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Coast Live Oak, *Quercus agrifolia*, Planting Success: Lessons from Topanga State Park, Los Angeles County, Santa Monica Mountains

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Abstract.—Oak woodlands not only provide critical habitat for hundreds of species, they are an iconic feature of California ecosystems. With extensive oak loss and little natural recruitment, the need for oak tree restoration increases. However, restorations can have varying success and can be a costly endeavor. We analyzed a 3 yr coast live oak restoration project, involving 367 plantings, located at Trippet Ranch within Topanga State Park of the Santa Monica Mountains, in Los Angeles County, to better understand factors that influence oak restoration success and its associated costs. After assessing environmental factors such as planting method, percolation rate, canopy cover, surrounding vegetation, soil type, rainfall, and year planted, we determined that planting sites resulted in significant differences in acorn/seedling survival. Based on a Random Forest analysis we determined that soil percolation, canopy cover, and planting year influenced survival across planting sites. We observed no significant difference in survival rate between acorns and seedlings. We also did not find rainfall to influence survival, potentially suggesting that continued maintenance/waterings contributed to restoration success.

Throughout California and the western U.S., native woodlands – in particular, oak woodlands – face numerous and increasing threats, including drought (Grunzweig et al. 2008; Williams et al. 2022), wildfires (Riano et al. 2002; Westerling et al. 2006), disease such as sudden oak death (Alexander and Lee 2010), extreme heat (McLaughlin and Zavaleta 2012), and resulting invasion by devastating insect pests (Clark et al. 2016) as well as invasive annual grasses which promote shorter wildfire intervals (Park et al. 2018). In urban-adjacent areas such as the Santa Monica Mountains of southern California, these threats are often compounded by development pressure (Swenson and Franklin 2000; Beltrán et al. 2014).

Recently, a combination of these factors has contributed to a dramatic, recent (post-2013) tree die off throughout Santa Monica Mountains National Recreational Area (SMMNRA), in which an estimated 32% of riparian trees were lost within the span of a few years, with local oak woodland patches showing little natural recruitment.[1] SMMNRA covers most of the natural habitat of the Santa Monica Mountains, extending from sea level to c. 915 m elevation and includes a high diversity of vegetative communities.[2] Drought, wind and heat events have

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[1] Dagit, R., S. Contreras, R. Dauksis, A. Spryka, N. Queally, K. Foster, A. Nickmeyer, N. Rousseau, E. Chang. 2017. Drought and invasive beetle impacts on wildland trees and shrublands in the Santa Monica Mountains. Final Report for LA County Contract CP-03-44.
[2] Tiszler, J., and P. Rundel. 2007. Proceedings from the 32nd Annual Southern California Botanists Symposium: Flora and Ecology of the Santa Monica Mountains.

contributed to extensive wildfires in the region. Most recently the 2018 Woolsey Fire, which affected over 38,850 ha (96,000 ac) in SMMNRA resulting in extensive loss of native woodlands.[3] Die-off of a variety of trees such as western sycamore (*Platanus racemosa*), white alder (*Alnus rhombifolia*) and valley oak (*Quercus lobata*) was widely observed; however, at 4,450 ha (11,000 ac), the most extensive and widespread woodland type in SMMMNRA is dominated by coast live oak (*Quercus agrifolia*), which saw an estimated loss of 9,000 live trees between 2013 and 2016.[1]

Coast live oak is a keystone species throughout its range along the coastal slope of California and adjacent Baja California, Mexico, supporting thousands of species of insects, amphibians, reptiles, birds, and mammals (Pavlick et al. 1991). Throughout their range, coast live oak woodlands have an ability to survive both the annual summer drought that defines Mediterranean climates, as well as cyclic climatic extremes (e.g., Pacific Decadal Oscillation, Madden-Julian Oscillation, and "atmospheric rivers" of precipitation).

Habitat restoration has emerged as a key activity to help flora adapt to climate change (von Holle et al. 2020) including oak restoration that has long been used to augment natural recruitment and replace loss of mature trees throughout California since the 1990's (Parikh and Gale 1998; Davis et al. 2019). Despite this, oak restoration efforts often see high tree mortality rates (Callaway and Pugnaire 1999; Brown and Diaz 2009). While some studies have offered strategies for selecting seeds, propagation, planting techniques and maintenance for certain oaks in rangeland, there is limited information on large-scale coast live oak woodland restoration within natural areas, particularly in southern California.

