthly water demand estimates in gpcd for turf, broadleaf trees, and conifers for Suppliers in each climate zone are shown in Figure 7-5. Palms did not account for enough water use to be visible in the graphs. Turf was on average the largest component of vegetation water demand for all months in all climate zones, while conifers were on average the least, except for the winter months in the Interior West region. Conifers were less common than broadleaf trees in all climate zones (Table 7-5), and were also found to have slightly lower transpiration rates than broadleaf trees given the same conditions (Litvak et al. 2017c). The high proportions of deciduous broadleaf trees in the Inland Valleys and Interior West regions are evident in the dramatic decrease in broadleaf water demand during months when these trees were expected to be dormant. High summer water demand values for the Inland Valleys, Interior West, and Southwest Desert climate zones reflect the hot, dry summer conditions in these regions. The relatively high and low water demand values in the Interior West and Southern California Coast climate zones, respectively, reflect the relatively low and high population densities of Suppliers in these areas.

Figure 7-5: Median monthly water demand of different vegetation types for Suppliers in each climate zone



Annual vegetation water demand values in gpcd varied widely for different Suppliers, largely due to differences in vegetated area per capita. Figure 7-6 shows the range of annual vegetation water demand per capita for Suppliers in each climate zone.

Figure 7-6: Annual per capita vegetation water demand for 383 Suppliers by climate zone. Note the log scale on the *y*-axis



1.3.4. Estimating Irrigation Reductions

As noted in Chapter 4, saturation rates for indoor fixture efficiency improvements are already high. Therefore, the majority of water use reductions needed to achieve objectives under AB 1668-SB 606 are expected to come from outdoor water use and primarily residential irrigation. For the purposes of this risk assessment, it was assumed that 85% of reductions due to the new objectives would come from outdoor water use. The projected 2030 outdoor water use value for each Supplier was correspondingly calculated as:

$$Outdoor_{2030} = Outdoor_{2020} - (0.85 \times (Baseline_{2030} - Objective_{2030})) \quad (17)$$

where $Outdoor_{2020}$ is the calculated outdoor water use for 2020, $Baseline_{2030}$ is the baseline total projected water use for 2030 in the absence of AB 1668-SB 606, and $Objective_{2030}$ is the objective calculated under one of the three scenarios outlined in Table 3-1. The estimation strategy guaranteed that any Supplier with a net reduction under the new standards was projected to see a reduction in outdoor water use.

In a few cases where large total reductions were necessary, the projected reduction in outdoor water use was greater than the current outdoor water use, yielding a negative projected outdoor water use value. These negative numbers were corrected to zero. While it is extremely unlikely that outdoor water use would actually reach zero, this projected value reflects the dramatic reductions that would be necessary to achieve the new objectives.

1.3.5. Impact Assessment

Translating changes in irrigation to effects on urban trees required a risk-based approach with multiple considerations, including

1) factors affecting tree lifespan;
2) responses of mature trees to changing irrigation practices;
3) evaluation of likely changes in irrigation in relation to modeled vegetation water demand.

The combination of factors was used in a multistep procedure that characterized the risk of AB 1668-SB 606 reductions to urban trees in a Supplier's service territory using risk categories of none, low, moderate, and high. The input considerations and assumptions to create the risk categorization scheme relied on the results from modeling and field studies, as well as expert judgement.

Factors Affecting Tree Lifespan and Mortality

The urban environment poses many challenges for trees, including compacted soils, low nutrient and water availability, and vandalism, which can contribute to relatively high mortality rates in urban forests (Nowak et al. 1990; Scharenbroch et al. 2017). On the other hand, maintenance practices including irrigation can promote urban tree survival (Roman et al. 2014). Numerous biophysical factors and human influences interact to affect urban tree mortality (Hilbert et al. 2019). Among human influences, maintenance has been shown to be particularly important in explaining tree survival in the first few years after planting, and survival rates have also been related to socioeconomic status and homeownership (Ko et al. 2015; Nowak et al. 1990; Roman et al. 2014). On the biophysical side, factors including tree age, size, and condition, as well as the intrinsic characteristics of different taxa, can affect trees' susceptibility to stressors such as drought, flooding, and pests (Hilbert et al. 2019). Because urban trees are typically planted from nursery stock, their drought tolerance, pest and disease susceptibility, and rates of establishment are also influenced by different nursery production systems (Allen et al. 2017). In urban areas, tree mortality may be caused by removal rather than natural death. Removal efforts sometimes preemptively target trees in poor condition, especially if they cause safety concerns, but trees may also be removed due to conflicts with infrastructure (e.g., sidewalk upheaval), construction or demolition projects, or aesthetic preferences (Hilbert et al. 2019).

The AB 1668-SB 606 legislation is expected to reduce outdoor water use in some places, and thus water stress is the most relevant factor related to tree mortality that is likely to be impacted by the legislation. Water stress, especially in combination with other stressors, can limit urban tree growth and lifespan (May et al. 2013; Nielson et al. 2007; Nitschke et al. 2017) and can also make urban trees more vulnerable to other health problems such as insect infestation (Cregg and Dix 2001; Dale and Frank 2017). In the arid and semiarid environments found across much of the state of California, where many urban trees rely on irrigation water (Bijoor et al. 2012b), a reduction in irrigation inputs could therefore have a negative impact on their health, growth, and survival, particularly in the face of increasing temperatures and drought severity associated with climate change (May et al. 2013).

Irrigation water constitutes variable proportions of the water used by urban trees. Bijoor et al. (2012) showed that mature trees in Los Angeles made use of groundwater resources even where irrigation was present, and groundwater constituted anywhere from 0–90% of total tree water use depending on species and location. On the other hand, many mature trees in the same study relied primarily on irrigation water, suggesting that they had developed shallow root systems and would be particularly sensitive to a sudden reduction in surface irrigation (Bijoor et al. 2012b). Even trees in unirrigated areas in California cities may use a substantial amount of water from urban runoff in the dry season (Bijoor et al. 2012b; Solins and Cadenasso 2020), suggesting that they may also be affected by changes in irrigation patterns. The high variability and uncertainty around irrigation dependence contributes to the difficulty in predicting the responses of individual trees or particular urban forests to reduced irrigation. However, trees that experience sudden reductions in water availability are likely to see negative health effects, particularly if they are species with greater water needs (May et al. 2013).

