Climate-Ready Tree Study: Update for Southern California Communities

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Introduction

Planting and stewardship of tree species well-suited to site growing conditions in the future as well as the present is an important urban forest climate adaption strategy (Roloff et al., 2009; Yang, 2009). Stressors associated with climate change, such as drought, heat, pests and extreme weather events are already increasing mortality in forests (Allen et al., 2010). Adverse effects on tree health can be amplified in cities because of urban heat islands and the impacts of existing stressors such as inadequate soils, polluted air, contaminated runoff and mechanical damage from construction activities, equipment, vehicles, and vandals. In the Southwest, urban forests are especially vulnerable to climate change stressors because most predominant native and non-native species rely on supplemental irrigation to augment natural precipitation (Hartin et al., Van der Veken et al., 2008).

Identifying and testing the resilience of tree species to climate change stressors is critical to the long-term stability of urban forests. By gradually shifting the planting palette to climate-ready trees, future generations can benefit from healthier and more resilient urban forests (McPherson and Berry, 2015).

This paper describes our initial evaluation of survival and performance of 14 species of trees being tested in Southern California's Inland and Coastal communities as part of the statewide Climate-Ready Trees study. The study was initially funded by the Western Chapter International Society of Arboriculture Britton Fund. This update follows a report in Western Arborist on the early performance of trees evaluated in the Sacramento region (McPherson et al. 2017).

Methods

Our approach used a 5-step process to identify and evaluate the vulnerability and suitability of tree species (McPherson et al. 2018) to climate change pressures. Vulnerability was defined as the degree to which a species is affected by and unable to cope with adverse effects of climate change (Glick et al. 2011). Trees were selected for testing based on evaluation of climate induced risk factors that impact their vulnerability or resilience. Risk factors used in the analysis are (1) habitat specificity: sunlight exposure, soil texture and pH, soil moisture (2) physiology: drought tolerance, salt tolerance, wind tolerance (3) biological interactions: invasiveness, major or minor pests and diseases, emerging pests and diseases. Coastal and Inland climate zones were identified based on aggregating Sunset climate zones (Fig. 1). Twelve species of trees were selected for evaluation in each climate zone based on input from horticulturists, quantitative rankings and availability from local nurseries. The same 10 species were planted in both climate zones, while the remaining two species varied (Table 1). Within each climate zone, the 12 species of trees were randomly planted in a reference site and each of 4 parks. Four replicates were planted in the reference site (4 replicates x 12 species, 48 trees), South Coast Research and Extension Center (SCREC) (Coastal) and University of California Riverside Citrus Experiment Station (Inland). Irrigation schedules were based on real-time reference evapotranspiration (ETo) estimated by California Irrigation Management Information System weather stations and varied by site. All other maintenance practices such as pruning, weed control, and pest management were the same at both sites. An additional 96 trees were planted in 4 parks (2 replicates per park, 24 trees per park). Long-term field testing at the UC plots and in nearby parks allows for direct comparisons of growth and longevity under a range of site conditions. Growing conditions and maintenance activities were more variable among park sites than reference sites. All trees are evaluated annually for the first 5 years after planting, and biannually thereafter for 15 years.(Fig. 1).

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Trees were obtained from 3 nurseries, ranging in size from bareroot to 24" box, and were planted February

Figure 1. Locations of park and reference planting sites in the Inland and Coastal climate zones.

through April 2016. Volunteers coordinated by the Hollywood Beautification Team planted park trees, with guidance from City of Los Angeles Recreation and Parks Department staff. UC staff planted trees at the Irvine and Riverside reference sites. Specific planting locations within each site were randomly assigned to each species, and trees were well watered and staked according to industry guidelines at the time of planting. A four inch mulch layer was applied at all sites after planting and reapplied as needed.

Trees that died within the first weeks after planting due to transplanting stress were replaced during the second year of the project. Trees that died for other reasons were removed and not replaced. Tree growth, health, and performance were evaluated during summer in 2016, 2017 and 2018. Further information on criteria for selecting the 14 species, experimental design and monitoring can be found in the publication "Performance Testing to Identify Climate-Ready Trees" (McPherson et al., 2018).

The UCCE reference plots in Irvine and Riverside are flat field sites. The sandy loam soils have a neutral pH (7.5-7.7). Trees received ample drip irrigation during the first three years of establishment.

The four Coastal parks are flat turf areas that receive recreational use and regular irrigation. Soils in Westchester and Vista Del Mar are very sandy. Vista del Mar has very low soil nitrate (3.3 ppm) and is subject to salt spray because it is adjacent to the Pacific Ocean. Bogdanovich Park is perched above the ocean, and somewhat sheltered by groves of mature trees. Westchester and Jim Gilliam Parks are further inland, and less strongly influenced by maritime weather effects. Some trees in Jim Gilliam Park appeared to be over-irrigated.