Given the local importance of coast live oak woodland, its recent die off, as well as limited observed natural recruitment in many stands, a "Priority Planting Plan" was prepared to support this species in the Santa Monica Mountains[4] which was immediately implemented in Topanga State Park in 2019. This plan used physical attributes to select locations where conditions are anticipated to support coast live oaks over the next 100-200 yr in the face of predicted climate change. To implement this plan, the authors proposed establishing at least 200 coast live oak trees in the Trippet Ranch sector of Topanga State Park, an area that had experienced extensive recent loss of mature trees, with minimal observed natural recruitment. Here we evaluate factors influencing tree survival and establishment (specifically ideal environmental conditions, and planting source) from this effort to provide management insights on how to most effectively produce new coast live oaks. As funding for restoration planting efforts is often limited, it is critical to not only maximize tree survival but also employ the most cost-effective planting strategies.

Methods

Study system.—Our study area was within the Trippet Ranch sector of Topanga State Park, located in the village of Topanga west of Los Angeles, Los Angeles County, California. Part of Santa Monica Mountains National Recreation Area, Topanga State Park extends over 4,664 ha (11,525 ac). Trippet Ranch represents a 7.3 ha (18 ac) site that was formerly a

[3] Algiers, J. 2022. Restoration plan, Santa Monica Mountains National Recreation Area 2022-2026. National Park Service.

[4] Dagit, R., T. Hartwig, C. Simon, J. Decruyenaere, D. LeFer, T. Scott, M. Witter, M. Ferriter, L. Jessup, R. Ly, and J. Spector. 2019. Los Angeles County Native Tree Priority Planting Plan for the Santa Monica Mountains National Recreation Area. Final Report for Los Angeles County Contract #SPF03-03. Resource Conservation District of the Santa Monica Mountains 12.

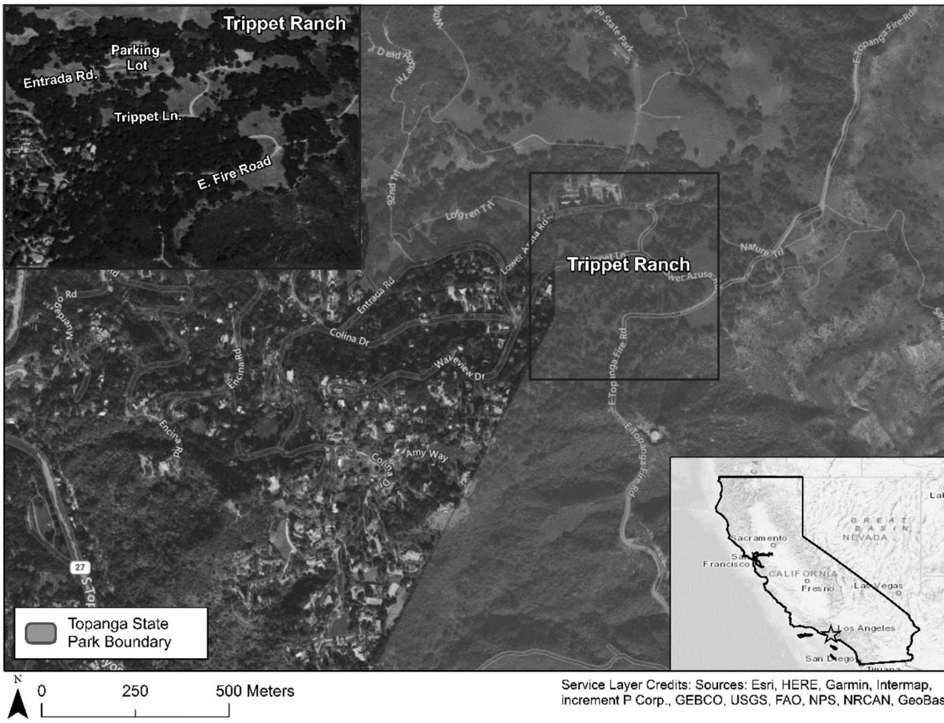

Fig. 1. Trippet Ranch within Topanga State Park, Los Angeles County.