Assessing the Response of Mature Shade Trees to Different Irrigation Practices

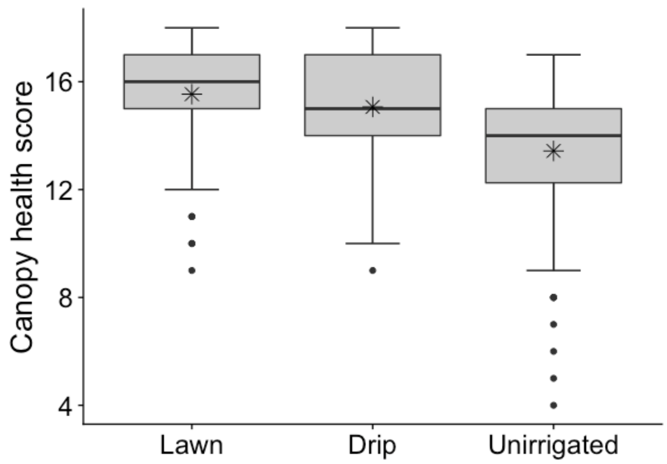
It is expected that changes in irrigation practices in response to AB1668-SB606 will be unevenly distributed across urban landscapes, with some residents reducing irrigation dramatically and others continuing to maintain current irrigation practices. Thus, it is likely that some mature trees will experience large changes in residential irrigation inputs, while others will continue to receive irrigation from lawns and other landscaping.

To provide a better understanding of how heterogeneously distributed changes in irrigation may affect the health of urban forests, a study was conducted to determine the effects of residential irrigation practices on the canopy health and water stress of mature street trees. London plane tree (*Platanus acerifolia*) was identified as the focal species for this investigation because it is one of the most commonly planted street trees throughout California and is rated as a medium-water-use species, reflecting the water needs of the majority of mature street trees in the state. A visual canopy health assessment was conducted on more than 400 mature London plane trees in Sacramento and Davis. These trees were growing in planting strips in front of properties with three contrasting irrigation practices in their front yards: 1) well-irrigated lawns, 2) "water-wise" landscaping with drip irrigation, and 3) unirrigated landscaping. In addition, midday and predawn water potential—indicators of maximum water stress and accessible soil water, respectively—were measured on a subset of 24 trees in Davis. All assessed trees had DBH values greater than 30 cm.

On average, trees in front of unirrigated front yards had lower scores for canopy health than those in front of yards with lawns or drip irrigation (Figure 7-7). Trees in front of unirrigated front yards also experienced more midday water stress and less access to soil water than those in front of yards with irrigated lawns, while those in front of drip-irrigated yards experienced intermediate levels of stress and soil water access (Figure 7-8). Canopy health scores for trees in front of drip-irrigated yards were also intermediate; however, the average difference between scores for trees in front of lawns and drip-irrigated yards was less than half a point.

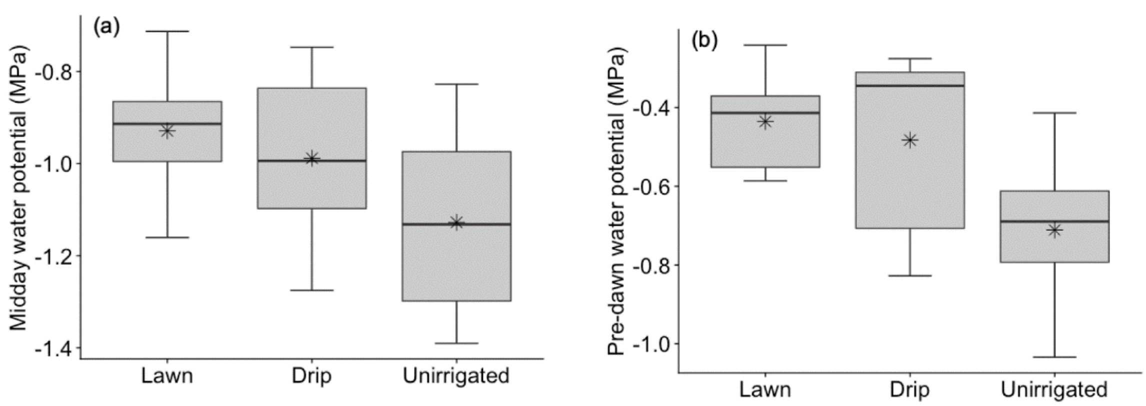
There was considerable spread in the data for trees neighboring all three types of yards, suggesting that factors beyond frontyard irrigation influenced tree health and water stress. However, these findings do suggest that if residents respond to calls for water use cutbacks by ceasing to irrigate their yards, the condition of mature trees is likely to be negatively impacted, possibly leading to eventual mortality. On the other hand, drip irrigation systems may save water without having a substantial negative impact on existing trees, assuming that the systems are properly installed.

Figure 7-7: Visual canopy health assessment scores for London plane trees in front of yards with different irrigation practices



Notes: Created by authors based on data collected by authors. Asterisks indicate mean scores, while boxplots show the minimum, 1st quartile, median, 3rd quartile, and maximum scores.

Figure 7-8: Midday stem water potential (a) and predawn water potential (b) measurements for London plane trees in front of yards with different irrigation practices

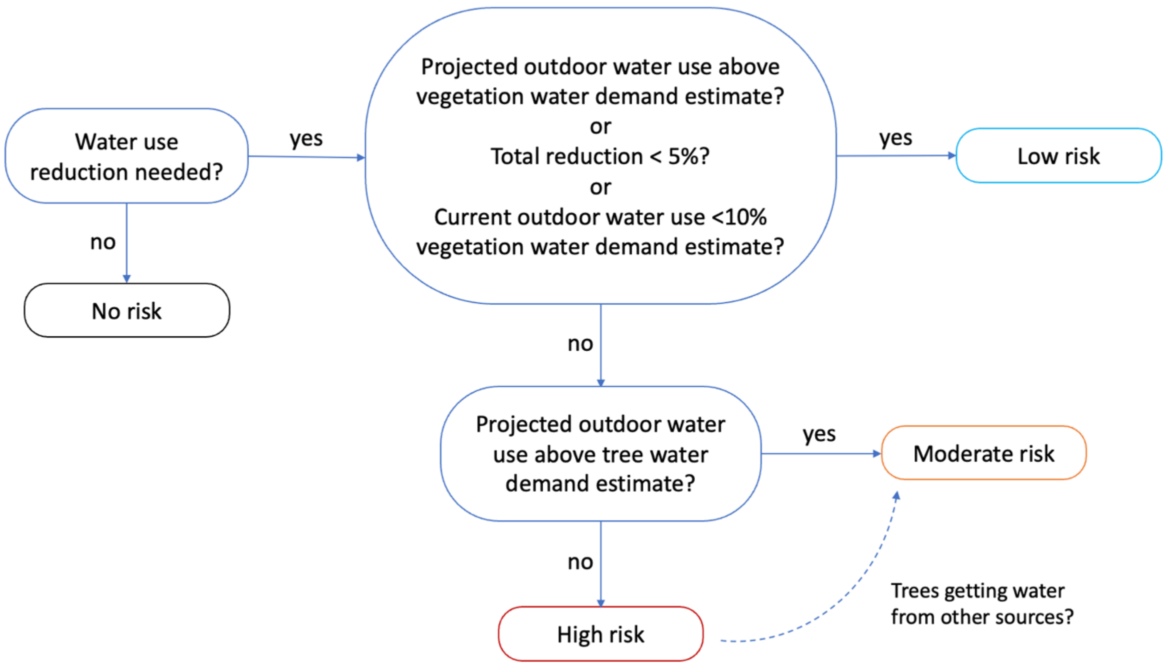


Notes: Lower (more negative) measurements indicate greater water stress. Asterisks indicate mean values, while boxplots show the minimum, 1st quartile, median, 3rd quartile, and maximum values.