Four Inland parks are in the San Fernando Valley. Trees in the Hansen Dam Recreation Area (off the Foothill Freeway, 210) are on an east-facing slope with intermittent grass and irregular irrigation. The Valley Plaza site (North Hollywood) is adjacent to the 170 Freeway. Sandy soil and various broadleaved weeds challenge tree growth. The turf at Woodley Park (Van Nuys, 405) is healthier and more uniformly irrigated than at the other two parks. Trees in the Holleigh Bernson Memorial Park (Porter Ranch) appear over-irrigated and are subject to the windiest conditions.

Data from the CIMIS stations closest to the reference sites collected during 2016-18 indicated that transplants were not exposed to unusual temperatures. In Riverside trees were briefly exposed to air temperatures below freezing (-0.4 °C for 1 hour in 2018). Over the 3-year period in Riverside, ETo averaged 12% more than the historic normal (1,320 mm), and average annual temperature by month was 6% greater. During 2016-18, annual precipitation at the Riverside reference site was 10% less than the historic normal (220 mm). In Irvine the average ETo for 2016-18 was comparable to the historic norm (1,276 mm), but average annual precipitation was 30% less than the historic norm (316 mm). These data indicate the importance of irrigating based on real-time ETo rather than historical ETo to avoid drought stress.

Results and discussion

Overall, 88% of all trees survived the first three years and survival rates for trees in reference sites (95%) were greater than for trees in parks (84%) (**Table 1**). Inland trees had a higher survival rate (92%) than Coastal trees (83%), despite exposure to greater evaporative stress. The unusually high rate of mortality for trees in the Coastal Vista Del Mar Park (54%) was largely responsible for this result. The high loss rate at Vista Del Mar is attributed to the cumulative effects of strong winds, salt spray, clouds and cool weather. Symptoms of stress included lack of foliage on the windward side of tree crowns and desiccation from salt spray (**Fig. 2**).

Trees in Coastal Westchester Park had 83% survivorship, while rates ranged from 88-92% in the other 6 parks. The trend of higher survival

Table 1. Survival rates (%) for park and reference sites in the Southern California Coastal and Inland climate zones.									
	Park Sites			Reference Sites			All Sites		
Survival (2016-2018)									
	Coast	Inland	All	Coast	Inland	All	Coast	Inland	All
Acacia aneura[a] (Mulga)	100	88	94	100	100	100	100	92	96
Cedrela fissilis[b] (Brazilian Cedarwood)	63			100			75		75
Celtis reticulata[a] (Netleaf Hackberry)	100	100		100	100		100	100	100
Chilopsis linearis 'Bubba'[c] (Desert Willow)		88			100			92	92
Corymbia papuana[a] (Ghost Gum)	63	100		75	100		67	100	83
Dalbergia sissoo[a] (Rosewood)	75	100		100	100		83	100	92
Hesperocyparis forbesii[a] (Tecate Cypress)	38	75	56	50	75	63	42	75	78
Mariosousa willardiana[a] (Palo Blanco)	63	100	81	75	100	88	67	100	83
Parkinsonia x 'Desert Museum'[c] (Palo Verde)		100	100		100	100		100	100
Pistacia 'Red Push'[a] (Red Push Pistache)	75	100	88	100	100	100	83	100	92
Prososis glandulosa x Maverick[a] (Mesquite)	100	100	100	100	100	100	100	100	100
Prunus ilicifola spp. *Lyonii*[b] (Catalina Cherry)	88		88	100		100	92		92
Quercus fusiformis[a] (Escarpment Live Oak)	88	38	63	100	100	100	92	58	75
Quercus tomentella[a] (Island Oak)	88	88	88	100	100	100	92	92	92
	78	90	84	92	98	95	83	92	88
a. in both Coastal and Inland sites									
b. Coastal sites only									
c. Inland sites only									

Figure 2. The native Catalina cherry (*Prunus ilicifolia* ssp. *Lyonia*) is one of the few species surviving in Vista Del Mar Park. Loss of windward crown structure and foliar desiccation from salt spray are shown in these figures.

rates in the Inland rather than Coastal climate zones was found for the Reference sites (98% Riverside, 92% Irvine).