working cattle ranch. The restoration area covers approximately 4.9 ha (12 ac) of mostly north-facing slopes southeast of the main parking area entrance from Entrada Road (Fig. 1). Trippet Ranch supports a mix of oak woodland, chaparral, and grassland vegetation, and is underlain primarily by sandstone formations with some conglomerate beds within an Upper Cretaceous Formation (Larson 2012). Dominant co-occurring shrub species include toyon (*Heteromeles arbutifolia*), blue elderberry (*Sambucus mexicana*), hollyleaf redberry (*Rhamnus ilicifolia*) and chaparral honeysuckle (*Lonicera subspicata*); the understory is dominated by a diversity of smaller shrubs and forbs, including giant wild-rye (*Elymus condensatus*) and non-native invasives such as Italian thistle (*Carduus pycnocephalus*) and various annual grasses (nomenclature follows Jepson Flora Project 2025).

We selected planting areas based on observed loss of mature oak canopy, augmenting existing woodland at locations that would reduce fragmentation and restore “canopy adjacency”, according to guidelines of the Priority Planting Plan.[3] Five distinct planting sites were selected within Trippet Ranch: 1. Amy Way; 2. Upper Topanga East Fire Road (UTEFR); 3. Lower Topanga East Fire Road (LTEFR); 4. Topanga Lane (TL); and 5. Waveview (Fig. 2).

To test soil percolation at each of the five sites, we took five soil samples that appeared representative of each site, which we analyzed using standardized methods (Derr et al. 1969). Soil percolation tests were performed at each sampling location by digging a 30 cm (12″) deep hole and filling the hole with 3.79 L (1 gal) of water. Duration of time for water to drain was recorded and averaged across each site to calculate drainage rate for the site. We categorized soil profiles by soil horizon observation, soil particle arrangement, soil texture, and soil shape retention when formed into a ball and ribbon. Seven random densiometer measurements

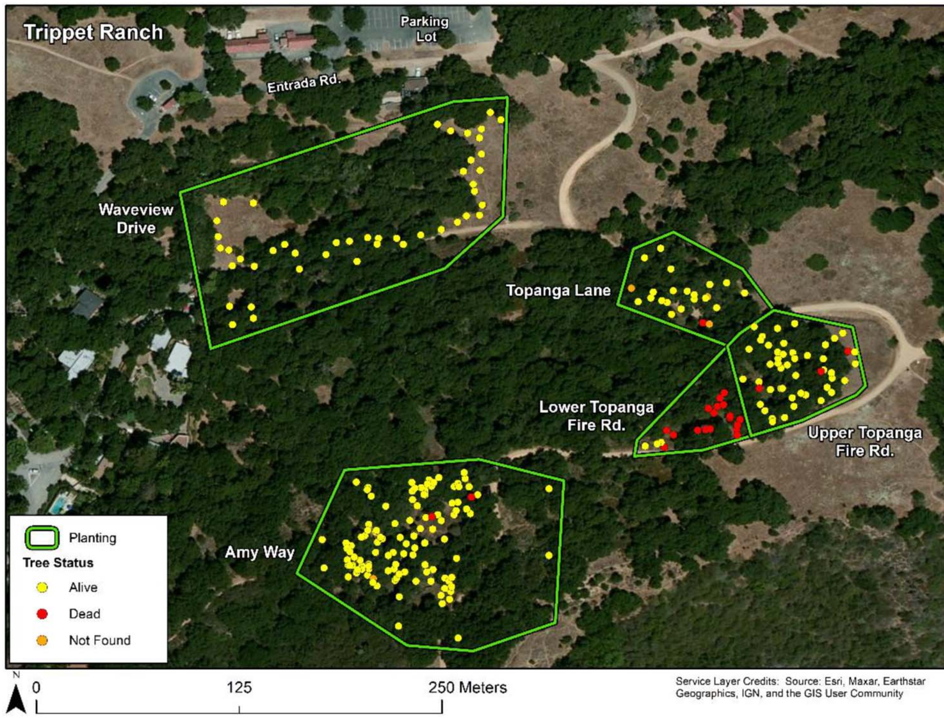

Fig. 2. All planting sites with corresponding tree status at end of restoration in December 2022. Yellow indicates surviving trees, red indicates deceased trees, orange indicates trees not found, and green boundary separates five planting locations.

were averaged to determine canopy cover by site. The five sites all had either clay loam, silty clay, or silty clay loam. Percolation rate ranged from 1.87–3.03 min./2.54 cm (1″), and the average pH ranged from 7.4–7.8. The average percent canopy cover ranged from 17.9% (Waveview) to 82.5% (LTEFR).