Risk-Based Approach

The likelihood that Suppliers would be at increased risk for negative impacts to their existing tree canopies was assessed based on projected changes in outdoor water use and whether projected outdoor water use levels would be below the needs of existing vegetation under different objective scenarios. For the 357 Suppliers with both vegetation data and baseline water use projections, categories of risk were assigned following the decision tree in Figure 7-9. The many site-specific factors affecting tree responses to reduced water inputs and the anticipated variability of resident responses to the new standards make it infeasible to estimate the number of trees that could be affected by AB 1668-SB 606.

Figure 7-9: Decision tree for assigning Suppliers to levels of risk facing their existing urban trees given new water use objectives under AB 1668-SB 606



Note: Developed by authors.

The risk categories are relative to changes anticipated to stem from the legislation. For Suppliers that are not expected to need reductions in water use to meet their objectives, urban trees will face no additional risks due to AB 1668-SB 606. However, once any reduction in water use is required to meet the new objectives, some risk exists for urban trees because it is possible that some residents will respond by reducing irrigation inputs that trees were relying on. The overall severity of that risk was judged to be low if the projected outdoor water use was above the estimate of total vegetation water demand (both trees and turf), because in that case, the needs of trees and other landscaping vegetation could likely be met simply by improving irrigation efficiency. The risk was also considered low if the overall water reduction to meet the objective was less than 5%, as irrigation levels would not need to change very substantially to meet the objective. In some cases—particularly in more rural areas—estimated vegetation water demand far exceeded outdoor water use, suggesting that most trees were not relying on irrigation to meet their water needs. Therefore, if current outdoor water use was less than 10% of the estimated vegetation water demand for a Supplier, the risk was also considered to be low.

If the projected outdoor water use fell below the estimate of vegetation water demand, the risk was judged to be higher. Irrigation efficiency improvements alone would be unlikely to meet the new objectives, meaning that a level of irrigation below the demand of current vegetation would be predicted for 2030. Therefore, depending on the adaptation and mitigation actions taken, some trees would likely experience reduced water availability. However, if the projected outdoor water use was still above the water demand of trees, the risk was considered moderate because the necessary reduction could potentially be met through turf reduction measures. If the projected outdoor water use fell below the water demand of trees alone, the risk was considered high. In this scenario, it would be unlikely for a Supplier to meet the objective and still have fully irrigated trees.

As noted above, irrigation is not the only source of water for trees and other vegetation. In most places, precipitation provides some water to landscaping plants, and trees may also access groundwater in certain areas. The amount of water these sources contribute to vegetation is very difficult to estimate. Detailed groundwater level data are not available across the state, and even if they were, the ability of different trees to access groundwater at different depths would still be highly uncertain. Although precipitation data are more readily available, the amount of precipitation water that is accessible to plants is highly variable in urban areas. Without considering these additional water inputs, though, some Suppliers would be assigned to the high-risk level even though their trees likely receive enough water from non-irrigation sources that outdoor water use reductions would not pose a severe threat.

An estimate for the amount of water vegetation was accessing from sources other than irrigation was determined by assuming that current outdoor water use was adequate to meet vegetation needs. Thus, if the vegetation water demand estimate was above current outdoor water use, the difference was considered to be the amount of water available from nonirrigation sources. This difference might also reflect an overestimate of vegetation water demand compared to actual vegetation water use, since water demand reflects transpiration under fully irrigated conditions, assumes that noncanopy vegetation is turf, and assumes that 50% of the area under canopy is turf. Wherever the difference comes from, this value represents an amount of water that does not need to be supplied by irrigation. This value was added to the 2030 projected outdoor water use for each Supplier in the high-risk category, and if the resulting value was above tree water demand estimates, the Supplier shifted to the moderate-risk category. Suppliers already in the moderate-risk category would not move to the low-risk category with this adjustment, because the projected outdoor water use—always lower than current outdoor water use—would still be lower than the total estimated vegetation water demand.

Results by Scenario

The three different objective scenarios had very different risk profiles for the 357 Suppliers analyzed, as shown in Table 7-8 and Figure 7-10. In Scenario 1, with a final indoor standard of 50 gpcd and outdoor standard of 0.7, 63% of Suppliers would need no reductions in total water use, and their trees would therefore be at no risk from AB 1668-SB 606. Only two Suppliers fell in the high-risk category, while 12% were at moderate risk and 24% were at low risk.

In Scenario 2, with a final indoor standard of 42 gpcd and outdoor standard of 0.62, the percent of Suppliers facing no risk fell steeply to 34%, while the number in the moderate-risk category increased substantially to 42%. Still, only four Suppliers fell in the high-risk category, and 23% were at low risk.

In Scenario 3, with a final indoor standard of 35 gpcd and outdoor standard of 0.55, only 22% of Suppliers were at no risk and 15% were at low risk. The majority of Suppliers (57%) were in the moderate-risk category, and the number in the high-risk category increased to 25, or 7%.

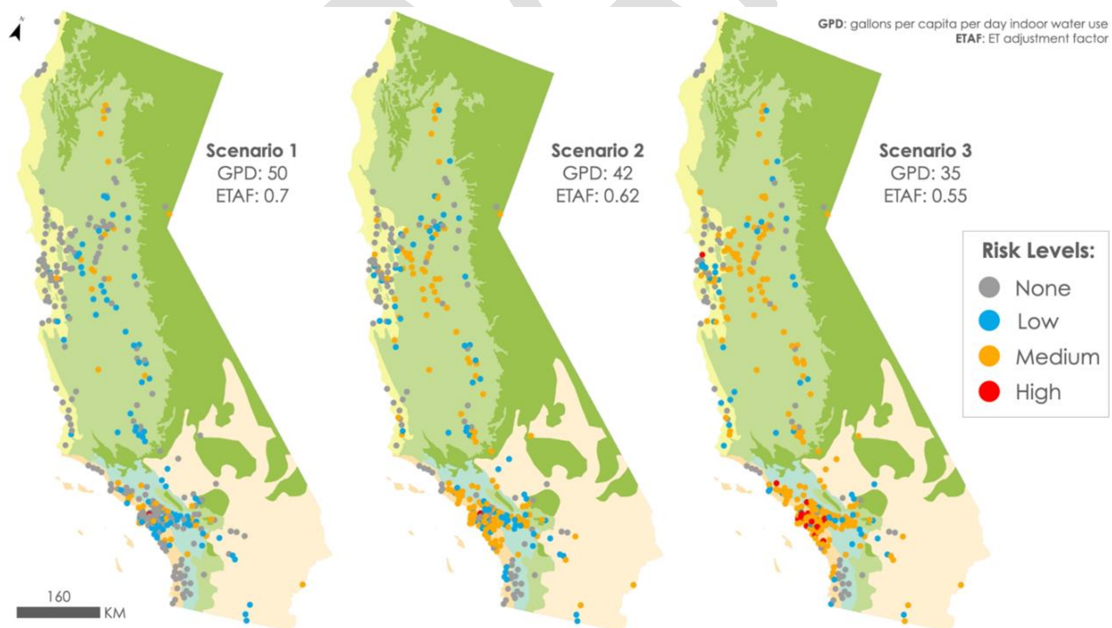
Table 7-8: Number of Suppliers in each level of risk for urban trees under three objective scenarios