Survival rates for the 10 species that were planted at both Coastal and Inland sites were lowest for escarpment live oak (75%, *Quercus fusiformis*) and Tecate cypress (78%, *Hesperocyparis forbesii*). The original oaks were dug bare root in Arizona and transported to holding sites in Los Angeles. Some trees died due to drying of roots during handling. Boxed replacement oak trees had higher initial survival rates. A root rot disease (*Phytophthora* spp.) was identified as the primary cause of death for two Tecate cypress trees that exhibited twig die-back at the Irvine reference site. Although this species is performing poorly in Coastal parks and

Figure 3. Brazilian cedarwood (left) and mulga (right) at Westchester Park near the Pacific coast. Note that the Brazilian cedarwood's crown is relatively sparse during the early years. This mulga requires pruning for structure and form.

the reference site, the other California natives, Catalina cherry (*Prunus ilicifolia* ssp. *Lyonii*) and island oak (*Quercus tomentella*) had 92% survival rates. In the Inland climate zone, escarpment live oak (58% survival) and Tecate cypress (75%) had the lowest survival rates.

Ghost gum (*Corymbia papuana*) and palo blanco (*Mariosousa willardiana*) had 83% survival rates, with all losses in Coastal parks and reference sites. Both species are native to arid environments (Australia and Sonora, Mexico) and are not very tolerant of cool, moist, coastal conditions.

Of the 4 species planted in a single climate zone, Brazilian cedarwood (*Cedrela fissilis*) fared the worst with 75% survival. The 2 trees planted at Vista Del Mar died, as did 1 at Jim Gilliam Park. The lack of branching structure and weak wood make this species especially susceptible to vandalism and mechanical damage during the early years (**Fig. 3**).

Performance

Subjective performance ratings were performed for each species after visits to each park and reference site. Scoring incorporated observations of survival, pruning requirements, aesthetics, and insect and disease damage. Pruning requirement is an important consideration when selecting trees. Species that require extensive pruning to develop strong structure are more costly to maintain than those that require less pruning. Species assessed as having a high pruning requirement exhibited poor structural characteristics (e.g., codominant stems, branches with included bark, and branches with a large diameter relative to the trunk). As these trees continue to develop, growth rates and structural characteristics likely will change, and pruning requirements may increase or decline accordingly.

In the Coastal sites, top performers included escarpment live oak (*Quercus fusiformis*) and Red Push pistache (Pistacia 'Red Push`) (**Fig. 4**). These species had high survival rates, strong structure and modest pruning requirements. Species with high survival rates but requiring more frequent pruning were rosewood (*Dalbergia sissoo*), Maverick mesquite (*Prosopis glandulosa* 'Maverick`), mulga (*Acacia anuera*), and netleaf hackberry (*Celtis reticulata*).

Figure 4. Red Push pistache (left) and escarpment live oak (right) in Jim Gilliam Park. Both these species have high survival rates and are developing good crown structures without extensive pruning.

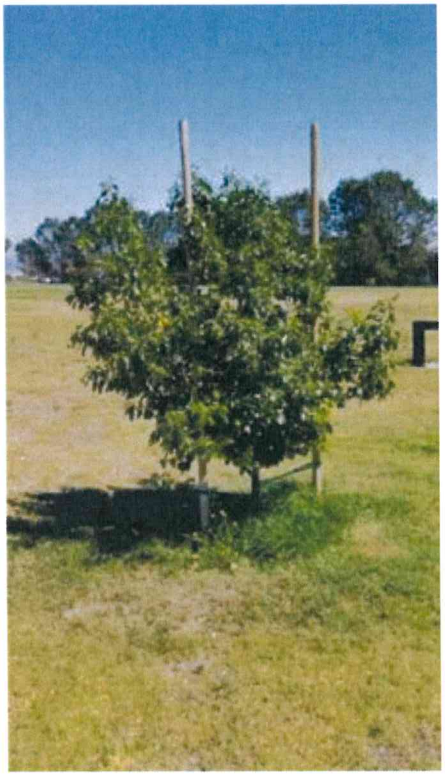

Figure 5. Catalina cherry at Bogdanovich Park has a high survival rate but is slow to establish a sound crown structure.

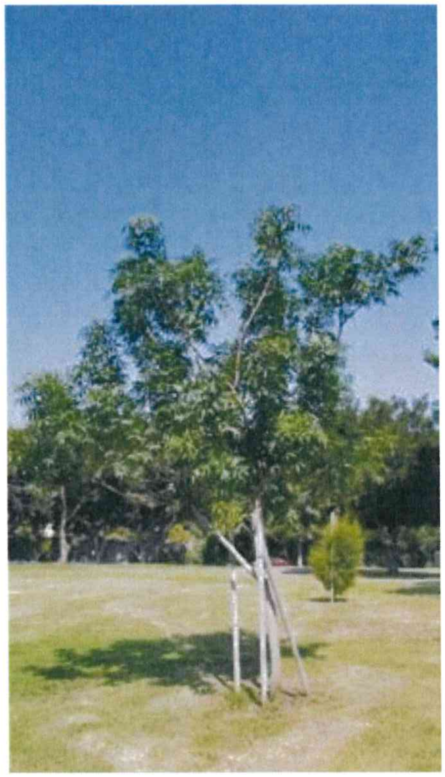

Figure 6. Red Push pistache (above left) and ghost gum (above right) at Hansen Dam Park. Both these species are top performers in the Inland sites.