We also collected readings (scale of 1-10) of soil moisture at 16-20 locations spaced at regular intervals at each planting site using a XLUX soil moisture meter, and assessed the presence of mesic vegetation (indicating a high groundwater table) using six moisture-loving (in our area) species, giant wild-rye, blue elderberry, sticky monkeyflower (*Diplacus longiflorus*), western poison-oak (*Toxicodendron diversilobum*), canyon sunflower (*Venegasia carpesioides*), and hummingbird sage (*Salvia spathacea*), measured on a 0-2 scale denoting absent (0), present but rare (1), and present and widespread (2) to create a "mesic species index". These variables are summarized in Table 1. Additionally, we recorded annual rainfall in the Topanga area across all four years from 2019 to 2022 (total inches of rain, total number of rain days; Fig. 3).

Planting & maintenance.—We planted a combination of acorns and saplings (c. 0.5 m in height) throughout all five sites, recording the location of each using various handheld GPS devices. Each planting hole was excavated to a depth of approximately 30 cm (12″) deep and 60 cm (24″) wide, removing all vegetation and roots with a watering berm created. We collected acorns within the Topanga Creek watershed or in immediately adjacent watersheds in accordance with state parks provenance guidelines. For sapling planting propagation, the Los Angeles County Malibu Forestry Unit propagated acorns collected into seedlings in "Deepot"

Table 1. Variables used in analysis of oak germination and survival.

Site	Perc. Rate (min./2.54 cm)	Ave. pH	Ave. % Canopy	Mesic Spp.	Soil Moisture
Amy Way	2.07	7.4	29.4	6	1.7
LTEFR	2.02	7.5	82.5	10	1.4
TL	1.87	7.8	22	5	2.1
UTEFR	3.03	7.5	62.5	12	1.35
Waveview	2.15	7.7	17.9	8	1.0

tree pots (D40; 6.35 cm × 25.4 cm) in a *Phytophthora*-free certified nursery. All remaining acorns were tested for viability using a water float test, (Gribko and Jones 1995) fully dried, and stored in the refrigerator at ∼2.7 °C in paper bags to prevent condensation, until planting.

Due to predation concerns, all trees were caged to reduce browsing (see Adams and Weitkamp 1992). Numerous local herbivores including burrows of ground squirrels (*Otospermophilus beecheyi*), pocket gophers (*Thomomys bottae*), and wood rats (*Neotoma fuscipes*) were present in all of the planting sites. Mule deer (*Odocoileus hemionus*) were also routinely observed and were documented nibbling leaves outside the cages. Cages were constructed using mesh chicken wire (1 m tall, 10 cm mesh) cut to form a ∼30 cm diameter basket cage for each planting. Each cage was placed at a depth of 15 cm into the hole to prevent ground predation (Fig. 4) and staked using rebar for stability. We affixed a metal tree tag with a unique number to each cage to track planting.

For acorn planting, the hole was backfilled, and air pockets were gently pressed down to match the surrounding grade. Two acorns were placed on their sides and covered with approximately 3 cm of soil that was lightly pressed down. For saplings, the hole was partially backfilled and a single sapling was gently placed into the hole, with roots as straight as possible.