Risk Level	Scenario 1 (Indoor std. = 50 GPCD, Outdoor std. = 0.70)	Scenario 2 (Indoor std. = 50 GPCD, Outdoor std. = 0.70)	Scenario 3 (Indoor std. = 50 GPCD, Outdoor std. = 0.70)
No risk	226	120	78
Low risk	87	83	52
Moderate risk	42	150	202
High risk	2	4	25

Note: Author estimates.

Although levels of risk were distributed across the state, the Northern California Coast region generally had fewer Suppliers in the higher risk categories, while the Southern California Coast region had more (Figure 7-10). In general, the wider Los Angeles region had the greatest concentration of Suppliers in the moderate- and high-risk categories under all scenarios.

Figure 7-10: Locations of Suppliers with different levels of risk for urban trees under three objective scenarios

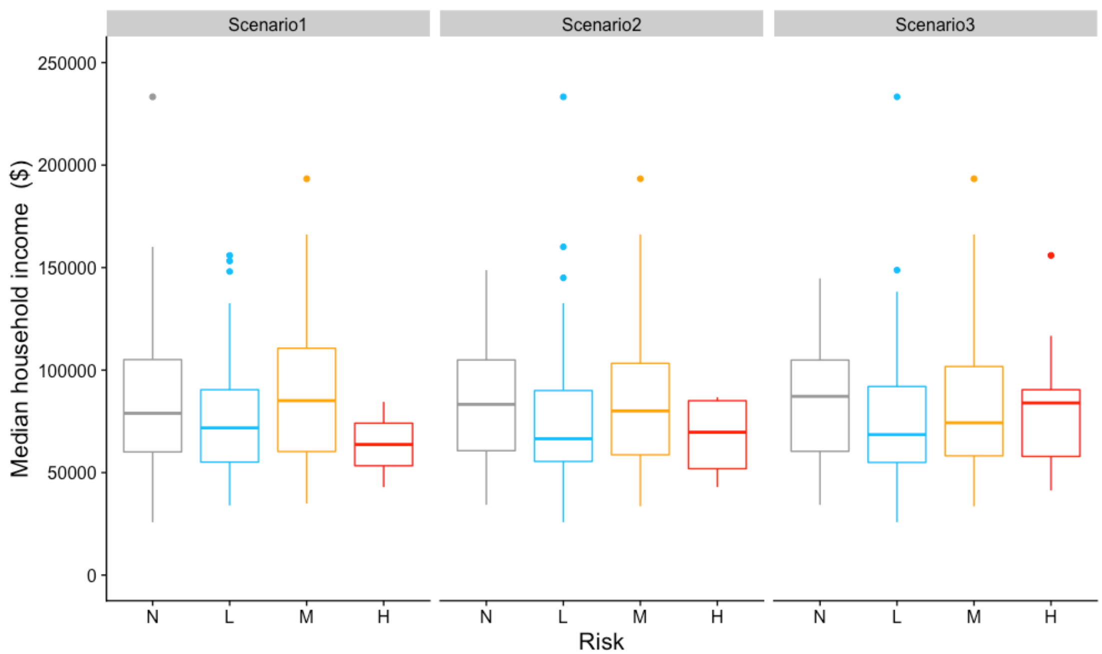


Note: Developed by authors based on multiple data sources applied through the risk framework.

Effects on Low-Income and Disadvantaged Communities

Risks to urban trees may be amplified in low-income and disadvantaged communities with fewer resources for adaptation and mitigation practices such as installing efficient irrigation systems and replacing turf with low-water-use landscaping. Risk from AB 1668-SB 606 under the three considered scenarios does not appear to be skewed by income or to disproportionately affect low-income and disadvantaged communities. There were no clear trends in the distribution of median household income (MHI) for communities served by Suppliers at different levels of risk, with wide ranges for all risk levels except the high-risk category in Scenarios 1 and 2, which included very few Suppliers (Figure 7-11). Although the median MHI value was highest for Suppliers with no risk in Scenarios 2 and 3, the median MHI value was lowest for Suppliers with low risk. MHI values were available for 350 of the Suppliers included in the risk assessment.

Figure 7-11: Median household income for Suppliers at different levels of risk in the three objective scenarios



Notes: Developed by authors. For risk levels, N = no risk, L = low risk, M = moderate risk, and H = high risk. Scenario 1: indoor standard = 50, outdoor standard = 0.7. Scenario 2: indoor standard = 42, outdoor standard = 0.62. Scenario 3: indoor standard = 35, outdoor standard = 0.55.

As noted in Chapter 4.3.7, California Water Code identifies water systems serving Disadvantaged Communities (DACs) and Severely Disadvantaged Communities (SDACs) as those with MHI less than $60,188 or $45,141, respectively. The percentage of Suppliers in the moderate- or high-risk categories was comparable across different income levels (Table 7-9). For Suppliers serving DACs and SDACs, the percent increased from 11% to 64% between Scenarios 1 and 3, while that of other Suppliers increased from 13% to 64%. However, a slightly greater proportion of Suppliers serving SDACs fell into higher risk categories. In Scenario 3, 67% of Suppliers serving SDACs were in moderate- or high-risk categories, and these communities are likely to face greater challenges to implementing water-saving measures that would protect trees. Thus, while DACs and SDACs are not affected in substantially greater proportions by AB 1668-SB 606, the consequences of water reductions for urban trees may be more severe in these areas.

Table 7-9: For the three objective scenarios, the number of Suppliers in each level of risk serving communities with different income levels

		Scenario 1			**Scenario 2**			**Scenario 3**		
		SDAC	*DAC*	*Other*	*SDAC*	*DAC*	*Other*	*SDAC*	*DAC*	*Other*
Risk level	High	1	0	1	1	1	2	2	6	17
	Moderate	3	7	32	13	28	106	17	38	143
	Low	8	24	53	6	21	55	4	13	35
	None	16	40	165	8	21	88	5	14	56
	Total	28	71	251	28	71	251	28	71	251

Note: SDAC = Severely Disadvantaged Community, median household income < $45,141; DAC = Disadvantaged Community, median household income < $60,188.