Figure 7. A rosewood (below left) is thriving at Valley Plaza Park, where irrigation and pruning are minimal and the soil is sandy. Desert willow (below right) had high survival rates and flowers throughout the summer. This desert willow at Woodley Park requires some initial pruning.

Both Catalina cherry (*Prunus ilicifolia* ssp. *Lyonia*) and island oak (*Quercus tomentella*) appear well adapted to coastal conditions but remain relatively small and shrub-like (**Fig. 5**). Observation over a longer period of time is necessary to determine their suitability as attractive small trees. Brazilian cedarwood has not performed well, appearing to require more intensive care than others during the establishment period. Tecate cypress, ghost gum and palo blanco need hotter, drier conditions to thrive.

In the Inland sites, Desert willow (*Chilopsis linearis* 'Bubba`), ghost gum, and Red Push pistache outperformed the other species (**Figs. 6, 7, Table 1**). They exhibited the best survival rates across a wide range of conditions and required the least pruning. Rosewood, Maverick mesquite, netleaf hackberry and Desert Museum palo verde (*Parkinsonia* x

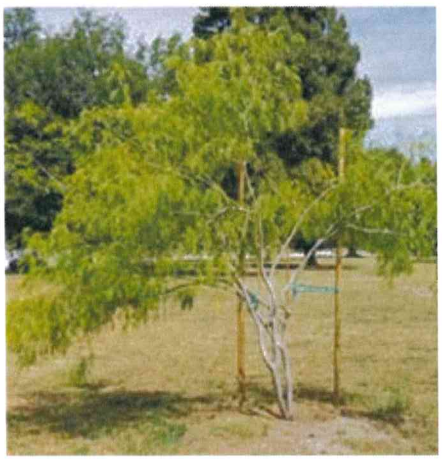

Figure 8. Attributes of (from top to bottom) the palo blanco, Maverick mesquite, and Desert Museum palo verde in Woodley Park. The crown structure of the palo blanco is very wispy. The mesquite and palo verde are developing full crowns, but they will require regular pruning for structure and form. The palo verde's yellow flowers are spectacular during late spring.

'Desert Museum') had high survival rates but substantial maintenance needs (**Fig. 8**). These species require more pruning and palo verde is subject to failure from blow-over when subjected to over-irrigation. These initial results parallel those reported for palo verde, mesquite, pistache, desert willow, and texas ebony in the Tucson area in which aesthetics, canopy density, tree quality, and overall health remained high even at 20% ETo (Schuch, 2018). While mulga, palo blanco, and island oak show promise to date, more time is needed to gauge their adaptability, pest vulnerability and pruning requirements as they mature. Tecate cypress and escarpment live oak had the lowest survival rates but merit further observation over a longer period of time before final conclusions regarding their suitability can be made. A brief description of each species can be found on the Climate Ready Trees website at: **http://climatereadytrees.ucdavis.edu/meet-the-trees/**.

Conclusions

Although it is premature to make definitive statements about tree performance through maturity, several trends merit continued observation. Certain species that are native to hot, arid conditions are not surviving and performing well in Coastal sites (e.g., palo blanco, Tecate cypress, ghost gum). Other desert species are tolerant of many Coastal conditions but require frequent pruning to maintain sound structure (i.e., Maverick mesquite, mulga, netleaf hackberry). Few of these potential climate-ready species are surviving in the extreme Coastal conditions found at Vista Del Mar Park.

Survival rates were higher in the Inland parks where growing conditions more closely matched the arid environments from which many of these species originated. Overwatering may be the greatest source of stress and responsible for crown growth that outpaces root growth for certain species (i.e., Desert Museum palo verde, Maverick mesquite). Trees like the Red Push pistache, rosewood, ghost gum and desert willow seem to tolerate the under- and over-irrigated soils in the Inland parks. Further observation is needed to determine the suitability and long-term performance of island oak, escarpment live oak, Catalina cherry, and palo blanco. Continued monitoring of growth, survival, and performance will help determine if emerging trends continue or change as each species matures.

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