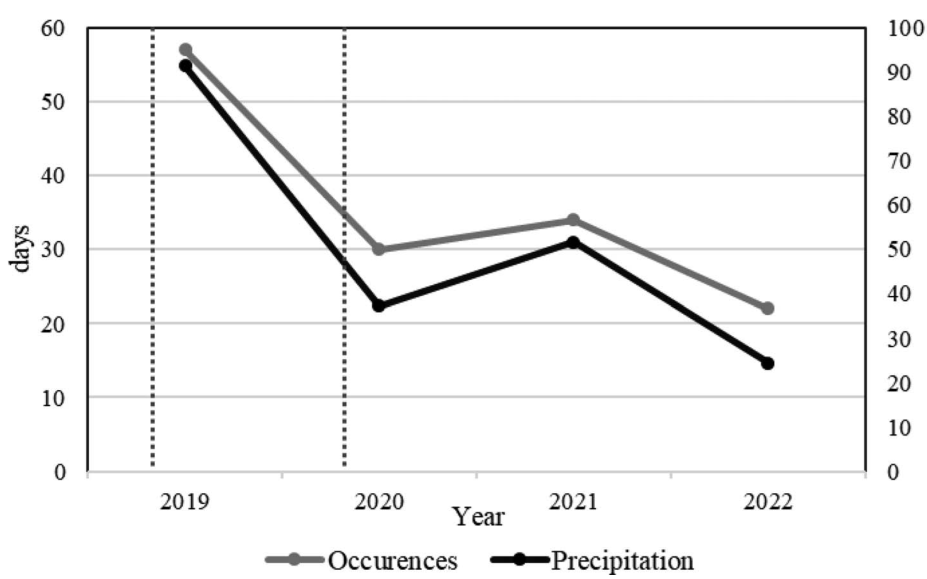

Fig. 3. Number of precipitation occurrences (days) and total precipitation (cm) between 2019-2022. The left green dashed line shows the first major planting event (at Waveview) in spring of 2019. The right green dashed line shows the second major planting (at Amy Way, UTEFR, LTEFR, and TL) in spring of 2020.

Fig. 4. Cage baskets to protect acorns and saplings.

Soil was added to backfill the hole and air pockets removed. Saplings were set approximately 3 cm above-grade so that if they settled, they were not below-grade. All plant holes and surrounding watering berm area was covered with a layer of 9-18 cm of oak leaf mulch gathered from beneath surrounding mature oak trees to prevent desiccation.

Between January 2019 and January 2022, acorns or seedlings were planted at a total of 258 points across the five sites. Total plantings (including repeated plantings for deceased trees) was 45 in 2019, 224 in 2020, 83 in 2021, and 15 in 2022. In addition, volunteers replanted where trees died, or did not emerge (from acorns), resulting in a total of 367 "attempts" (Table 2). Trees were counted as having "survived" if they were alive by the end of 2022, the end of the planting project (regardless of when they were planted).

Each tree (acorn/seedling) received a once-monthly watering of 11-15 L (3-4 gal) of water each year between December and June, followed by twice-monthly watering between June and November (or during dry conditions as needed), for 3 yr post-planting. Watering was performed through volunteers and staff using a combination of manually carrying buckets and arranging up to 610 m of hose to access the plantings. At each watering event, weeds in a 152 cm perimeter were removed, mulch was replaced as needed, and data was recorded on individual tree health. Caging was removed, and tags were placed on each sapling once the oak reached $\sim$1 m in height, a size we have found that is resistant to herbivory.

Table 2. Summary of acorn/seedling planting and survival rate 2019–2022.

Site	# Acorns	# Seedlings	# Survived	Survival rate
Amy Way	95	45	115	82.1
LTEFR	58	10	55	80.1
TL	38	1	19	48.7
UTEFR	43	3	4	8.7
Waveview	72	2	48	64.9

Data collection & statistical analyses.—Volunteers – overseen by staff – assessed oak health twice monthly using three status categories: 1) green leaves and evidence of new growth; 2) leaves present but with brown spots and no evidence of new growth; and 3) brown, dried or no leaves, and performing a gentle tug on branches resulted in pulled tree out from ground suggesting fully dead. Trees that died, or failed to sprout, were recorded and replanted in spring or late fall when environmental conditions were optimal. If a tree died and was replaced, data collection was reinitiated with the newly-installed plant. In December 2022, all surviving oak tree heights were recorded as the project ended. For our analysis, we pooled survival across all years (2019–2022) recording whether a planting resulted in a living tree by the end of the study in 2022 as well as determined if each tree survived for at least one year (Y1 Survival) post planting to compare relative survival regardless of planting date. We included year-planted in our analysis to account for a range of environmental factors, particularly rainfall.

We used a logistic regression to assess planting type (acorn vs seedling) success and determined there was no significant difference ($p = 0.744$) in tree survival between planting types. We initially used a Regression Tree (Ripley 2023) analysis to identify which predictor variables contributed most significantly to tree survival. We used “Y1 Survival” as the response variable, indicating whether the acorn or seedling produced a tree that survived for one year post planting (binary variable, either 1 or 0). We used the following predictor variables: planting type (acorn or sapling), % canopy cover, percolation rate, year planted, soil moisture, and mesic species diversity score. Each of these variables was essentially pooled by site, such that each acorn/seedling planted was associated with one of five sites and the associated environmental variables for that particular site. We then used a Random Forest analysis (Liaw and Wiener, 2002) to understand how much variation in the model was explained by our measured variables. Both approaches converted oak tree survival to a probability (that a tree will survive for one year post planting or not) per site. All statistical analyses were conducted in R version 4.4.1 (R Core Team 2024).