Uncertainty and Data Limitations

It is important to note that despite best efforts to improve the accuracy of vegetation water demand estimates in this analysis, some uncertainty in the risk assessment is inherent given the available data and methods, and the assumptions included in the calculations may be more accurate for some Suppliers than others. Key uncertainties for the tree water demand modeling come from assumptions that the inventoried trees are representative of the species and size distributions of the whole residential urban forest; that the sapwood area and crown area estimates of different individuals and species in an area converge on mean values; that tree canopy area accuracy and tree crown overlap do not substantially influence estimates of tree density; and that the transpiration equations for different types of trees hold across the different suites of species found in different parts of the state. Uncertainties surrounding these assumptions are magnified for Suppliers that lacked tree inventory data. Notably, Suppliers were much less likely to have inventory data if they served disadvantaged communities, leading to greater uncertainty in these areas. Only 21% of Suppliers serving SDACs and 37% of those serving DACs had inventory data, while 70% of Suppliers serving other communities had inventory data. Lack of inventory data is another factor that will contribute to challenges in planning and implementing mitigation and adaptation actions to protect trees in disadvantaged communities.

For turf water demand estimates, key uncertainties result from the assumption that 50% of the area under tree canopy was turf; that all non-canopy vegetation was turf; and that differences in the built environment did not substantially affect shading of turf that was not under the tree canopy. For areas where noncanopy vegetation already comprises primarily low-water-use species or where areas under the tree canopy are primarily unvegetated, water demand was likely overestimated and may have led to a risk rating of “moderate” where “low” would have been more appropriate. Finally, the projected outdoor water demand estimates themselves are a source of uncertainty, as the responses of individual Suppliers to the objectives are unknown, and current outdoor water use estimates are also based on calculations with embedded uncertainty.

2. Urban Parklands

Parks provide important spaces for recreation, reflection, socializing, and cultural expression, and their vegetation can contribute to the well-being of urban residents. Urban parklands are included as part of the Institutional category in the Commercial, Industrial, and Institutional (CII) outdoor water use designation as defined by AB 1668-SB 606. Outdoor water demand for park landscapes with dedicated irrigation meters are included in the regulatory framework and water use objectives. Many gaps exist in understanding the relationship between urban parks and water use, including how parklands without dedicated irrigation meters may be considered as part of the AB 1668-SB 606 legislation

2.1. Baseline Conditions

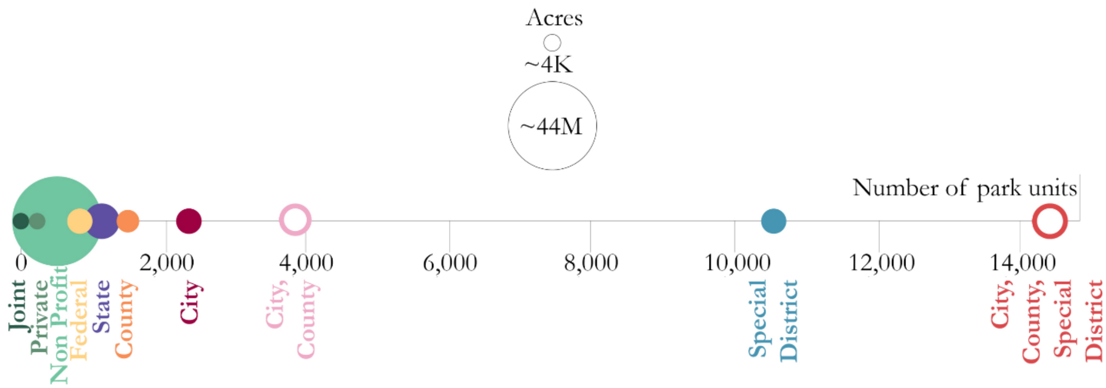
The California Protected Areas Database (CPAD) represents the most robust collection of statewide park data (Table 8-1). CPAD includes GIS and attribute data on public land area from over 1,000 agencies across the state. The dataset was developed by the GreenInfo Network and funded through the California Natural Resources Agency and others that supported work by the GreenInfo Network.

Table 8-1: Identified CPAD database for evaluating effects on urban parklands, both statewide and for case studies known to date

Data	Source	Description	Format	Year and Geographic Extent
California Protected Areas Database	GreenInfo Network	Boundaries, management agencies, and names of national, state, and regional parks and preserves	Polygon (.shp)	2020/State of CA

Using data from CPAD, the distribution of protected land units and acreage by their management agencies was assessed (Figure 8-1). The largest acreage by a single agency is represented by nonprofits, which is primarily conservation areas and land trusts. These are nonirrigated, undeveloped lands. State and federal lands are similarly dominated by nonirrigated resource management and conservation lands.

Figure 8-1: A breakdown of the California Protected Areas Database showing the distribution of protected land units (along the x-axis) and acreage (size of circles) across management agencies



Notes: Figure created by the authors. Hollow circles represent the combined counts and acreage for city and county units and city, county, and special district units

City and county as well as city, county, and special district agencies do not manage the largest number of acres. They do, however, collectively manage the largest number of individual open space units. While these three agencies manage a range of land types from recreation spaces to resource management and conservation areas, they manage all but one of the 9,407 "Local Park" units (~370,000 acres) and all of the 2,006 "Local Recreation Areas" (~300,000 acres) within the CPAD.

Looking at just the "Local Park" units managed at the city, county, and special districts level, 70% are under 10 acres. In highly-developed regions, these predominantly smaller units are largely embedded in the urban landscape. For both developed and undeveloped parklands in the urban environment, water demand is determined not only by vegetation type and climate zone, but also the complex interactions of the surrounding built infrastructure. This is in contrast with open spaces with greater acreage, where the landscapes are more uniform, simplifying evapotranspiration patterns.

Urban Park Landscapes and Management

Urban parks in California range from highly managed turfgrass sports fields and botanical gardens to less intensively managed parks or conservation areas. While the maintenance of turfgrass, young trees, and gardens often requires noticeable interventions, such as irrigation, mowing, weeding, and pruning, even park areas that appear naturally vegetated may still be actively managed to promote or remove certain species (Gobster 2013) and reduce fire risk (Doyle 2019).

Climate is particularly crucial to the maintenance of highly-managed urban parks. Where water is scarce, management of turfgrass and high-water vegetation depends on water availability and budgets that accommodate the cost of scarce, often imported water. Where water is more abundant, urban parks with turfgrass and high-water vegetation require fewer irrigation interventions, and park managers do not need to allocate as much of their budgets toward obtaining sufficient water.