Results

Of 367 total oaks (acorn or seedling) planted between 2019 and 2022, 241 survived by the end of 2022, for an overall mean survival rate of 65.7% across all five sites (range 8.7–82.1%, SD $\pm$ 30.1) (Fig. 5). We calculated a 29% survival rate of replanting a tree location that had already failed. We found no significant difference in mortality by year planted.

The Regression Tree analysis identified three top predictor variables, soil percolation, canopy cover, and year planted (Fig. 6). Highest survival rates were found in areas of relatively fast (= low number) soil percolation, with relatively high canopy cover, and for those trees planted in 2020. From the Random Forest analysis, percolation rate was found to be significant ($p < 0.001$) for sites with rates ≤ 2.15, with percolation rate and mesic species diversity relatively more important than the other variables analyzed (Fig. 7). Planting type (acorn vs. seedling) was

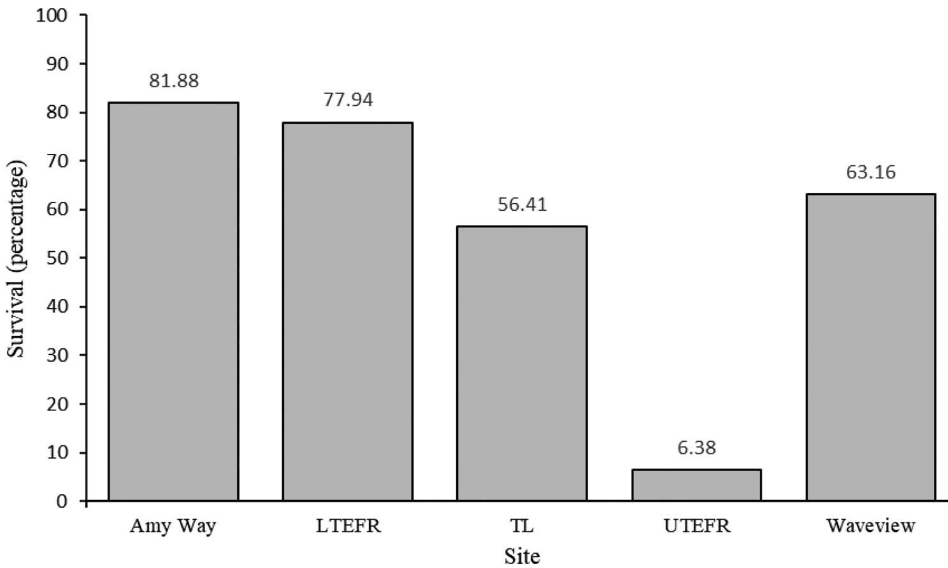

Fig. 5. Breakdown of oak survival across all sites.

consistently found to be unimportant in predicting tree survival and all predictor variables explained just 24.3% of overall variation in the Random Forest model.

A total of 2,894 hours were spent by local volunteers and affiliated staff for planting and long-term care (including watering), making for c. 12 hours of volunteer time per successful tree planted. Approximately $136.20 was spent per tree regardless of source, however including cost of labor, seedlings planted were approximately an additional $23.17 per oak. Grant funding for this restoration was $49,987.30 over 3 yr.

Discussion

Our research represents one of the few empirical studies on the oak planting survival within existing woodland habitat in California. Although survival varied widely across all sites, one site in particular, UTEFR, demonstrated extremely low survival (<10%), even after multiple re-plantings of acorns and seedlings, despite being in close proximity to the site with the second-highest survival rate, LTEFR (c. 80% survival). This suggests that "planting at a bad site" may be a waste of time (and money, and volunteer effort), and that effort is probably best redirected to sites that are producing living saplings.