While water availability and cost may determine the capacity for urban park managers to maintain certain types of landscapes, the various preferences of local publics for specific kinds of parks shape their distribution and characteristics. These preferences have been related to factors including age and race (Elmendorf et al. 2005; Payne et al. 2002). For instance, in Los Angeles, seniors expressed interest in using park space to grow vegetables and fruits (Loukaitou-Sideris et al. 2016), while middle school children were more attracted to playing fields (Loukaitou-Sideris and Sideris 2009). Equitable access to and benefit from parks can thus be enhanced by designing parks to accommodate the preferences and needs of particular underrepresented communities. Incorporation of these design considerations may involve altering the ways in which vegetated areas are managed (Gibson et al. 2019). These considerations sit alongside the resource constraints—water availability, budgets, staffing, etc.—that influence park vegetation management.

2.2. Mitigation and Adaptation Strategies

Managers of open space and parklands across California's climate zones face pressures to preserve greenness and mature vegetation. In water-scarce regions and areas that may need to adjust water use based on the new objectives, the preservation of greenness may conflict with water conservation. As climate change progresses, regions of the state where parks departments have previously known only temporary water scarcity may find that they face an inexorable tradeoff between conservation and the maintenance of existing vegetation.

Some vegetation has the capacity to adapt to changing irrigation patterns. Turf, and unshaded turf in particular, is a water-intensive land cover often found in California parks and recreation areas. It has been shown that turf with poorly developed root systems can be successfully weaned from overwatering over the course of several seasons (Glenn et al. 2015). However, the adaptive timing and strategies of other mature vegetation like trees to changes in irrigation regimes are less uniform and are subject to cascading effects from irrigation changes on nearby vegetation, including turf (Bijoor et al. 2012a; Cernusak 2020).

Due to the complexity of the urban landscape with its diversity of plant compositions, ages, and adaptations, quantifying the overall effect of changing irrigation regimes on urban parklands is quite challenging. The creation and maintenance of verdant, mesic landscapes is a resource-intensive undertaking that may become financially or practically infeasible for some urban parks departments as water becomes scarcer and more expensive. However, new water use efficiency objectives and projected changes in water availability create opportunities to maintain the value of open spaces by adapting landscapes such that they reflect the resources available in specific contexts, and in some cases, redefine what a valuable open space looks like. Alternatives that minimize the use of the most water-intensive forms of vegetation (i.e. varieties of turf or more targeted use of turf) yet remain hospitable, welcoming, and appropriate for a variety of recreational activities exist. Examples include the mixture of mature trees and packed dirt surfaces typical of older urban parks in Latin American cities, and contemporary landscape designs that make extensive use of native and drought-tolerant species palettes, limiting turf to high-use and recreational areas.

Urban parks departments' choices of water use mitigation and climate adaptation measures will depend on local climatic, economic, and social factors. Generally speaking, however, parks departments in wealthier locations will be more likely to experiment with and implement technological measures to more accurately measure park water consumption and increase irrigation efficiency. This is because submetering of existing water lines and installing smart irrigation systems are significant capital expenses that are out of reach of many municipal parks departments. These measures may be deployed to maintain parks with mesic landscapes at lower long-term cost or may be installed as part of drought-tolerant renovations of existing urban parks. Urban parks departments in areas with smaller tax bases and smaller budgets may be unable to finance such technological upgrades, and so will be forced to find other means of adapting to increasing water scarcity. Such measures may include the reducing turf to selected spots, eliminating turf in favor of synthetic or organic surfaces, or forgoing cultivation of underused areas.

Regardless of the fiscal resources available to parks departments, increasing water scarcity, the scrambling of previously stable precipitation patterns, and increasing average temperatures will entail rethinking the extensive use of turf and may threaten to diminish tree canopy cover in urban parklands. Ideally, attempts to preserve or expand urban tree canopy will involve choosing more climate- and water-conscious species and reassessing irrigation methods than were implemented in the past: for example, parks departments could determine whether existing trees can adapt to new irrigation practices in current and projected climate conditions and replace those that cannot with species better adapted to such conditions as existing trees die off. In some areas, especially in arid climate zones with few large tree species, it may be most practical to adopt alternatives to large trees for shading, such as shade arcades or ramadas.

2.3. Results: Effects on Urban Parklands

To address the current gap in our understanding of the applicability of the new objectives on urban parks and inform statewide decisions about data collection related to parks and water use, the team adopted a case-study approach. The team conducted semi-structured interviews with case study agencies to 1) assess if urban parkland areas could directly fall under the AB 1668-SB 606 framework, 2) evaluate broader issues of water management for parklands, and 3) understand any actions parks managers have taken and can take to adapt to changing water availability.

2.3.1. Analysis of CPAD Database

The CPAD was used to identify parks and management agencies across the state potentially served by a URWS and therefore potentially subject to the new objective.

All park boundaries within the CPAD that lie within a service area boundary were extracted and filtered to target local urban park agencies that maintain at least some irrigated, highly-managed spaces. Because not all park units fit perfectly within retailer boundaries, only open space units that were over 50% contained within a supplier boundary were considered. A summary of that breakdown can be found in Table 8-2. While there are potential inaccuracies in the CPAD and possible unintended exclusions and inclusions due to the filtering process, the refined CPAD layer gives a baseline understanding of the distribution of managed parklands across the URWS. This table does not include special district areas, which account for a large portion of the number of local park and recreation areas, because they were not included as case studies.

The parks layer was refined further by joining park boundaries to the six climate zones. Parks within the resulting layer were split based on climate region, and the number of park units, acreage, and associated URWS were aggregated based on the management agency. A more detailed breakdown of the distribution of local park units and acreage across the suppliers and climate zones is available in Technical Appendix-8.

Table 8-2: A breakdown of the California Protected Areas Database that shows the distribution of parks and park acreage within the boundaries of the Suppliers at varying stages of the filtering process

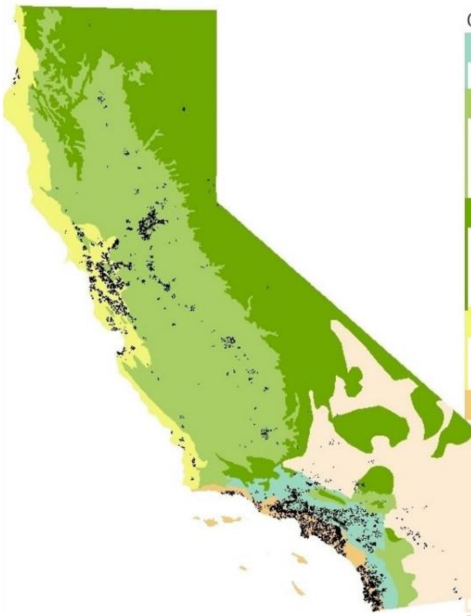
Geographic Area	**Open Space Units**		**Acres**			**Suppliers**
	Total	*% of total CPAD units*	*Total*	*% of total CPAD acres*	*% of total URWS service area*	*Of 413*
CPAD	17,155		49,515,946			409
>50% Contained by URWS	13,800	80	1,062,277	2	12	406
"Local Park" & "Local Recreation" Units >50% Contained by URWS	10,546	61	326,765	1	4	403
City/County "Local Park" & "Local Recreation" Units >50% Contained by URWS	9,298	54	244,409	<1	3	382

Notes: Calculations by authors based on analysis of the CPAD database. City of Vernon, Myoma Dunes Mutual Water Company, California Water Service Company Antelope Valley, and San Bernardino County Service Area 70J do not intersect with the CPAD boundary areas.