Aside from showing that successful sites have soil with relatively low (i.e., less time for soil to drain, therefore fast draining) percolation rate, our ability to explain the factors responsible for this result is limited, as the model used in our analysis explained less than 25% of the variation observed. Studies on the effect of percolation rate on coast live oak survival (of any species) appears to be limited, probably because of the high variation in sites in which they thrive, from mesic streambanks to arid ridges. In a two-year study of Mediterranean oak seedling survival, Gómez-Aparicio et al. (2008) found that both increased desiccation risk and increased waterlogging resulted in seedling mortality, with "strong site-specificity" in the best predictors of survival across experimental plots. Our finding of no significant difference in survival of planting acorns versus seedlings conforms with prior research on the subject

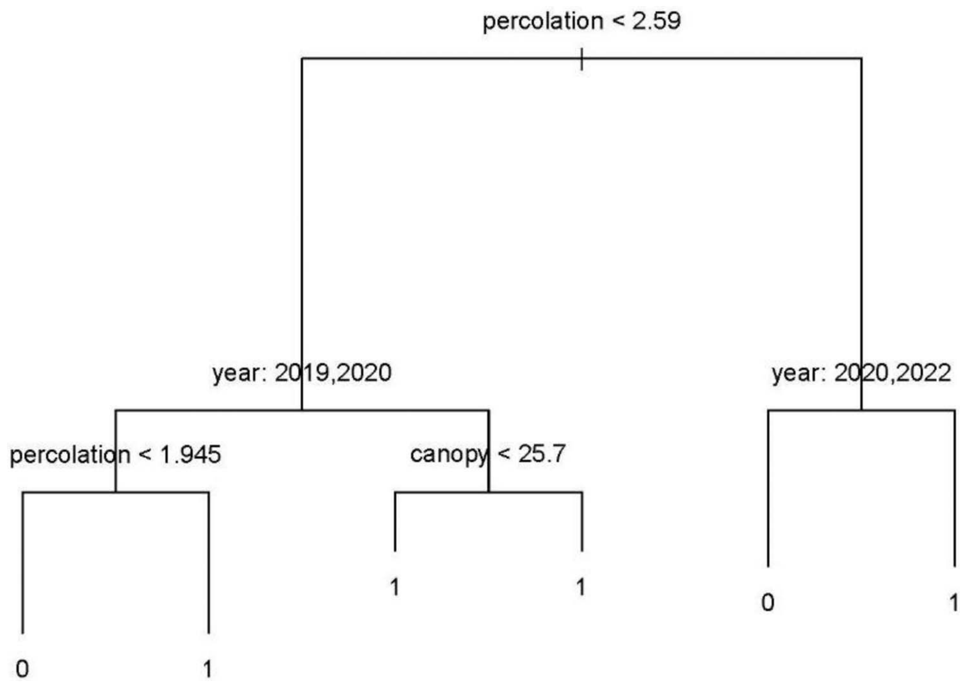

Fig. 6. Regression Tree analysis identified three variables as most contributing to observed variation in oak survival; soil percolation rate by site, canopy cover average by site, and year planted.

appears to be inconclusive (Leverkus et al. 2021). This is particularly promising for future restoration efforts, as planting from acorn is usually a less labor-intensive and cost-effective strategy. The finding that planting year – and 2020 specifically – helps explain some of the variation in our data may be related to rainfall that year. Rainfall, as measured both in number of rain events and total precipitation, declined through the life of the study (2019–2022), and trees planted in 2020 may have taken advantage of saturated soil from the prior year's (2019) precipitation. Despite this, as the Waveview site was the only site planted in 2019, oaks here would have received this increase amount of rain, yet they had a relatively modest survival rate, similar to that observed for other sites in following years (c. 65%). We also saw no significant difference in mortality by year planted across years 2019-2022. This lack of a strong effect of year may have been the result of consistent, annual care and watering of planted oaks, allowing survival even in low rainfall months, regardless of the year they were planted. This conforms with other findings as well, including Parikh and Gale (1998) that utilized irrigation, resulting in a nearly 100% survival rate with irrigated trees (cf. Davis et al. 2019, which used no irrigation.) We recommend that future studies compare irrigated vs. non-irrigated plantings within the same site to clarify this relationship.

Future restoration plantings may be more cost effective by planting acorns over saplings, not replanting the same location multiple times if initially unsuccessful, and continued watering/care during dry months until trees are established. We also encourage future studies to examine other environmental factors such as soil chemistry, and physical factors such as slope and aspect to maximize restoration effectiveness. While our study area boundaries and logistical constraints limited our ability to plant, water and monitor trees at widely-scattered locations, we recommend maximizing separation of planting sites to the extent feasible to improve statistical power. We also recommend taking measurements at the level of the planting, rather than the entire plot, which would also have increased statistical power and confidence.

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