2.3.2. Case Studies

A list of potential case study agencies was compiled. Each climate zone was represented and, when possible, diversity of population and park density within each climate zone was considered. Figure 8-2 shows the characteristics of a sampled selection of case study agencies along with the distribution of their parks across the climate zones. Eight semi-structured interviews were completed.

Figure 8-2: A sample selection of case study park agencies that span the six climate zones. The number of potential water Suppliers is listed in the URWS column



Climate Zone (CZ)	URWS	Parks in CZ	Acres in CZ	% Parks in CZ	% Acres in CZ	% Acres in City/ County
Inland Empire	40	52	3,361	3%	5%	**0%**
	3	41	623	2%	1%	2%
Inland Valleys	2	55	1,650	2%	4%	2%
	2	88	1,287	4%	3%	2%
	4	207	3,595	8%	8%	6%
	10	15	7,095	1%	15%	**1%**
Interior West	1	9	203	20%	36%	2%
	1	5	118	11%	21%	1%
	1	7	29	13%	4%	0%
	1	9	88	17%	12%	0%
N CA Coast	3	196	2,650	10%	5%	9%
	3	182	1,577	9%	3%	1%
	1	28	104	1%	0%	2%
S CA Coast	7	32	4,804	1%	4%	**0%**
	10	460	20,732	15%	16%	13%
	2	118	1,917	4%	2%	6%
	3	43	821	1%	1%	7%
SW Desert	1	13	93	6%	4%	1%
	1	10	243	4%	8%	**0%**
	1	21	67	9%	2%	1%
	1	15	129	6%	4%	3%

Notes: Created by authors. While multiple suppliers may be listed, some park facilities may be exclusively or partly supplied by other water sources such as local groundwater. The map on the left shows the estimated park area (in black) of all the agencies listed in the table.

2.3.3. Interviews with Park Management Agencies

Semi-structured interviews, consisting of both specific and open-ended questions, were conducted with urban parks department managers and staff to serve as case studies. Interviews explored basic information about the parks and water management strategies including irrigation infrastructure and watering regimes, water sources, plantings, mitigation actions the park managers have used to deal with drought conditions, as well as any budgetary concerns related to water management and vegetation maintenance. In addition, impacts of water and vegetation management activities on park users were also discussed. Table 8-3 summarizes basic information about each of the parks departments interviewed.

Table 8-3: Descriptions of urban parks departments interviewed and responses to basic questions regarding irrigation techniques, water sources, and the presence of dedicated meters

Case Study	Parks System Description	Park Acreage	Irrigation Methods & Technologies	Water Sources	Presence of Dedicated Meters
Case Study 1	Parks with both developed and undeveloped park land; about 1/5 of the total acreage are regional, community, neighborhood, mini, and joint use parks.	over 40,000 acres	• Automatic controllers w/ timers • Manual Irrigation with weather-informed pause and resume notifications from department	• Imported potable water • Recycled water	• Dedicated water irrigation meters on parks are billed separately.
Case Study 2	Very large and varied urban parks system. Includes neighborhood parks, regional Parks, aquatic centers, golf courses, wildlife and conservation Areas.	Over 70,000 acres	• Weather-linked, computer-controlled irrigation • Automatic controllers w/ timers • Manual Irrigation	• Local groundwater • Groundwater wells • Local surface water • Imported water • Recycled water	• Both single combined meter and dedicated metering are common. No information on the proportion.
Case Study 3	Parks system includes large areas of working and wild lands, including the American River Parkway. Includes neighborhood parks, golf courses, and athletic centers.	Over 10,000 acres	• Weather-linked, computer-controlled irrigation. • Automatic controllers w/ timers • Manual Irrigation	• Local groundwater • Groundwater wells • Imported water	• No dedicated meters.
Case Study 4	Large system of mostly urban parks, including athletic and aquatic centers, and coastal recreation facilities. Includes Golden Gate Park.	Over 3,000 acres	• Weather-linked, computer-controlled irrigation. • Automatic controllers w/ timers • Manual Irrigation	• Recycled water (70% of consumption in 2022) • Local groundwater • Groundwater wells • Imported water	• Both single combined meter and dedicated metering are common. All new parks require a dedicated outdoor/irrigation meter.

Case Study 5	Medium sized parks system, mostly neighborhood parks and athletic fields, some natural areas. Department responsible for street medians and other accessory areas. Includes the Kern River Parkway.	Over 6,000 acres	• Weather-linked, computer-controlled irrigation. • Automatic controllers w/ timers • Manual Irrigation	• Local groundwater • Groundwater wells • Recycled water	•Some parks have dedicated outdoor meters; others do not, respective proportions unknown.
Case Study 6	Medium sized parks system, neighborhood parks, large athletic facilities, etc. Responsible for housing development frontage areas.	500 acres	• Automatic controllers w/ timers • Manual Irrigation	• Local groundwater • Imported water	•Some parks have dedicated outdoor meters; others do not, respective proportions unknown.
Case Study 7	Neighborhood parks, natural recreation areas, recreation centers, etc.	Over 40 acres	• Networked automatic controllers with timers • Manual Irrigation	• Local groundwater • Groundwater wells • Recycled water	•Single meter for parks, billed on volume of incoming water.
Case Study 8	Neighborhood parks, natural recreation areas, recreation centers, etc.	Over 100 acres	• Manual Irrigation	• Imported water	• Most parks on a single meter; some adjacent facilities metered separately.

Open-ended questions during the interviews were meant to stimulate conversation about the specific characteristics of parks systems, the populations that use them, and the difficulties that parks managers face – especially those related to climate change and increasing water scarcity. When the responses of the parks departments interviewed were compared, several themes emerged:

- **The presence of dedicated outdoor meters depends on administrative organization, water source, and age of the park infrastructure:** Across the surveyed park systems, there is very little consistency with respect to the use of dedicated meters for outdoor watering. The presence of dedicated outdoor meters depends on the age of parks, a particular park management agency's administrative and organizational structure, and the source of water for irrigation. None of the park management departments interviewed have fully submetered facilities and irrigation systems. Some departments, eager to understand trends in their water consumption so as to irrigate more efficiently, would prefer to submeter more of theirs.

Some parks managers contend that, with a better understanding of their outdoor water consumption, they can better assess their irrigation practices and appropriately adjust techniques or plant palettes. Dedicated meters are typically installed when there is a compelling fiscal or practical reason to know how much water is being used to irrigate certain parks. Retrofitting existing parks with dedicated meters is also an expensive proposition, and consequently it is rarely done; the desire to get "more data" on outdoor water consumption is often not a high priority for municipal governments. Other budget items take priority.

- **Automatic irrigation systems help save water and labor, but must be supervised:** All districts noted the utility of automated irrigation systems. They all noted that such systems are valuable technologies that increase efficiency of water delivery and, critically, help parks departments economize on labor. Automated irrigation systems allow management agencies to irrigate consistently with fewer work-hours dedicated to the task. Such systems are not, however, a replacement for an experienced and conscientious facility staff. Systems must be monitored, inspected, and maintained if they are to yield maximum value. Multiple districts noted that their automated irrigation systems reduce the number of work-hours devoted to irrigation and allow them to maintain their parks with smaller crews and less contract labor. Human intervention is necessary to alter irrigation patterns in response to seasonal changes, special events, and unforeseeable circumstances. All parks departments with automated systems, networked or not, weather-linked or not, have invested considerable time and resources to install, calibrate, and maintain them. These are capital investments with long service lives and are not easily altered or reorganized.
- **In some locations, water delivery infrastructure needs repair:** When asked about efforts to economize on water use in parklands, several agencies noted that the condition of the water delivery infrastructure feeding their parks, and the large water pipes within those systems, is of major concern. One agency cited the condition of internal water delivery infrastructure as a barrier to upgrading their irrigation systems. Compatibility issues between old and new water delivery and irrigation technologies is also a major reason why parks departments forgo-submetering.
- **Anxiety over water rate increases in park departments that rely heavily on urban water retailers:** Water rates can change during particular periods, such as during drought when Suppliers implement surcharges to pay for conservation programs. Multiple park agencies noted that changes in water rates was a major concern, citing the lack of predictability and the cost/availability of water during the most recent extended drought period as reasons for their renewed interest in eliminating waste and curbing consumption. Park management agencies that purchase water, especially potable water, from urban retailers are most anxious to reduce their consumption. One district noted a perverse dynamic between the department and the urban water retailers that serve its parks. The district stated that it had seen their water rates increase or have had their accounts be reclassified into higher rate tiers in response to their decreasing use. The department noted that these rate increases may consume any budgetary slack generated by reductions in water consumption. Large park management districts may receive water from multiple Suppliers that have different rates, further complicating tracking and interaction with those Suppliers.
- **Standard measures to reduce parklands water consumption—converting parks to "drought-tolerant landscaping," installing drip/bubbler irrigation, switching to recycled water—are neither simple nor cheap:** All park management agencies interviewed have pursued one or more of these measures to permanently reduce their water

consumption in response to either fiscal pressure, the effects of prolonged drought, or climate change. (The reasons given by park departments varied.) All of them also reported that none of these measures alone was a panacea for hitting conservation goals, but could yield reductions in water consumption if pursued diligently with appropriate resources. Several parks departments mentioned that public desire for mesic park landscapes and municipal regulations requiring public hearings and comment periods discouraged them from developing drought-tolerant conversion plans for city parks. Extensive use of recycled water is also only possible in contexts where the infrastructure to purify and deliver it at an acceptable cost already exists. One agency had already committed considerable investment of public funds over the course of a decade to support a complete transition to recycled water for park irrigation.

- **The public enjoys a variety of amenities and landscapes:** All of the representatives from park management agencies mentioned that the people they serve value a range of amenities and park types, especially neighborhood parks. Despite the costliness of maintaining well-watered turf, multiple agencies across both coastal and inland climate zones noted that their residents want at least some turf areas for socializing and recreation. Managers from these departments said that proposing to eliminate turf completely would likely engender significant public opposition. One district in particular noted that it had an interest in the increased application of xeriscaping and had recent success implementing xeriscaping in a small neighborhood park. However, the agency expected significant pushback if they were to propose the elimination of turf in regional parks.
- **Public perception of how to implement drought mitigation in parks is mixed:** All park management agencies representatives said that the public both takes drought mitigation seriously, yet also wants verdant, healthy vegetation in parks. Multiple agencies said that, during the last drought period, residents were keen to report leaks from infrastructure or park water use they felt was wasteful or inappropriate. Residents were either attempting to help the park management agencies find and fix leaks, or were angry about what they saw as profligate use. Meanwhile, other members of the public have complained about brown turf and watering restrictions remaining in place beyond the summer months.
- **Climate change adaptation is taken very seriously by some parks departments, less so by others, but is not yet a budgetary priority for most:** While most of the parks departments interviewed said that climate change and increasing water scarcity are of grave concern to them, most of the pressure to reduce water consumption has been driven by recent drought conditions and related fiscal impacts, such as one-time investments in efficient irrigation fixtures or increased bills due to drought-based surcharges. None were being instructed to prepare integrated plans that included extensive adaptation measures based on down-scaled climate projections. All of the park management agencies except San Francisco receive water consumption data from their billing departments, sometimes only in terms of dollars spent on water rather than volumes of water consumed. Water consumption is primarily thought of as a fiscal issue, and proof of a particular water-saving intervention's effectiveness is rarely measured in terms of water saved, but rather dollars saved. Currently, drought mitigation is often considered to be equivalent to climate adaptation.

2.3.4. Summary

A key political difficulty inherent in adapting to climate change is deciding how to balance water conservation with the desires of the public. Parks are vital pieces of urban infrastructure, and as is evident from conversations with parks managers, there exists a desire among many to adapt to new climatic conditions (reducing water consumption by technological means and cultivating less water-intensive vegetated landscapes) and to rationalize the management of parks, treating them more like roads and the electrical grid, which are instrumented and monitored for performance.

Mitigating drought and transitioning to climate-appropriate landscapes are expensive and complicated tasks, and a purely technological approach to either or both appears not only prohibitively expensive for most parks departments, but also unlikely to yield the dramatic reductions in park water consumption that municipal governments or water agencies may call for. In some regions, municipalities are already demanding such reductions, especially during drought. Integrated landscape management plans that make use of local climate projections are necessary to accomplish this task. New thinking about how to create aesthetically pleasing landscapes that eliminate the thirstiest forms of land cover is also needed.

Water scarcity will undoubtedly drive landscape change. Examples exist of welcoming parks and open spaces that use turf more sparingly, targeted to the most important recreational needs, while implementing a creative new approach to landscaping other recreational spaces. Examples can be found in other parts of the world, and even in California's historical parks, like around missions, where this is the norm and is accepted. The tree palate will also have to evolve over time to ones that are more adapted to California's shifting climates, with some losses in the interim. While trees have been the main (and patchy) approach to creating shade in neighborhoods, other approaches also exist and have been long utilized in hot, dry climates, including shade arcades, shade structures, street configurations that take advantage of shade cast by buildings, and more. The changing climate in the state is demanding novel approaches that better integrate open space and shading into planning urban morphology. This can be done in a way that increases equity to amenities across cities and does not end up correlating those amenities with wealthier neighborhoods. Water scarcity is an opportunity to improve thermal comfort for urban residents and access to open spaces that cities can maintain with their limited fiscal capacities.